# Electrical Circuits

## R.J. Marks II Lecture Notes

## Texas Tech University (1976)

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FALL 1976                    TEXAS TECH UNIVERSITY                      PAGE  2
                           STUDENT INFORMATION SYSTEM                      8141

                          - PRELIMINARY CLASS ROLLS -                     RR001

             DEPARTMENT 590 (E E )  COURSE 233   SECTION 002

             INSTRUCTOR    NO INSTRUCTOR        Seacat
   STUDENT
   NUMBER          LAST NAME         FIRST NAME   MI SCHOOL CLASS SEX

460 76 9218 STARK                   JOHN           R     04     3     1

453 78 3617 SUGAREK                 RICHARD        H     04     4     1

526 11 1482 TAI                     HSU-CHEN       J     02     2     1

467 86 9902 WISCHNEWSKY             GLENN          R     04     3     1

460 06 5345 WORSHAM                 MICHAEL        H     02     4     1

*TOTAL NUMBER OF STUDENTS    28
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EE 233 and 234

HINTS FOR LAB INSTRUCTORS Fall 1976

1. Be prepared to discuss in detail the homework which has already been taken up in lecture. Homework assignments will be posted on the blackboard in Room 154.

2. Be prepared with a lecture on the theory, and with typical example problems. To do a good job, prepare well. You're there to help them learn the material. Spend the allotted time.

3. Have problems for students to work in class. Send them to the board to do problems.

4. Pass out lab experiment sheets one week in advance.

5. Get together with the other lab instructors at a convenient time (ex. on Friday before the students do an experiment) and perform the experiment to be done the next week. Check out the necessary equipment for the week. Equipment should be checked into the stock room at the end of the week by the instructor who has the last lab of the week.

6. Explain purpose of the experiment and measuring techniques to be used.

7. Give frequent quizes on lab experiments and lecture material.

8. The laboratory grade will count 20% of the student's total grade for the course. Keep a record of absences. Turn in a numerical grade at the end of the semester as follows:

    a. Record each student's full name, number of absences, the final numerical grade and class average on a ditto master which you get from the departmental secretary. Indicate how final grades are determined.

    b. Make a copy for each instructor in the lecturer sections, and turn them in to Tom Stenis by the first day of final exams.

# 1976 Lab Schedule, EE 233 & 234

| Date | EE233 | EE234 |
|---|---|---|
| Sept. 7-10 | *P | Rectifiers |
| Sept. 13-17 | P | P |
| 20-24 | P | BJT & FET Amplifiers |
| 27-Oct. 1 | P | P |
| Oct. 4-8 | P | Freq. Response |
| 11-15 | Meters | P |
| 18-22 | P | Recording Instruments |
| 25-29 | Resonance | P |
| Nov. 1-5 | P | Op Amp |
| 8-12 | Power & 3 phase | P |
| 15-18 | P | Transducers |
| 29-Dec. 3 | Transformers | P |
| Dec. 6-10 | P | Machines |

* Problem session.

# Lecture and Lab

Instructors in EE233, 4. Fall 1976

## EE233

| | | | | | |
|---|---|---|---|---|---|
| Lecture Sections | 001 | 7:30 | MW | E156 | Stenis |
| | 002 | 11:30 | MF | E156 | Marks |
| | 003 | 8:30 | MF | E251 | Brock |
| | 004 | 7:30 | TT | E251 | Stenis |
| | 005 | 9:00 | TT | E215 | Gordon |

| | | | | | |
|---|---|---|---|---|---|
| Lab Sections | A, J | 1:30 - 3:30 | F | E202 | Trotter ✓ |
| | B | Arrange | | | Trotter ✓ |
| | C | 1:30 - 3:30 | Th | E156 | Hubbard ✓ |
| | D | 3:00 - 5:00 | Th | * | Hubbard × |
| | E | 1:30 - 3:30 | M | E202 | Kirbie ✓ |
| | F | 3:30 - 5:30 | M | E67 | Mote ✓ |
| | G | 3:30 - 5:30 | W | E67 | Mote ✓ |
| | H | 1:30 - 3:30 | Tue | E67 | Huang |

## EE234

| | | | | | |
|---|---|---|---|---|---|
| Lecture Sections: | 001 | 10:30 - 12:00 | TT | | Stenis |
| | 002 | 9:00 | TT | E251 | Stenis |

| | | | | | |
|---|---|---|---|---|---|
| Lab Sections: | A | 3:30 - 5:30 | F | E202 | Yao |
| | B | 10:30 - 12:30 | Tu | * | Yocum |

*These are scheduled for E157, which is not available. Meet in E67 until a suitable class room is found.

## Chapter II Problems

1. A point charge $Q_1 = +1.6 \times 10^{-18}$ coulombs, is separated from another point charge $Q_2 = -3.2 \times 10^{-17}$ coulombs, by a distance of $10^{-3}$ meters. The charges are in a vacuum.

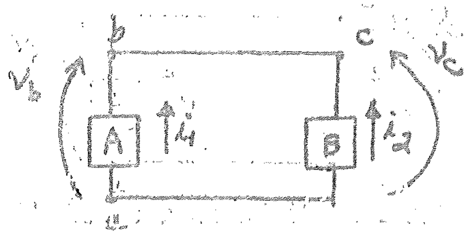
   a) Sketch a diagram of the physical layout.

   b) Find the force on each charge and indicate the direction on the sketch.

2. A $+1.6 \times 10^{-19}$ coulombs charge ($Q_3$) is brought into the vicinity of the charges of problem 1. If $Q_1 + Q_2$ remains fixed in position, find at least one point where $Q_3$ could be located and the net force on it be zero. How many such points are there?

3. In the glass tube of fig. 2, the density of free electron is equal to the density of free ions, and is $1.6 \times 10^{-12}$ coulombs per cubic meter. If the electrons are travelling at $10^4$ m/sec. and the ions at $10^2$ m/sec., calculate the current from plate (a) to (b), assuming plate (a) is positively charged.

4. A copper wire, 0.01 meters in diameter, has a density of free electrons equal to $84 \times 10^{28}$ electrons/$M^3$. If a current in the wire is 2 amperes what is the average velocity of the electrons?

5. 

   In the circuit shown, $i_1 = 1$ ampere $= -i_2$. $v_b = v_c = 5t$.

   1) Sketch curves of $i_1$, $v_b$ and power supplied by box A vs. time, from zero to 10 seconds.

   2) Calculate the power supplied by box A at time = 1, 2, and 5 seconds.

   3) Calculate the power absorbed by box B at 1, 2 and 5 seconds.

   4) Calculate the energy supplied by box A from 0 to 5 seconds.

6. In the circuit of problem 5, $v_b = 10-5t$, $i_1 = -i_2 = 10t$.

   a) Sketch the curve of $p_s$ of box A vs t, from 0 to 5 seconds.

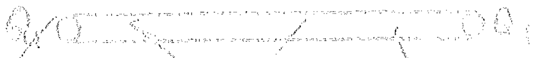
   b) Calculate $p_s$ of box A at t = 0, 1, 2, 3, 4 seconds.

   c) Calculate energy supplied by box A from 0 to 5 seconds.

7. Same problem 6, [illegible]

8. For problem 7, find the power absorbed by box B at t = 0, .5, 1 and 2 seconds.

9. Omit



~~A glass-ceramic rod, 0.1 meters long, 1 cm in diameter, has equal charges concentrated in each end. This is crude model of an insulator supporting two conductors. Consider the charges as point charges. What is the maximum charge, $Q_1$, before the rod will break in tension. The tensile strength of the glass ceramic is 20,000 psi.* Assume the forces will produce a uniform stress throughout the material.~~

*p.132 CRC Handbook of Tables for Applied Engineering Science.

10. A consumer of electrical energy requires 100 amperes of steady current over an 8 hour period, from a steady voltage source of 110 volts.

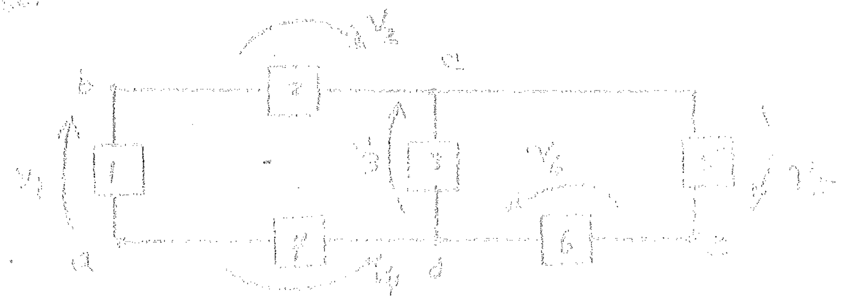
a) What power is the customer using?

b) How much energy in joules and watt-sec. is he using in the 8 hr. period?

c) If he is paying 3 ¢ per killowatt- hr. for the energy, what is the cost for the 8 hrs?

11. How many electrons make up a coulomb? If a gas ion is doubly ionized (lost 2 orbital electrons), how many such ions are there in a coulomb of charge?

12.



Using the defined voltages shown in the figure, write KVL around the following loops:

1) A b c d a     2) d c e d     3) a b c e d a

4) d e c d     5) a d c b a

13. For the circuit of problem 12:

a) Define element currents.

b) Write KCL, using the currents of part (a), for the following nodes:

1) b  2) c  3) d  4) e  5) a

c) What elements (boxes) are in series in this circuit?

d) Define the branch currents. Write KCL, using these currents, for nodes c and d.

14. The voltages in the circuit of problem 12, are as follows:
$V_1 = 10^V$, $V_2 = -2^V$, $V_3 = 4^V$, $V_5 = -2$ volts

a) Find $V_4$, $V_6$, $V_{cd}$, $V_{db}$.

b) If the loop current circulating around a b c d a is 2 amperes., and the loop current circulating around d c e d is 3 amperes, find the following:

1) Power supplied by : (a) element 1 (b) element 3.

2) Power absorbed by : (a) element 2 (b) element 5.

3) Which elements in the circuit are sources?

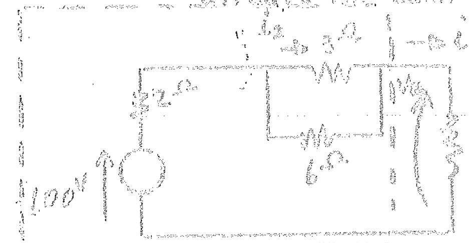
4) Is the sum of power supplied by the sources equal to the sum of all the absorbed power?

Marks

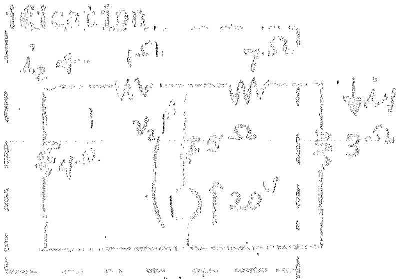
# LAB Problems for EE 233

1. For each circuit assigned by the instructor, do the following:

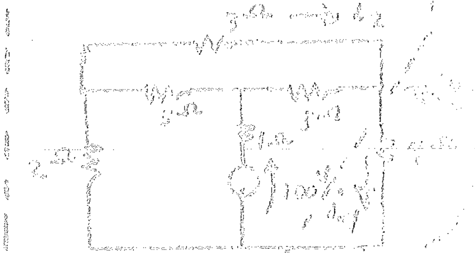
   A) Reduce each to one resistor in series with the source. Draw a new circuit for each simplification.



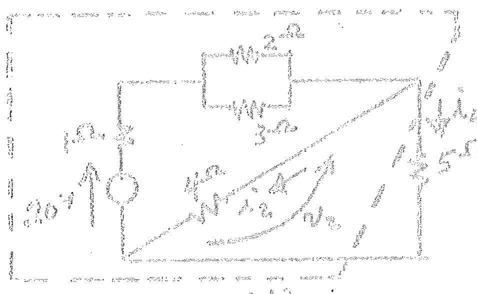
(a)



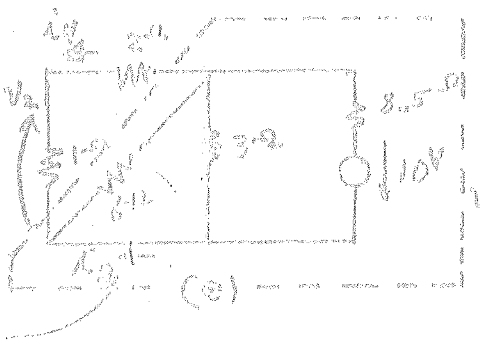
(b)



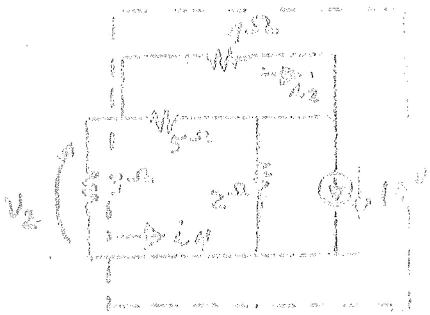
(c)



(d)



(e)



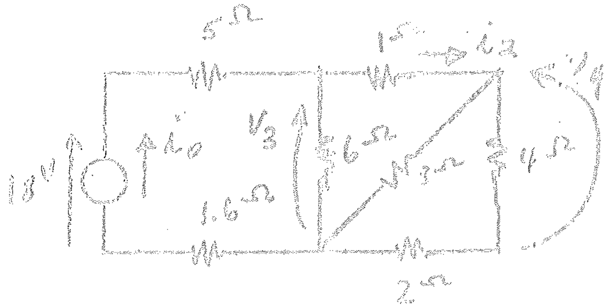
(f)

   b) Find the power supplied by each ideal source.

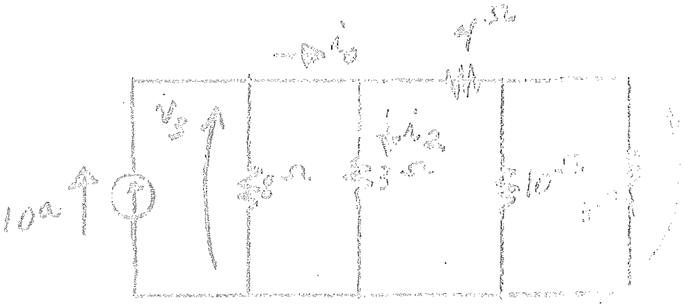
   c) Find $V_2$.

   d) Find $i_2$.

2. Simplify the following circuits to one resistor in series with the source. Draw a new circuit for each simplification.

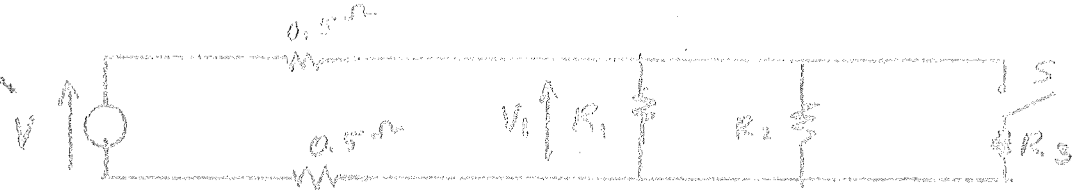


(a)



3. In each of the circuits above, calculate the following: $i_o$, $V_3$, $i_2$, $V_4$.

4.



A 1000 volt source is providing power to resistive loads $R_1 = R_2 = R_3 = 33$ ohms., through a transmission line having 0.5 ohms resistance per wire.

a) With switch S open, find the following:

$V_1$, power loss in the transmission line, power absorbed by the loads, current in $R_1$ or $R_2$.

b) Repeat part (a) with switch S closed.

5. Refer to problem one for the circuits assigned by your instructor:

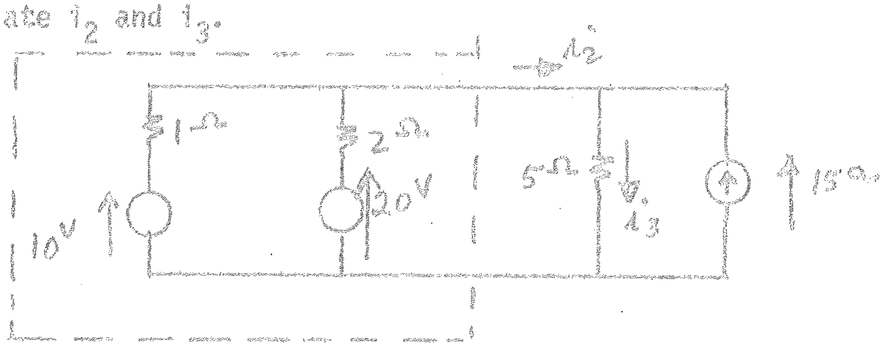
a) Reduce the active portion of the circuits which are enclosed in boxes, to a single voltage source and resistor in series.

b) Convert each active portion enclosed by a box, to a constant current source and parallel resistor.

c) Find the current $i_4$ for each circuit assigned.

6. a) Reduce the active portion of the circuit which is enclosed in a box, to one resistor and one ideal source.

b) Calculate $i_2$ and $i_3$.



7. A manufacturer's specification on a power supply is as follows: No load (open circuited) voltage is 100 volts, full load current is 10 amperes, full load voltage is 99.99 volts.

a) What is the full load resistance?

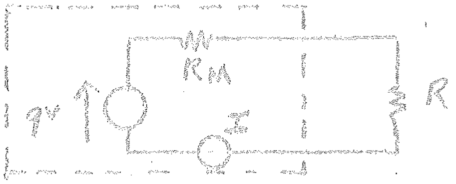
b) What is the internal resistance ($R_T$) of the power supply?

c) If a 20 ohm resistor is connected to this power supply, what is ther terminal voltage?

8. Draw a diagram and explain the operation of a D'Ansonval type permonent-magnet moving-coil meter.

9. A DDAnsonval type meter is used as a basic movement for constructing D.C. ammeters or voltmeters. In a particular movement, full scale deflection occurs with 1 ma of current in the meter and a 50 MV voltage across the meter.

   a) What parallel resistor (shunt) should be provided with this movement, to make an ammeter with a 10 ampere full scale reading?
   b) What shunt is needed to make a 100 ampere full-scale reading ammeter?
   c) What series resistor is needed to make a voltmeter with 5 volt full scale reading?
   d) Repeat (c) for a 100 volt full scale reading.

10. 

The circuit in the box represents an ohmmeter (used to measure resistance). The meter is a D'Ansonval type having full scale reading with 50μ a current and a voltage accross it of 50 m volts. R represents the unknown resistance.

   a) What resistive value should $R_m$ have if full scale deflection is desired when R = 0?
   b) If $R_m$ is 100K ohms, what value of R would produce full scale deflection?
   c) What value should $R_m$ have if a full scale reading is desired when R = 50K ohms?

11. These resistors are connected in series, to a source which provides 100 volts open circuit, and has 9 ohms of internal resistance. The resistors have the following ohmic values: $R_1 = 8900$, $R_2 = 1001$, $R_3 = 90$.

   a) Draw the circuit diagram.
   b) Find the voltage across each resistor.
   c) A voltmeter having a full scale reading of 100 volts and a sensitivity of 200 ohms/volt, is used to measure the voltage across each of the three resistors. Calculate the voltage which the meter will measure, as it is connected across each resistor. Compare these readings with part (b) calculations.

12. A power supply has 8 ohms of internal resistance and supplies 800 volts when open circuited. A 2 ohm resistor is connected across the supply terminals.

a) Draw the circuit diagram.

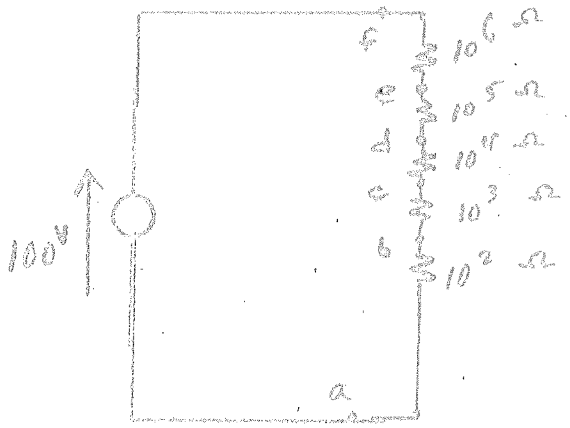
b) Calculate the current in the 2 ohm resistor and the voltage across it.

c) An ammeter with 0.5 ohms resistance is connected in series with the 2 ohm resistor. Calculate the current which the meter will measure and the voltage across the 2 ohms with the meter in the circuit.

13. An electronic d.c. voltmeter has a switch with which the following full-scale ranges are available:

0- .01 volts, 0- .1 volts, 0-1. volt, 0-10 volts, 0-100 volts.

The meter resistance is 1 M ohm for each range. The meter is used to measure the following voltages, as indicated in the circuit shown:



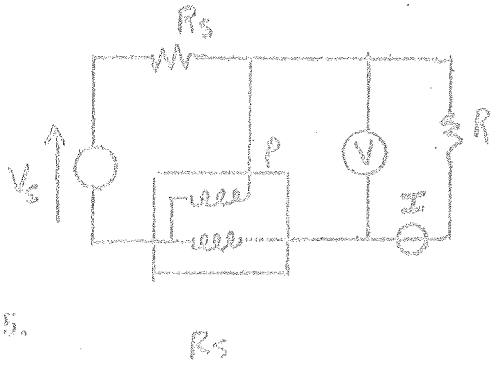
$V_{af}$, $V_{ab}$, $V_{bc}$, $V_{cd}$, $V_{de}$, $V_{ef}$.

1) For each of the voltages, indicate the following:

a) Which range should be selected? (The upper half of the meter range is best).

b) What value does the meter indicate in each case? Compare each voltage with the value before the meter was added.

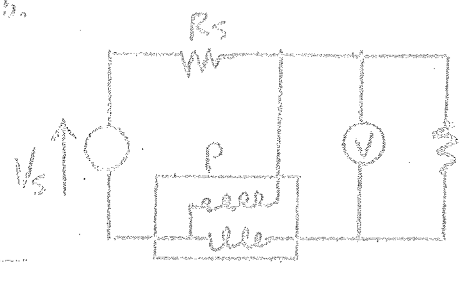
14.



The wattmeter and ammeter shown connected in the accompanying circuit diagram, read the following values: P = 200 watts, I = 2 amperes.

Find the value of R and the voltage across it. Neglect the voltage across the ammeter.

15.



The wattmeter in the accompanying circuit reads 4 K watts and the voltmeter reads 0.5 K volts. Find the value of R and the current through R. Neglect any circuit changes which the meter produces.

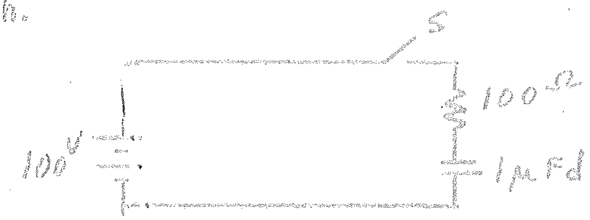
16. A d.c. generator supplies 1 KV open circuited, and has 1 ohm of internal resistance. It is connected to a pair of wires (transmission line) each one being 200 feet long and having 0.01 ohms/ft. resistance. A 20 ohm load resistor is connected at the end of the line:
    a) Draw a circuit diagram and include meters for measuring the power, current and voltage at the generator and load ends of the line.
    b) Calculate each of the meter readings, neglecting any effect the meters have on the circuit.

17. The load resistor of problem 16 is changed so that the voltmeter and ammeter at the generator end read, respectively: 900 volts and 100 amperes.
    a) Find the readings of the rest of the meters in the circuit of problem 16.
    b) Find the value of load resistance.

18. A 400 KV d.c. transmission system is capable of supplying 100 M watts at the generator end. A 50 mile transmission line from the generator to a load center uses number 00 AWG copper wire. Assume 400 KV at the generator end, and theggenerator is supplying rated power.
    a) What is the full-load current at the generator end?
    b) What is the voltage at the receiving end?
    c) What is the power delivered to the load and power loss in the transmission line?

19. Describe a double-pole, single throw switch; a double-pole, double throw switch.

20.

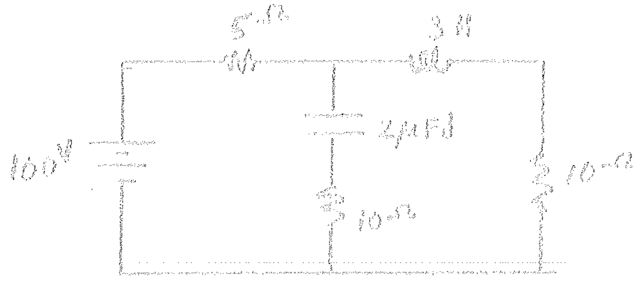


The switch S is closed at t = 0, and the capacitor has no charge on it at that time.

a) Determine the equation for the current.

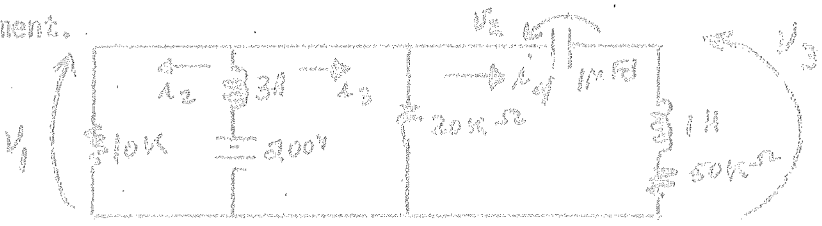
b) What value does the current have in one time constant? Two time constants?

21.



Find the steady-state current in each element and the voltage across each element.

22.



Find the steady-state values of the following:

a) Current in the source

b) $i_2$, $i_3$, $i_4$

c) $V_1$, $V_2$, $V_3$.

Maps

Here is a set of problems suitable for lab. work. When you finish with little set # II, and don't wish to keep it, return it to me (put it in my box). If you have solutions to any of the problems in that set, I would appreciate a copy.

T Stanis

I'll be out of town Fri., so check my blackboard before [illegible]

TS

Marks

1. A size AWG (American Wire Gauge) 14 copper conductor with RUW insulation has an allowable current carrying capacity of 20 amperes. This is based on a room temperature of 86°F, using open wiring.

   Reference:
   Bolz, Ray E., and George L. Tuve, "Handbook of Tables for Applied Engineering Science", Ohio: The Chemical Rubber Company, 1970.

   a) What is the resistance of 20 feet of AWG 14 copper wire?

   b) What is RUW insulation?

   c) What is the diameter in mils, of this wire?

   d) What is the power absorbed by 20 feet of the wire when carrying its maximum allowable current?

   e) What is the voltage across the 20 feet of wire when carrying maximum allowable current?

2. Repeat problem 1 for AWG 00 wire which has 225 amperes allowable current.

3. The resistivity of nichrome is $100 \times 10^{-8}$ ohm - meters at 20°C, and its temperature coefficient is $4.4 \times 10^{-4}$ $\Omega/\Omega/^{\circ}C$. A 100 ohm wire wound resistor is to be made from #22size nichrome wire ($6.44 \times 10^{-2}$ cm. diameter).

   a) What length of wire is needed (20°C)?

   b) When the voltage across the resistor is 10 volts, how much power is it absorbing?

   c) If the temperature rises to 60°C, what is the resistance?

4. A cable 20 meters long is used to connect a 400 volt source to a 5 ohm load. The cable has two copper conductors, each of size AWG 10.

   a) What is the voltage across the load?

   b) Repeat part (a) if aluminum is substituted for the copper.

5. A 1000 ohm resistor is rated for 25 watts.

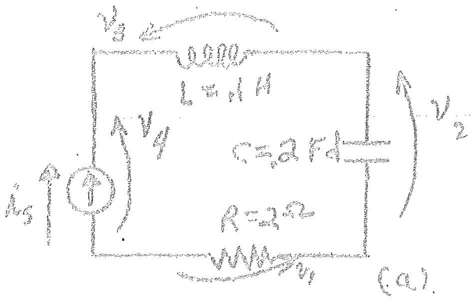
   a) What is the maximum possible current through it ~~and maximum voltage across it~~ without exceeding its rating? What is the voltage in this case?

   b) What is the maximum possible voltage across it, without exceeding its rating? What is the current in this case?

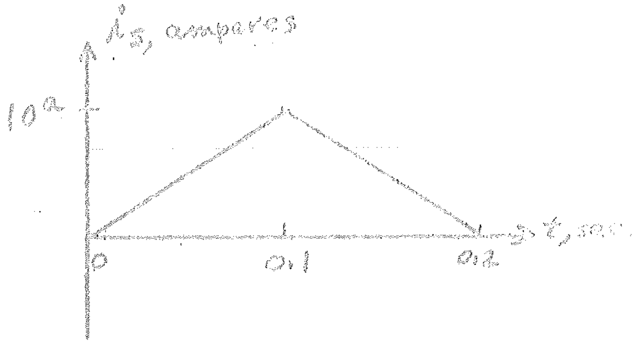
6. a) A 10,000 ohm resistor in an electronic circuit will have 100 volts across it. What should be its power-rating?

b) If two 5000 ohm resistors in series are substituted for the 10,000 ohm resistor, what should be the power-rating of each one?

7.



(a)



The circuit shown in fig. (a) has a source supplying current as shown in figure (b). There is zero energy stored in L and C at t = 0.

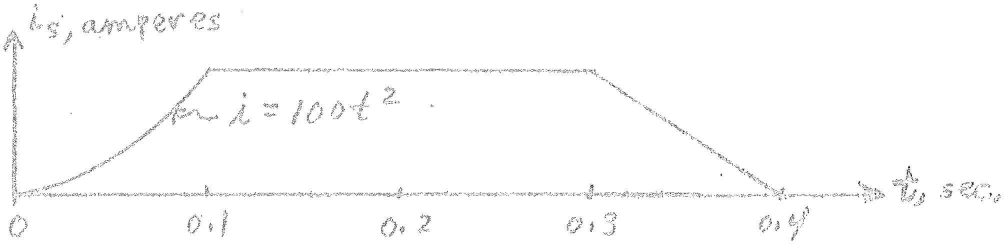
a) Sketch curves of $v_1$, $v_2$, $v_3$, and $v_4$ vs. t, showing values at t = 0, .1 and .2 seconds, .3 and .4 sec. for prob. 8.

b) Sketch curves of energy stored in L and energy stored in C vt t, showing values at t = 0, .1 and .2 seconds, .3 and .4 seconds for prob. 8.

c) What is the instantaneous power absorbed by R at t = 0.05 and 0.15 seconds?

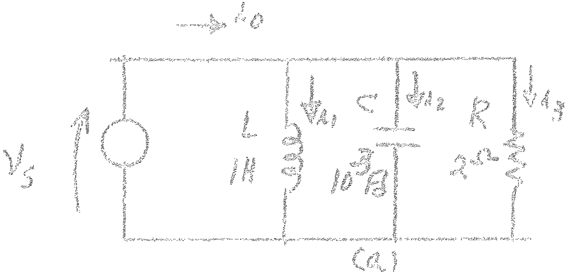
d) Repeat (c) for the inductor, and for the capacitor.

8.

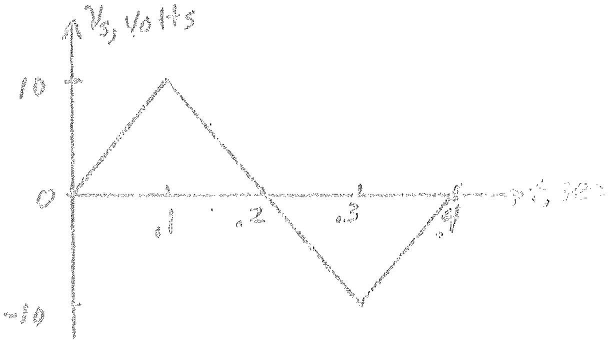


Repeat problem 7 using the current shown.

9.



(a)



The source voltage waveform for circuit (a) is given in fig. (b). No energy is stored in L or C at t = 0.

a) Sketch $i_1$, $i_2$ and $i_3$ vs t. Show values at t = .1, .2, .3, .4 and .5 seconds.

b) Sketch a curve of $i_o$ vs t.

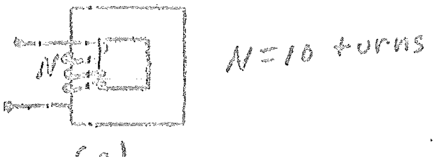
c) What energy is stored in L and in C at t = .3 seconds?

d) What instantaneous power is the source supplying at t = 0.2 seconds?

c) How much energy has each of the elements absorbed by time $t = 0.5$ seconds?

d) Find the energy supplied by the source, by time $t = 0.5$ seconds.

11.



(a)

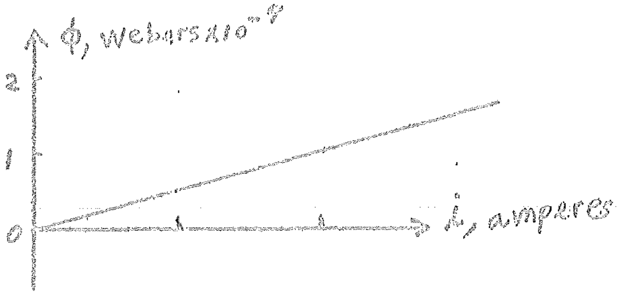


Figure (a) shows a coil with a closed iron core. The $\phi$-i curve for this coil without the iron core is shown in fig. (b).

a) What is the inductance of the coil without the iron core?

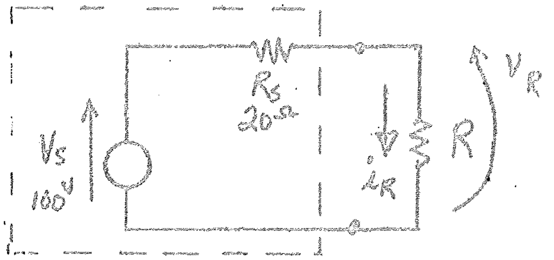
b) If the iron core increases the slope of curve fig. (a) by 2000 times, what is the inductance of the coil ... with the iron core?

c) If the numbe of turns for coil of part (b) is doubled, find the new value of inductance.

12. A parallel plate condenser with an air dielectric has a value of capacitance of $10^{-8}$ Fd.

a) What is the new value of c if the distance between plates is doubled? How much is c increased by changing the dielectric to polystyrene?

13.



The model for a practical source connected to a load is shown in the figure.

a) Find $v_R$ and $i_R$ for the following values of R (in ohms).

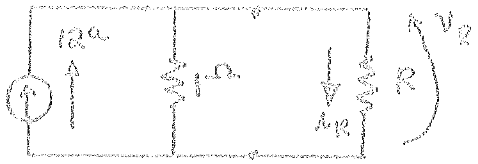
R = 0.5, 10, 20, 100, 200 and infinity.

b) Plot a curve of $v_R$ vs $i_R$.

c) On one set of axes, plot a curve of power absorbed by R and power absorbed by $R_s$ vs R.

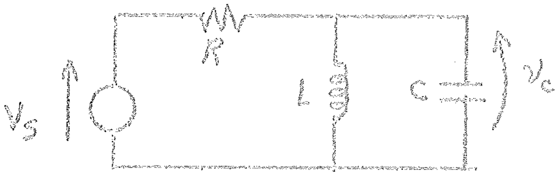
d) What is the relative values of the two resistors ($R$, $R_s$) for the case of maximum power absorbed by R?

14.



Plot curves of $v_R$ and $i_R$ vs R, using these values of R (ohms): 0, .5Ω, 1, 2, 10, 100, infinity.

15.

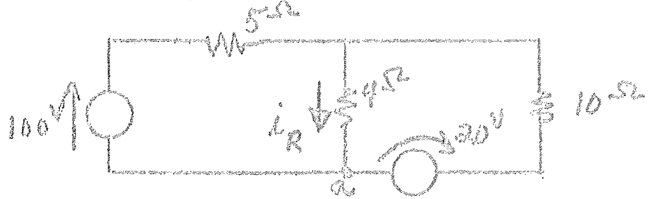


$v_c(0) = -2$ volts

a) Define loop currents.

b) Write the voltage equations in terms of the defined currents and circuit elements.

16.



a) Using the loop method, solve for the currents in each source.

b) Find the power supplied by each source

c) Find the power absorbed by each resistor.

17. a) For the circuit in problem 16, define branch currents and solve for the current in the 20 volt source.

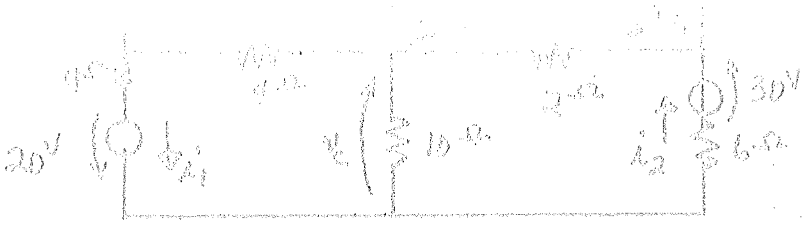
b) Find the power supplied by the 20 volt source.

18. a) For the circuit of problem 16, define the minimum number of unknown voltages, using node 'a' as a reference.

b) Solve for the voltage(s) of part (a).

c) Find $i_R$.

19.



a) Solve for current $i_1$ using the loop method.

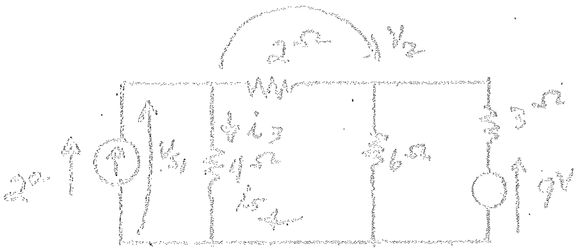
b) Solve for voltage $v_c$ using the node method.

20. For the circuit of problem 19:

a) Solve for current $i_2$ using the loop method.

b) Solve for voltage $v_b$ using the node method.

21.



Find the current in the 4 ohm resistor.
Find $v_2$, power supplied by the 9 volt source.

22. For the circuit of problem 21, find the voltage across the 6 ohm resistor.
Find $i_3$, $v_{s1}$, power supplied by the 2ampere source.

23. For the circuit of problem 21, find the current in the 2 ohm resistor, and $i_4$.

24.

When maximum detail is desirable, and a digital computer is available for a solution, circuit analysis can be done using the following procedure:

1) Define branch voltages $v_1$, $v_2$, $v_3$, $v_4$, $v_5$, $v_6$.

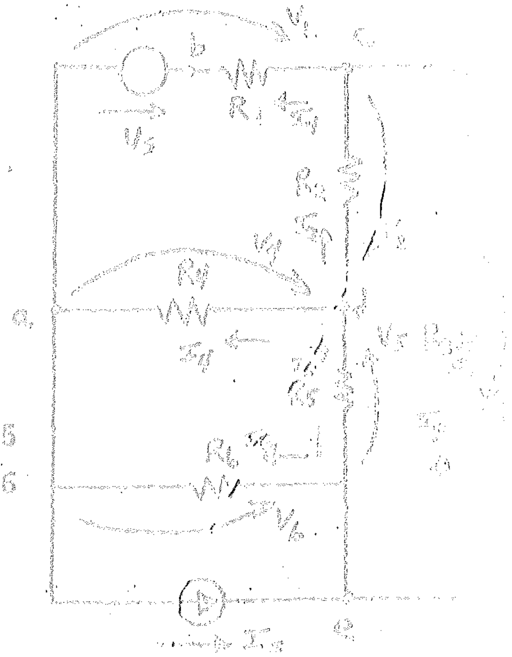
2) Define branch currents $I_1$, $I_2$, $I_3$, $I_4$, $I_5$, $I_6$.

3) Write KVL in terms of voltages defined in step 1.

$$V_1 + V_2 - V_4 = 0$$
$$V_4 - V_5 - V_6 = 0$$
$$V_3 - V_5 - V_2 = 0$$

4) Write ohms law relations for each branch voltage

$$V_1 = V_s + I_1 R_1 \qquad V_3 = I_3R_3 \qquad V_5 = I_5R_5$$
$$V_2 = I_2R_2 \qquad V_4 = I_4R_4 \qquad V_6 = I_6R_6$$



5. Write KCL for each major node

Node C: $-I_1 + I_2 + I_3 = 0$

Node D: $I_2 + I_4 + I_5 = 0$

Node E: $I_s + I_5 - I_6 - I_3 = 0$

6. Solve the above 12 equations for the particular unknowns of interest.

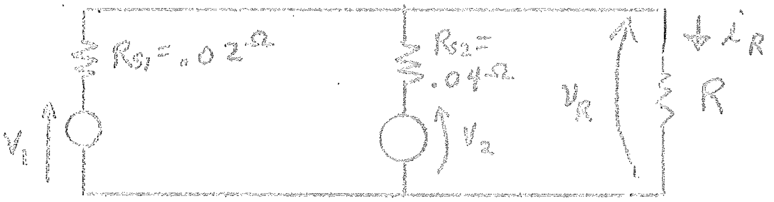
PROBLEM

a) Write the determinant for the voltage $V_4$.

b) Write the determinant for the current $I_1$

c) What compiler language is best suited for the solution of equations of part (a) or (b)?

25.



$V_1 = 400$ volts

Two generators are supplying power to an industrial plant, represented by R = 0.5 ohms. The voltage $v_R$ is to be 392 volts.

a) Find the value of $v_2$ needed to provide the required $v_R$.

b) Find the power supplied by each source. (Subtract the loss in $R_{s1}$ or $R_{s2}$).

c) Express the power loss in each generator as a percent of the power absorbed by the load.

d) Find Efficiency.

26. Generator 2($V_2$) in problem 24, is removed from the circuit, (open circuited).

a) Find $V_1$ needed to provide 392 volts to the load.

b) If the maximum voltage for $V_1$ is 410 volts, what will be the maximum value of $v_R$?

27. In the circuit of problem 24, $V_2$ = 400 volts.

a) What value will $V_R$ have?

b) What power will each generator be supplying?
(subtract power loss in $R_{S1}$ or $R_{S2}$.)

23. A 12 battery is discharged when its terminal voltage is 10.8 volts. It has internal resistance of 0.01 ohms. A source is connected in series with the battery in order to charge it.

a) Draw the circuit and indicate the polarity of the battery and charging source.

b) What charging voltage is needed to provide 5 amperes of charging current?

c) After one hours time, the battery voltage has risen to 13.2 volts. What charging voltage is needed to maintain the 10 amperes charging current?

29.

(a)

(b)

Several power supplies of each type depicted in the figure are available in a laboratory.

a) How should two supplies of the Fig. (a) type be connected to provide simultaneous voltages of 0, +10, and +20 volts? Indicate the reference node in the connection: Draw the connections.

b) Show how to connect two supplied of Fig. (b) to provide simultaneous voltages of: 0, +20, +40, -20, -40 volts.

c) Show the connections required to provide simultaneous voltages of -40, -20, 0, +10 volts.

marks

EE 233 Lecture instructors

This experiment will be done, beginning on Oct 25. When you finish Ch. V, go to p180 in Ch. VII and discuss Resonance, to prepare them for lab.

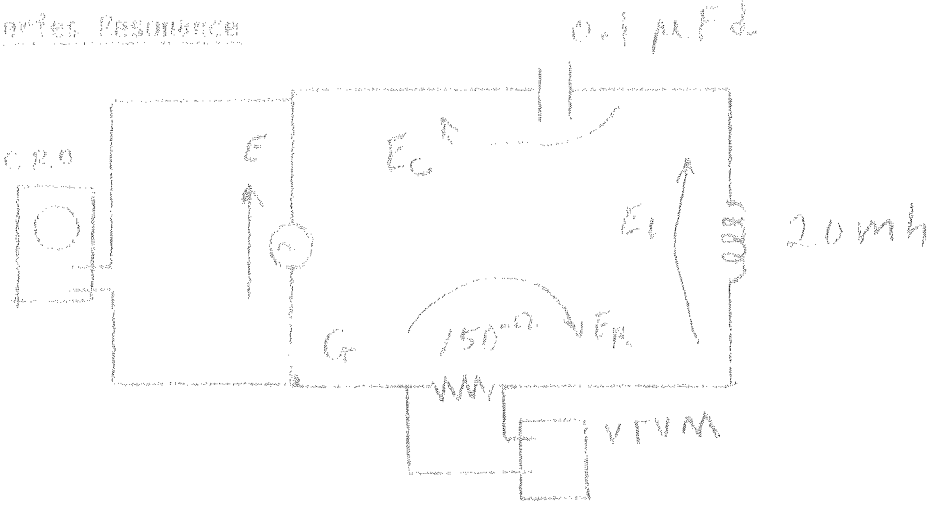
T Stevens

[illegible] Lab [illegible]

## Series and Parallel Resonance

The instruments of interest in this experiment are the variable frequency audio oscillator, the HP 400 vacuum tube voltmeter (VTVM), and the oscilloscope. The VTVM is a high impedance voltmeter with reasonable accuracy over the audio frequency range. The oscilloscope is particularly useful as a voltmeter and observing the actual waveforms. Current resonance in the series circuit and voltage resonance in the parallel circuit are to be observed as the source frequency is varied.

### Series Resonance



A) Connect the circuit shown. (Caution) Since the CRO and VTVM are each grounded through the a.c. line, be sure the ground terminal of each is connected to point G of the circuit. E is the audio oscillator with the amplitude dial set on about 1/5 maximum. Use the oscilloscope to measure E and the VTVM to measure $E_R$.

B) Vary the frequency until resonance occurs. (Maximum $E_R = E_{RO}$). At resonance record the frequency, $E_R$, and E. Keep E constant for parts B, C, D, and E. Measure the frequency using CRO.

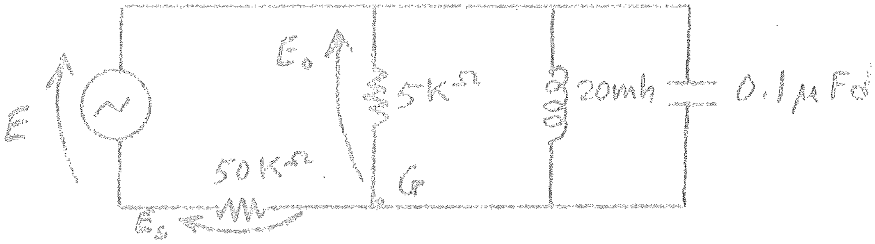
C) Disconnect the CRO (both terminals), and measure $E_L$ and $E_C$ at resonance with VTVM.

D) Reconnect the meters as in part (A), and with f set at each half power point (.707 $E_{RO}$), record the reading of part (B).

E) Take additional data so you can plot a resonant curve ($E_R$ vs f).

### Parallel Resonance

An RLC parallel circuit supplied by a constant current source has a resonant effect because the voltage across it maximizes at a particular source frequency. Connect the circuit shown, simulating a constant current source by using a large (100 KΩ) resistor in series with the audio oscillator.



Set the amplitude of the oscillator dial to 0.9 maximum for this part of the experiment. Use the VTVM to measure $E_s$ and the CRO to measure $E_o$. (Common ground at G).

A) Confirm that $I_s$ remains constant over the frequency range of 2 to 5 KHz. Do this by measuring $E_s$ ($I_s = E_s/ 50$ K) at several frequencies. While doing this, observe $E_o$ with as oscilloscope and note the frequency where $E_o$ maximizes.

B) Take data to plot a resonant curve ($E_o$ vs f). Be sure to include the resonant point and the half power points.

### Report

A) Record the type of VTVM used, the ranges of voltages it can read, and its input impedance (see instruction manual).

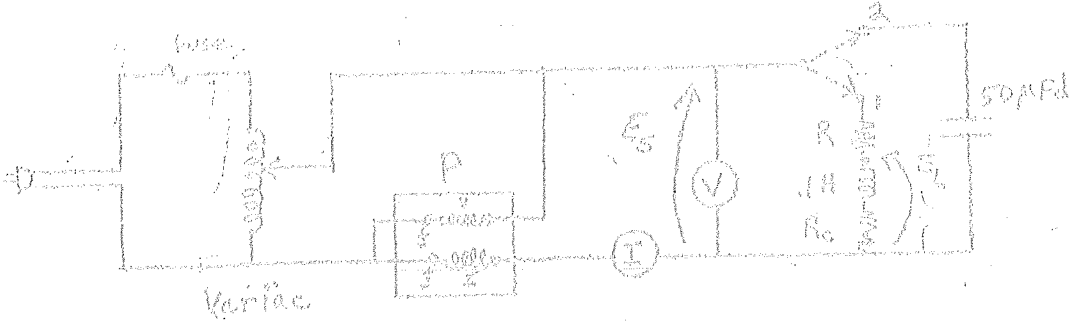
B) Record the type of oscilloscope used, the minimum and maximum voltage sensitivity, minimum and maximum sweep speed and input impedance (see Manual).

C) Include a sketch of the front of the oscilloscope in your report.

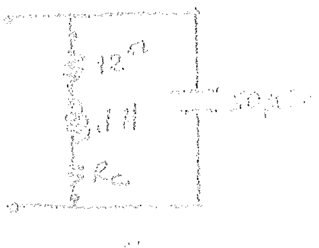
D) Plot the two resonant curves and calculate the band width and Q ($\omega_o$/BW) in each case, from the curves. Check by calculating Q and bandwidth from circuit parameters.

EE 233 Expt. #3

# Power Measurements



(a)



(b)

This experiment shows how to use a wattmeter, voltmeter and ammeter to determine real and apparent power and power factor. Learn how to connect a wattmeter into a circuit. Measure $R_c$ using a bridge.

a) Connect the circuit shown in Fig. (a), S in position 1, and R = 0. Gradually increase $E_S$ to 72 V RMS. (Watch the meters as $E_S$ rises. If any meter reads unusually high, recheck the circuit and correct any bad connections). Record meter readings of I, P and $E_S$.

b) Increase R to 12 ohms. Gradually raise $E_S$ until $E_L$ = 72 volts. Record readings of $E_L$, $E_S$, P and I.

c) With S in position 2, increase $E_S$ to the same reading it showed in part b). Record readings of $E_S$, P and I.

d) Connect the circuits of parts b) and c) in parallel (Fig. b) and increase $E_S$ to the same value as in parts b) or c). Record readings of $E_S$, P and I.

## Report

1.) Do the following calculations, for each part of the experiment.

  a) Calculate the real power using $I^2R$, and reactive power using $I^2X$ (use the measured value for I).

  b) Draw the power triangle to scale, using the calculations of part a). Determine the apparent power and the power factor using the triangle.

  c) Find power factor using the measured values of $E_S$, I and P.

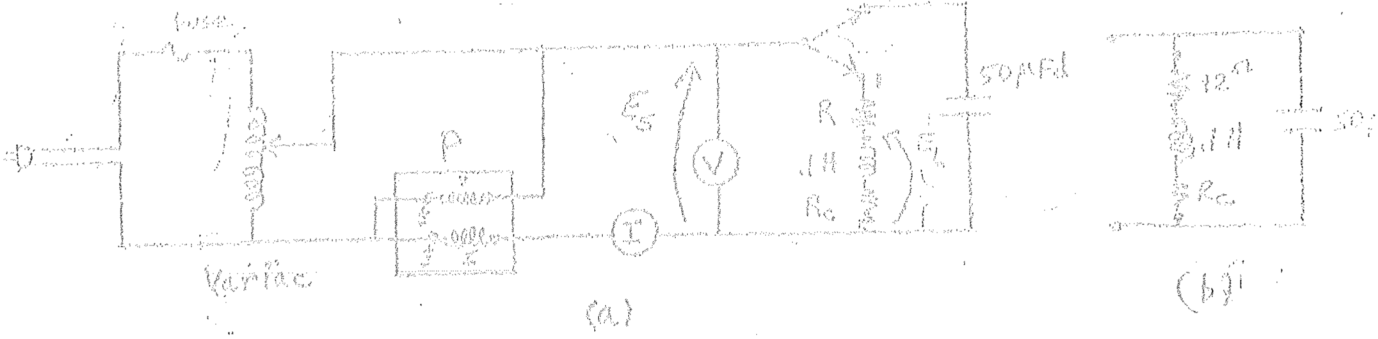
2.) How close does the real power, as calculated above compare with the wattmeter reading (calculate the % error);

3.) Calculate the error between apparent power as determined from the triangle, with apparent power calculated from the meter readings ($E_SI$).

4.) Calculate the error between the P.F. calculated from parts b) and c).

EE 133 Expt. #3

# Power Measurements



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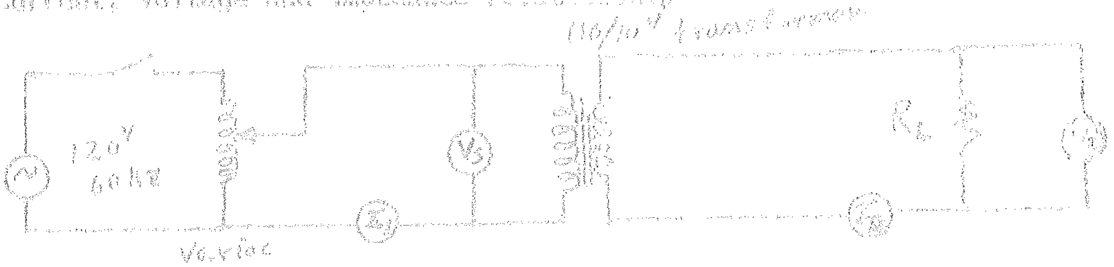
4.) Calculate the error between the P.F. calculated from parts b) and c).

marks

## TRANSFORMERS, 3 phase

This experiment illustrates the current and voltage transformations occurring between the primary and secondary of a transformer. It also shows how the secondary voltage changes as the transformer is loaded. A current transformer is used to extend the current range of the ammeter. The transformer is also used to improve power into a load, when energized with a source containing an appreciable internal resistance.

A. Current, voltage and impedance relationships



Connect the circuit shown, and have the instructor check before energizing it.

1) With the secondary open circuited ($R_L$=infinity) gradually increase the variac, setting $V_s$ to 105 volts. Watch the ammeters for any excess readings. Read $V_{s1}$ and $V_2$.

2) For each of the following values of $R_L$, read $V_2$, $I_1$ and $I_2$ (setting $V_s$ to 105 volts): $R_L$=9, 8, 7, 6 and 5 ohms.

3) Replace meter $I_2$ with a current transformer, connecting the meter to the secondary of the current transformer. Set the current transformer ratio to 10/5.

Repeat part (2) for values of $R_L$=5, 4, 3 and 2 ohms.

[illegible]

a) Calculate the open circuited voltage ratio and assume it is the turns ratio.

b) Plot a curve of $V_2$ vs $I_2$.

c) From the meter readings, calculate the current ratio $I_2/I_1$, and compare to the turns ratio. Use the values for $R_L$ = 2 ohms only.

d) Calculate the input impedance of the transformer using metered values $V_s$ and $I_1$ ($R_L$ = 2 ohms). Compare to the input impedance calculated using the turns ratio and $R_L$ = 2 ohms.

Transformers, 3 phase, Exp #4, EE233

## Part B

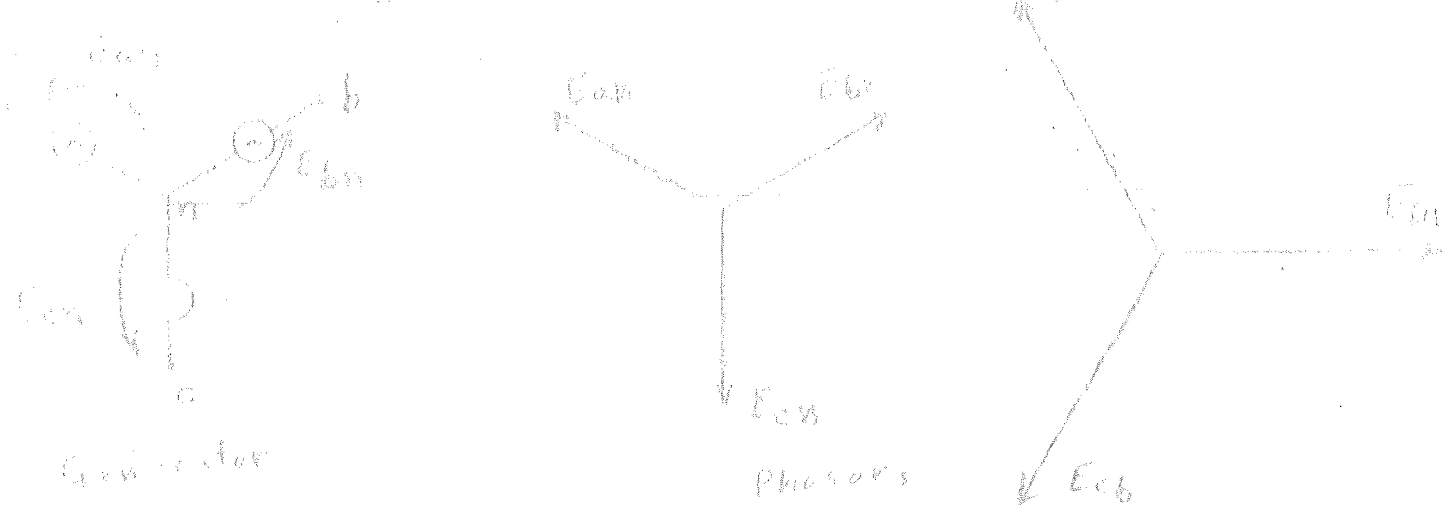


FIGURE 2

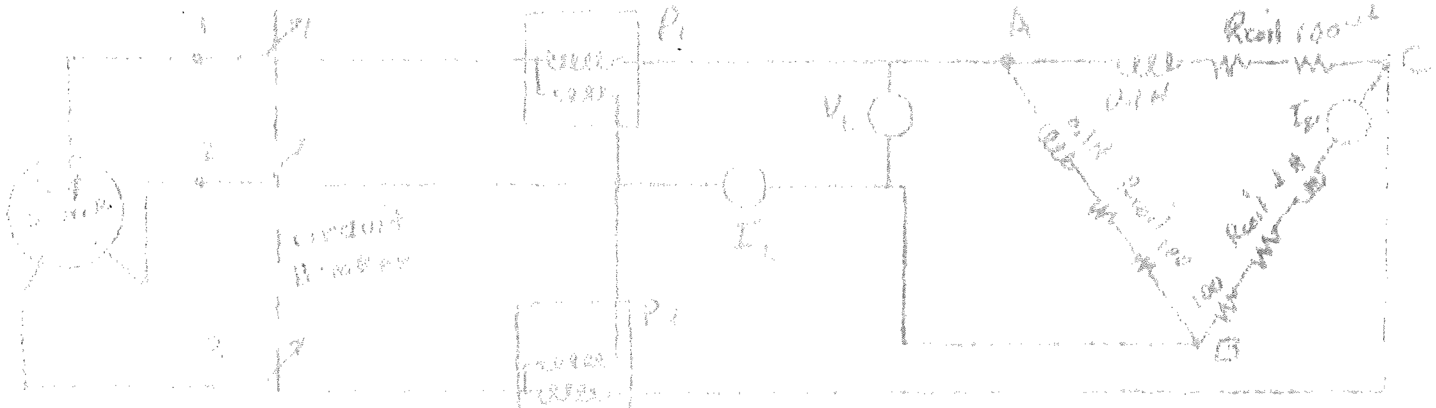


FIG. 2

[illegible] make the connections shown in Fig. 2. The line [illegible] preliminary calculations to determine [illegible] across each wattmeter [illegible] connected either [illegible] carefully [illegible] repair,

## Part B

[illegible] reference [illegible]

[illegible]

[illegible] wattmeter [illegible]

[illegible] current is the same as the cor [illegible] line voltage [illegible]

[illegible]

| TOPICS | CH | PAGES |
|---|---|---|
| Charge, current, voltage, power, energy | 1 (1) | 3-16 (5-14) |
| Circuit elements, stored energy, energy sources | 1 (2) | 16-24 (14-27) |
| Circuit laws, solution for currents ✓ | 2 (2) | 29-37 (27-36) |
| Solution for voltages | 2 (2) | 38-40 (36-39) |
| Passive network reduction, current and voltage dividers | 2 (6) | 42-44 (210-211) |
| Active network reduction, superposition theorem<br>Quiz #1 | 2 (6) | 44-51 (211-217) |
| Exponential and sinusoidal waveforms, complex numbers ✓ | 3 (3) | 51-75 (40-60) 77-83 (77-79) |
| Phasors, effective values, meters, Wattmeters ✓ | 3 (3,7) | 75-87 (60-68, 163-165)<br>599 (541), 606 (550) |
| Natural response, first order system ✓ | 4 (4) | 87-93 (73-79) |
| → Forced response for D.C. ✓ | 5 (5) | 110-113 (109-111) |
| Forced response to sinusoids | 5 (5) | 116-124 (111-118) |
| Series and parallel circuits ✓ | 5 (6) | 128-133 (118-123) |
| Power calculations ✓ T ← | 7 (7) | 169-177 (167-175) |
| ○ Frequency response and resonance T ✓ | 7 ( ) | 177-191 (175-189) |
| Three phase circuits T ✓<br>Quiz #2 | 7 (7) | 192-207 (190-198) |
| One port networks, maximum power transfer T | 9 (8) | 209-215 (209-217, 217-224) |
| Transformer coupling T | 8 (11) | 215-225 (360-367) |
| Cathode Ray tube and oscilloscope T | 10 (9,27) | 255-267 (247-257, 663-664) |
| Diode characteristics T | 10 (9)<br>11 (9) | 271 (262-263,<br>299-303 (274-281) |
| Diode Models and application T | 12 (10,12) | 313-319 (?) 276, 391-395 |
| Bipolar Junction Transistor (BJT) curves & amplification | 13 (9) | 340-347 (289-293) |

20%

Quiz #3

| | |
|---|---|
| QUIZ | 40 |
| LAB | 20 |
| FINAL | 30 |
| HW | 10 |

## FUNDEMENTAL ELECTRIC QUANTITIES

[CHARGE, (COULOMB'S LAW), $\overset{\text{CURRENT}}{\text{VOLTAGE}}$, POWER, ENERGY]

1. CHARGE: A FUNDEMENTAL ELECTROSTATIC UNIT. S.I. UNITS ARE "COULOMBS"

$\underline{1}$ COULOMB $\Rightarrow 6.24 \times 10^{18}$ ELECTRONS

COULOMB'S LAW

$$q_1 \circ \xleftarrow{\quad} r \xrightarrow{\quad} \circ\, q_2$$

$$\vec{F} = \frac{q_1 q_2}{4\pi\epsilon_o r^2} \vec{a_r}$$

$\epsilon$ = PERMITTIVITY

$\epsilon_o$ = " OF FREE SPACE = $8.854 \times 10^{-12} \frac{\text{FARA}}{\text{METE}}$

$\vec{a_r}$ = UNIT VECTOR

FOR $q_1 > 0$ AND $q_2 > 0$, CHARGES REPEL

" $q_1 < 0$ " $q_2 < 0$, " "

" $q_1 > 0$ " $q_2 < 0$, " ATTRACT

" $q_1 < 0$ " $q_2 > 0$, " ATTRACT

2. CURRENT: RATE OF CHANGE OF CHARGE WITH RESPECT TO TIME:

$$i = {}^{dq}/_{dt} \quad \left(\text{AMPS} = \frac{\text{COULOMBS}}{\text{SEC}}\right)$$

$$\longrightarrow q^{+} > 0 \quad (\text{HOLES, POSITRONS})$$

$$\longleftarrow q^{-} < 0 \quad (\text{ELECTRONS})$$

$$\Longrightarrow \text{ RESULTING CURRENT}$$

$$i = \frac{dq^{+}}{dt} + \frac{dq^{-}}{dt}$$

3. ENERGY: THE ABILITY TO DO WORK
 - MEASURED IN JOULES

4. VOLTAGE (POTENTIAL - EMF) THE ENERGY TRANSFER CAPABILITY OF A FLOW OF ELECTRIC CHARGE.

$$v = {}^{dw}/_{dq} \quad \left(\text{VOLTS} = \frac{\text{JOULES}}{\text{COULOMB}}\right)$$

. TO SPECIFY A VOLTAGE, WE NEED TO DESIGNATE TWO REFERENCE POINTS (AS IN A GRAVITATIONAL POTENTIAL)

5. POWER - THE RATE AT WHICH ENERGY IS TRANSFERED:

$$p = {}^{dw}/_{dt} \quad \left(\text{WATTS} = \frac{\text{JOULES}}{\text{SEC}}\right)$$

NOTE THAT

$$p = \frac{dw}{dt} = \frac{dw}{dq}\,\frac{dq}{dt} = vi$$

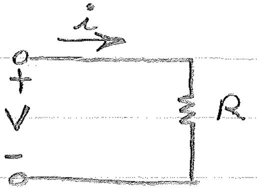
THUS, W = TOTAL ENERGY $= \int p\,dt$

$$= \int v i\,dt$$

# THE FUNDEMENTAL (PASSIVE) CIRCUIT ELEMENTS

## 1. RESISTANCE

a. CIRCUIT



IDEAL RESISTOR

$V = iR$ (OHM'S LAW)

R IS IN "OHMS"

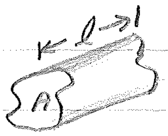
$G = \frac{1}{R}$ = "CONDUCTANCE" IN "MHOS" OR "SIEMENS"

b. AN EXAMPLE OF A PHYSICAL RESISTER

$\rho$ = RESISTIVITY (PROPERTY OF MATERIAL)

IN DHM-METERS

CONSIDER A TUBE:



$\rho$ = UNIFORM RESISTIVITY

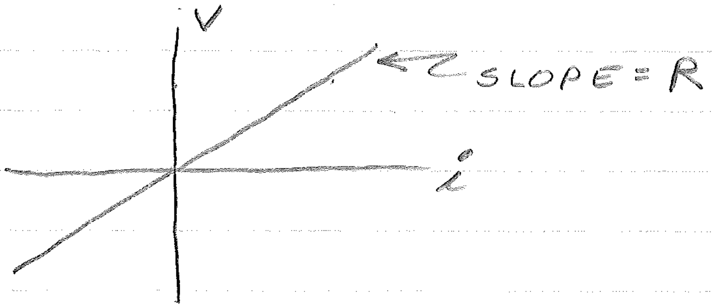
A = CROSS SECTION OF TUBE

$l$ = LENGTH OF TUBE

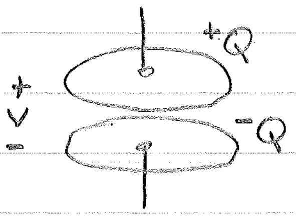
THEN $R = \rho l/A$ (INTUITIVE)

(WE ARE ASSUMING UNIFORM CURRENT DENSITY

c. NOTE THAT WE CAN EXPRESS A RESISTOR ON A V-$i$ CURVE



## 2. CAPACITANCE (CONDENSOR)



THE CHARGE OF THE CAPACITOR IS PROP. TO VOLTAGE:

$$q = CV$$

C = CAPACITANCE (IN FARADS)

DIFFERENTIATING:

$$\frac{dq}{dt} = \frac{d}{dt}(CV) = C\frac{dV}{dt}$$

OR

$$i = C\frac{dV}{dt}$$

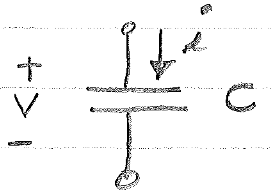
NOTE THAT

$$V = \frac{1}{C}\int_{-\infty}^{t} i\,dt$$

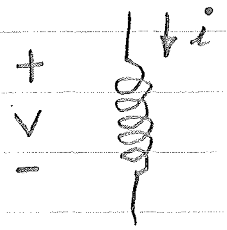
THUS, PAST CURRENT HISTORY IS STORED. THE CAPACITOR STORES ENERGY IN AN ELECTRIC FIELD.

THE CAPACITOR IS SYMOLIZED BY THE FIGURE

SCHEMATIC



3. INDUCTANCE (COIL, CHOKE)



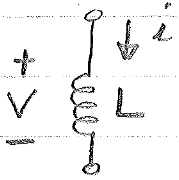
THE VOLTAGE IS PROP. TO RATE OF CHANGE OF CURRENT

$$V = L\frac{di}{dt}$$

L = INDUCTANCE (IN HENRYS)

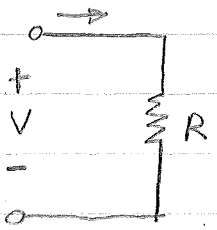
INDUCTORS STORE ENERGY IN A MAGNETIC FIELD.

THE INDUCTOR IS SYMBOLIZED BY THE FIGURE:



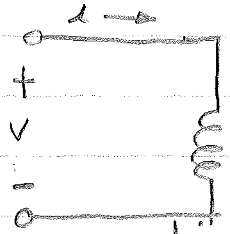
SUMMARY OF THE THREE BASIC (PASSIVE) CIRCUIT ELEMENTS

RESISTOR



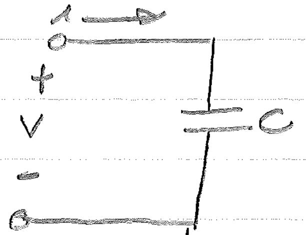
$V = Ri$

INDUCTOR



$V = L\frac{di}{dt}$

CAPACITOR



$i = C\frac{dv}{dt}$

## ENERGY STORAGE AND DISSIPATION IN THE LINEAR PASSIVE ELEMENTS

(1) LINEARITY. FOR R, L, & C, WE HAVE

$$v = f(i)$$

BY LINEARITY, WE MEAN

$$f(a i_1 + b i_2) = a f(i_1) + b f(i_2)$$

$\Rightarrow$ a & b ARE CONSTANT. SIMILARLY

$$i = g(v) (= f^{-1}(v))$$

THE R, L, & C ARE ALSO LINEAR IN THE SENSE THAT

$$g(a v_1 + b v_2) = a g(v_1) + b g(v_2)$$

(2) ENERGY CONSIDERATIONS

RECALL THAT WE SHOWED

$$w = \text{ENERGY} = \int v i \, dt$$

(a) FOR AN INDUCTOR : $v = L \frac{di}{dt}$

$$\Rightarrow w_L = \int L \frac{di}{dt} i \, dt = \int L i \, di$$

LET'S LOOK AT THE ENERGY OVER A TIME INTERAL $0 < t < T$ AND ASSUME $i(t=0) = 0$ AND $i(t=T) = I$

THEN $W_L = \int_0^T L i \frac{di}{dt} dt = \int_0^I L i \, di = \frac{1}{2} L I^2$

$\Longrightarrow$ INDUCTANCE IS A MEASURE OF THE ABILITY OF A DEVICE TO STORE ENERGY IN THE FORM OF A MAGNETIC FIELD.

(b) FOR A CAPACITOR ; $i = C\frac{dv}{dt}$

LET'S LOOK AT THE ENERGY OVER A TIME INTERVAL $0 < t < T$ AND ASSUME $v(0) = 0$ AND $v(T) = V$

THEN $W_L = \int_0^T v\,C\frac{dv}{dt}dt = \int_0^V C\,v\,dv = \frac{1}{2}CV^2$

$\Rightarrow$ CAPACITANCE IS A MEASURE OF THE ABILITY OF A DEVICE TO STORE ENERGY IN AN ELECTRIC FIELD.

(c) FOR A RESISTOR: $v = Ri$

LET'S LOOK AT THE ENERGY OVER A TIME INTERVAL $0 < t < T$ AND ASSUME A CONSTANT CURRENT $i(t) = I$ FOR $0 < t < T$ :

THEN $W_L = \int_0^R R\,i^2(t)\,dt$

$= RI^2T$

$\Rightarrow$ RESISTANCE IS A MEASURE OF THE ABILITY OF A DEVICE TO DISSIPATE ENERGY (IRREVERSABLY AS HEAT)

THE POWER OF A RESISTOR HAS BEEN SHOWN TO BE

$$p = vi$$

USING OHM'S LAW: $v = Ri$

WE MAY WRITE THIS AS

$$p = i^2R$$

$$p = v^2/R$$

ENERGY CONTINUITY

ENERGY CANNOT BE CHANGED INSTANTLY (FOR EXAMPLE, CONSIDER THE INERTIA OF A MASS)

1. FOR A CAPACITOR:

$W_L = \frac{1}{2} C V^2$

SINCE $W_L$ CANNOT CHANGE INSTANTLY, AND C IS FIXED $\Rightarrow$ V CANNOT CHANGE INSTANTANEOUSLY ACROSS A CAPACITOR.

2. FOR AN INDUCTOR

$W_L = \frac{1}{2} L I^2$

$\Rightarrow$ I CANNOT CHANGE INSTANTLY ACROSS AN INDUCTOR.

3. FOR A RESISTOR

~~$W_R = IR^2T = (IR)IT = VIT$~~

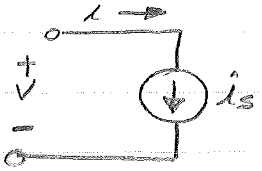
~~VOLTAGE (CURRENT) CAN CHANGE INSTANTLY ACROSS (THRU) A RESISTOR. IT IS ACCOMPANIED, HOWEVER, BY AN INVERSE CHANGE IN CURRENT (VOLTAGE) IN SUCH A MANNER TO ALLOW NO INSTANTANEOUS CHANGE IN ENERGY.~~

SINCE THE RESISTOR CANNOT STORE ENERGY, THERE IS NO LIMITATION ON THE RAPIDITY WITH WHICH V & I CHANGES CAN OCCUR.

## ENERGY (VOLTAGE & CURRENT) SOURCES

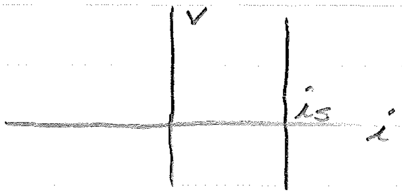
R, L, & C ARE "PASSIVE"
VOLTAGE & CURRENT SOURCES ARE "ACTIVE"

### 1. CURRENT SOURCE (GENERATOR)

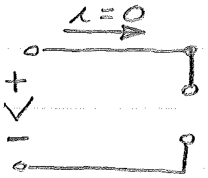


$i = i_s \ \forall v$

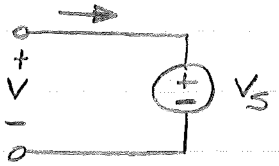
V-i CURVE ⇒



FOR $i_s = 0$, WE HAVE AN "OPEN CIRCUIT":

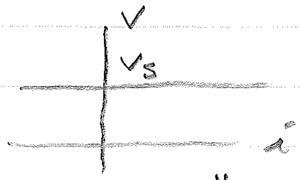


### 2. VOLTAGE SOURCE (GENERATOR)

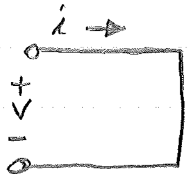


$v = v_s \ \forall i$

V-i CURVE ⇒



FOR $v_s = 0$, WE HAVE A "SHORT CIRCUIT"



$v = 0 \ \forall i$

THESE MODELS ARE "IDEAL"

## NOTE ON SCHEMATIC REPRESENTATION

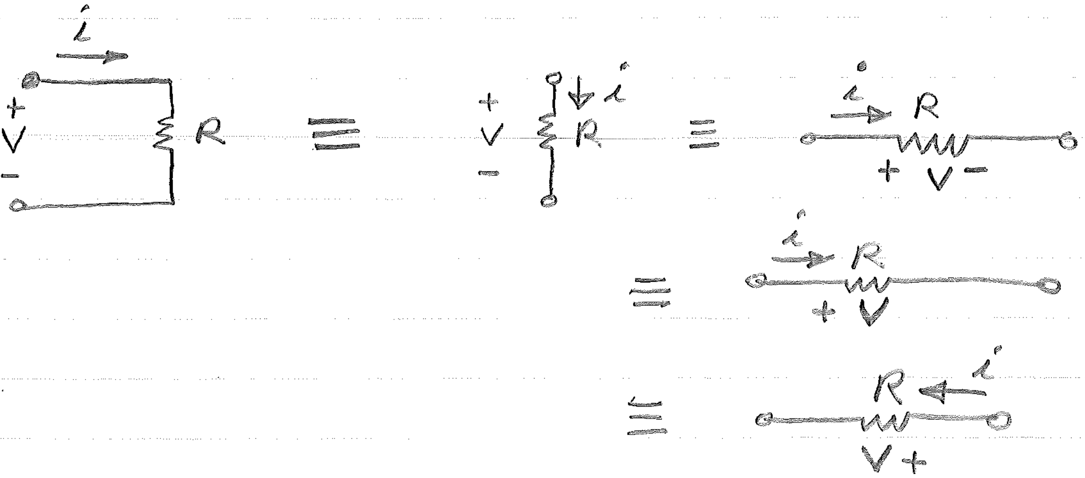
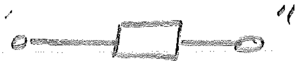


TABLE 1-4 IN TEXT GIVES GOOD SUMMARY OF ACTIVE & PASSIVE CIRCUIT ELEMENTS
(R, G, I, C, SC, OS, Vsource, Isource)
(MEMORIZATION ADVISED)

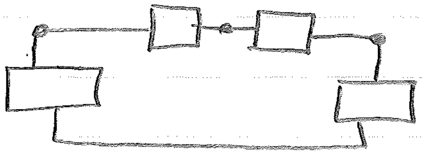
## SOME CIRCUIT ANALYSIS NOMENCLATURE

1. LUMPED CIRCUIT ELEMENT - A REGION IN SPACE IN WHICH AT LEAST TWO POINTS ARE DEFINED. "SCHEMATIC ⇒ ""

   EX: L, R, C, $V_s$, $I_s$

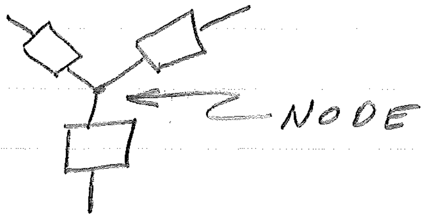
2. LUMPED CIRCUIT: A COLLECTION OF LUMPED CIRCUIT ELEMENTS WHOSE METHOD OF CONNECTION IS SPECIFIED

   EX:

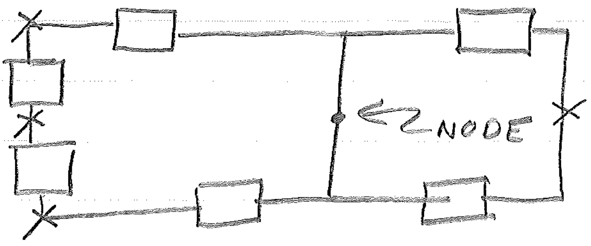


3. NODE: A POINT AT WHICH TWO OR MORE CIRCUIT ELEMENTS HAVE A COMMON CONNECTION

   EX:

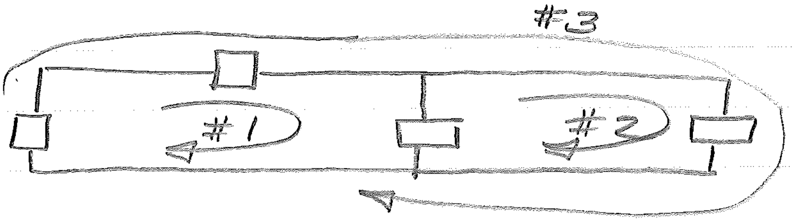


EX.



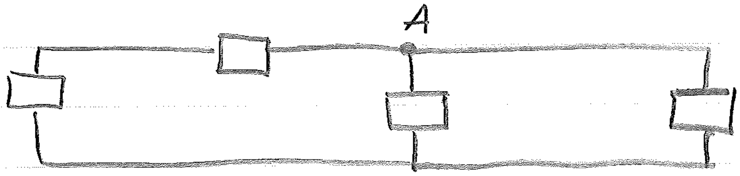
4. LOOP: ANY SEQUENCE OF CIRCUIT ELEMENTS FORMING A CLOSED PATH WHICH DOES NOT PASS THRU A NODE MORE THAN ONCE.

EX:



! BRANCH: A PART OF A NETWORK EXTENDING FROM ONE NODE TO ANOTHER.

EX:



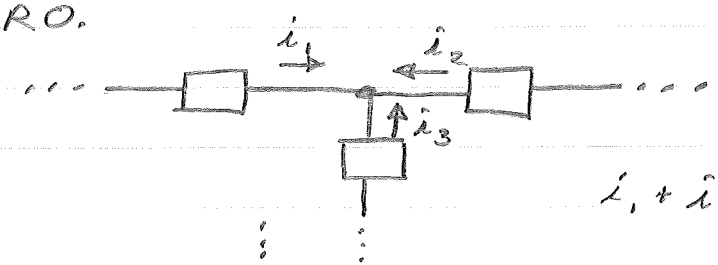
NODE A HAS 3 CORRESPONDING BRANCHES

5. MESH: ANY LOOP CONTAINS NO CIRCUIT ELEMENT IN ITS ENTERIOR. ALL MESHES ARE LOOPS. ALL LOOPS ARE NOT MESHES (#1 & #2 ABOVE, ARE MESHES. LOOP #3 IS NOT)

## KIRCHHOFF'S LAWS

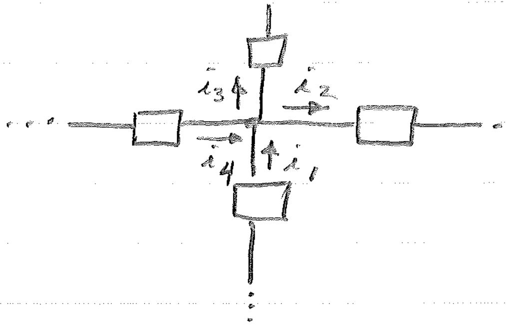
1. KIRCHHOFF'S CURRENT LAW: THE ALGEBRAIC SUM OF THE CURRENTS INTO A NODE AT ANY INSTANT IS ZERO.

EX:



$i_1 + i_2 + i_3 = 0$

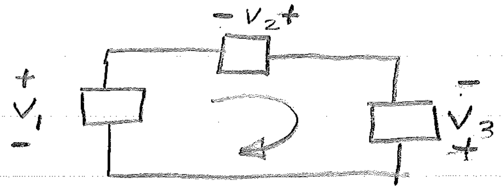
EX:



$i_1 + (-i_2) + (-i_3) + i_4 = 0$

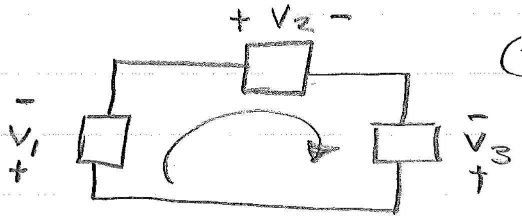
2. KIRCHHOFF'S VOLTAGE LAW: THE ALGEBRAIC SUM OF THE VOLTAGES AROUND A LOOP AT ANY INSTANT IS ZERO

EX:



$V_1 + V_2 + V_3 = 0$

EX:



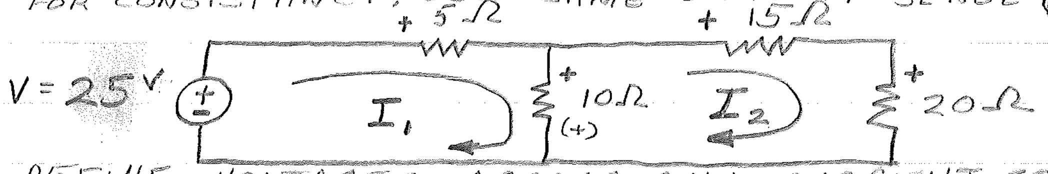
$(-V_1) + (-V_2) + V_3 = 0$

# APPLICATION OF KIRCHHOFF'S LAWS

## 1. LOOP CURRENT METHOD (USING KIRCHHOFF'S VOLTAGE LAW)

STEPS:

1. DRAW "LOOP CURRENTS" IN THE CIRCUIT (USING "MESH" CURRENTS ASSURES NO REDUNDANCY)
   FOR CONSISTANCY, USE SAME CURRENT SENSE (CW)



DEFINE VOLTAGES ACROSS ANY CURRENT SOURCES

2. FOR EACH LOOP, SUM THE VOLTAGES AND SET TO ZERO
   (a) IF A LOOP CURRENT ENTERS A POSITIVE TERMINAL OF A V SOURCE, THE VOLTAGE IS DESIGNATED AS POS
   (b) IF A LOOP CURRENT ENTERS A PASSIVE ELEMENT, DENOTE THE POINT OF ENTRY AS A POSITIVE V
   (c) DO SUBTRACT EFFECTS OF ADJACENT LOOP CURRENTS
3. USE OHM'S LAW: $V = IR$

FOR $I_1$

$$-25 + 5I_1 + 10I_1 - 10I_2 = 0$$

OR $$15I_1 - 10I_2 = 25$$

FOR $I_2$

$$15I_2 + 20I_2 + 10I_2 - 10I_1 = 0$$

OR $$-10I_1 + 45I_2 = 0$$

IN SUMMARY

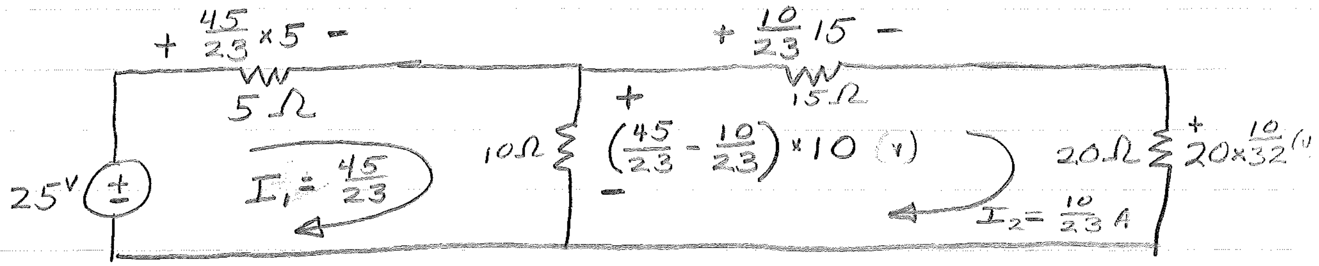
$$15I_1 - 10I_2 = 25$$
$$-10I_1 + 45I_2 = 0$$

TWO EQUATIONS / TWO UNKNOWNS

SOLVING GIVES

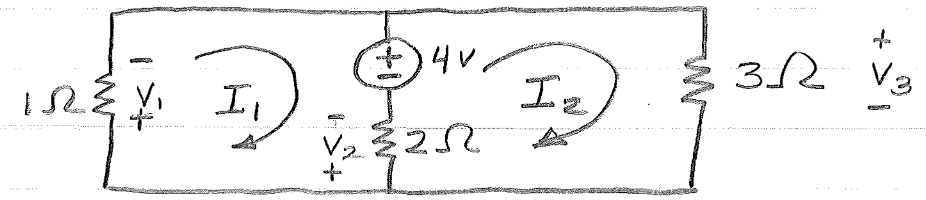
$$I_1 = \frac{45}{23} \text{ AMPS}$$
$$I_2 = \frac{10}{23} \text{ AMPS}$$

WE CAN NOW ASSIGN VOLTAGES TO ALL THE CIRCUIT'S RESISTORS.



NOTE THAT THE 10Ω RES. IS SHARED BY BOTH $I_1$ & $I_2$. IT IS THE "MUTUAL RESISTANCE" BETWEEN THE TWO LOOPS. LOOP 1 HAS 5Ω OF "SELF-RESISISTANCE". LOOP 2 HAS 15Ω + 20Ω = 35Ω OF "SELF-RESISTANCE"

EXAMPLE <u>(SKIP)</u>



$$1 I_1 + 4 + 2 I_1 - 2 I_2 = 0$$

OR $$3 I_1 - 2 I_2 = -4$$

$$3 I_2 + 2 I_2 - 2 I_1 - 4 = 0$$

OR $$-2 I_1 + 5 I_2 = 4$$

SOLUING: $I_2 = 4/11$ $\quad I_1 = \frac{-12}{11}$

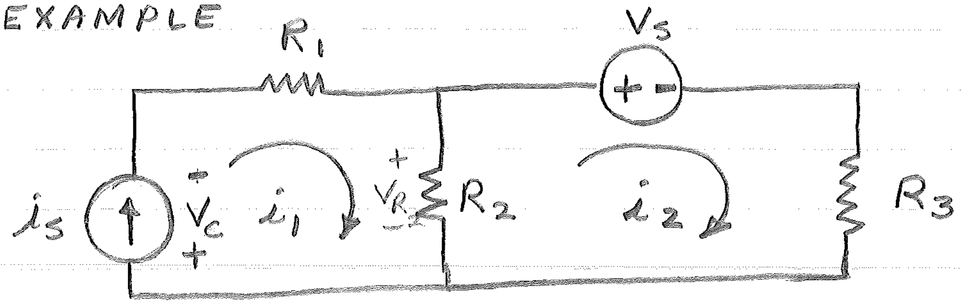
$$V_1 = (1\,\Omega)\left(\frac{-12}{11\,A}\right) = \frac{-12}{11} \text{ VOLTS}$$

$$V_2 = (2\,\Omega)\left(\frac{4}{11} - \left(\frac{-12}{11}\right)\right) \text{AMPS}$$

$$= \frac{32}{11} \text{ V}$$

$$V_3 = (3\,\Omega)\left(\frac{4}{11} A\right) = \frac{12}{11} \text{ V}$$

EXAMPLE



$$i_1 = i_s$$

$$\begin{cases} V_c + (R_1+R_2)\,i_1 - R_2\,i_2 = 0 \\ V_s + (R_2+R_3)\,i_2 - R_2\,i_1 = 0 \end{cases}$$

OR

$$\begin{cases} V_c + (R_1+R_2)\,i_s - R_2\,i_2 = 0 \\ V_s + (R_2+R_3)\,i_2 - R_2\,i_s = 0 \end{cases}$$

TWO EQUATIONS - TWO UNKNOWNS

$$i_2 = \frac{R_2 i_s - V_s}{R_2 + R_3}$$

$$V_c = R_2 i_2 - (R_1+R_2)\,i_s$$

$$= R_2\left[\frac{R_2 i_s - V_s}{R_2+R_3}\right] - (R_1+R_2)\,i_s$$

$$V_{R_1} = R_1\,i_1 = R_1\,i_s$$

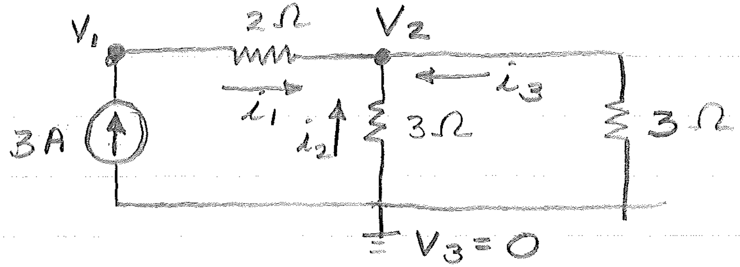
$$V_{R_2} = R_2(i_1 - i_2) = R_1\left[i_s - \frac{R_2 i_s}{R_2+R_3} + \frac{V_s}{R_2+R_3}\right]$$

$$= R_1\left[\left(1 - \frac{R_2}{R_2+R_3}\right) i_s + \frac{V_s}{R_2+R_3}\right]$$

## 2. NODE-VOLTAGE METHOD (USING KIRCHHOFF'S CURRENT LAW)

STEPS

1. SPECIFY A VOLTAGE AT EVERY NODE



SET ONE OF THE NODES TO ZERO VOLTS

DEFINE A CURRENT THRU ANY V SOURCE.

2. FOR EACH NODE, SUM THE INCOMING CURRENT AND SET TO ZERO. THE CURRENT OF A BRANCH IS THE DIFFERENCE IN POTENTIAL ÷ RESISTANCE

$$V = iR \Rightarrow i = V/R$$

FOR NODE 2:

$$i_1 + i_2 + i_3 = \frac{V_1 - V_2}{2} + \frac{V_3 - V_2}{3} + \frac{V_3 - V_2}{3}$$
$$= \frac{V_1 - V_2}{2} - \frac{2}{3}V_2 = -\frac{7}{6}V_2 + \frac{V_1}{2}$$

FOR NODE 1:

$$3A - i_1 = 3A - \frac{V_1 - V_2}{2} = 0$$

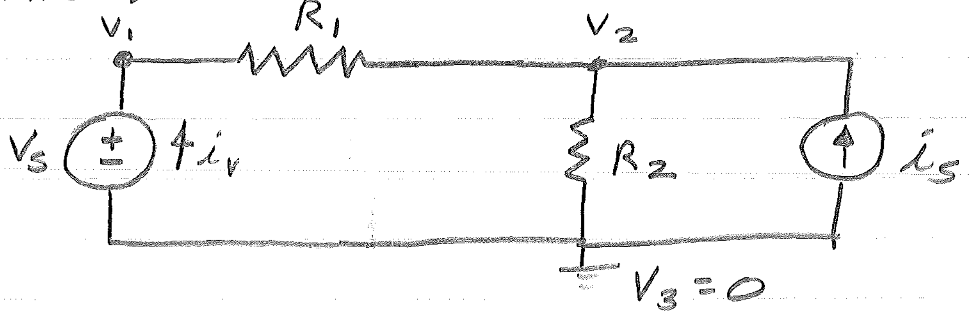
WE THUS HAVE EQUATIONS

$$-\frac{7}{6}V_2 + \frac{V_1}{2} = 0 \quad \Big| \quad 3 - \frac{V_1}{2} + \frac{V_2}{2} = 0$$

$V_1 = 9/2$ VOLTS $\quad V_2 = 27/14$ VOLTS

NOTE: WE CAN SOLVE FOR ALL CURRENTS

EXAMPLE:



AT NODE 1:

$$i_V + \frac{V_2 - V_1}{R_1} = 0$$

BUT $V_S = V_1 - V_3 = V_1$

$$\Rightarrow i_V + \frac{V_2 - V_S}{R_1} = 0$$

$$i_V R_1 + V_2 - V_S = 0 \qquad ①$$

AT NODE 2:

$$\frac{V_1 - V_2}{R_1} + \frac{V_3 - V_2}{R_2} + i_S = 0$$

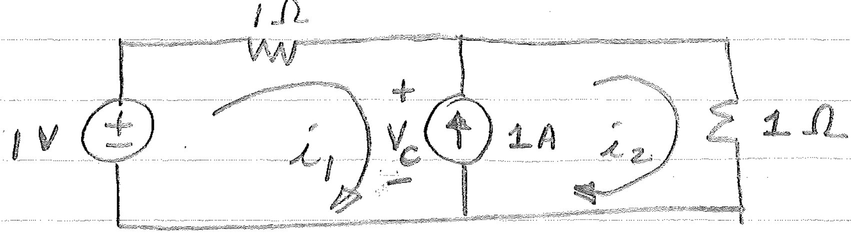
$$\frac{V_S}{R_1} - \left(\frac{1}{R_1} + \frac{1}{R_2}\right) V_2 + i_S = 0 \qquad ②$$

TWO EQUATIONS, TWO UNKNOWNS

SOLVE FOR $V_3$ AND $i_V$

EXAMPLE:

USING LOOPS



$$\begin{cases} -1 + i_1 + V_C = 0 & ① \\ -V_C + i_2 = 0 & ② \\ i_2 - i_1 = 1 & ③ \end{cases}$$

UNKNOWNS: $i_1$, $V_C$, $i_2$

FROM ② $V_C = i_2$

FROM ③ $\Rightarrow i_2 = 1 + i_1$

$\Rightarrow V_C = 1 + i_1$

SUBSTITUTING INTO ①

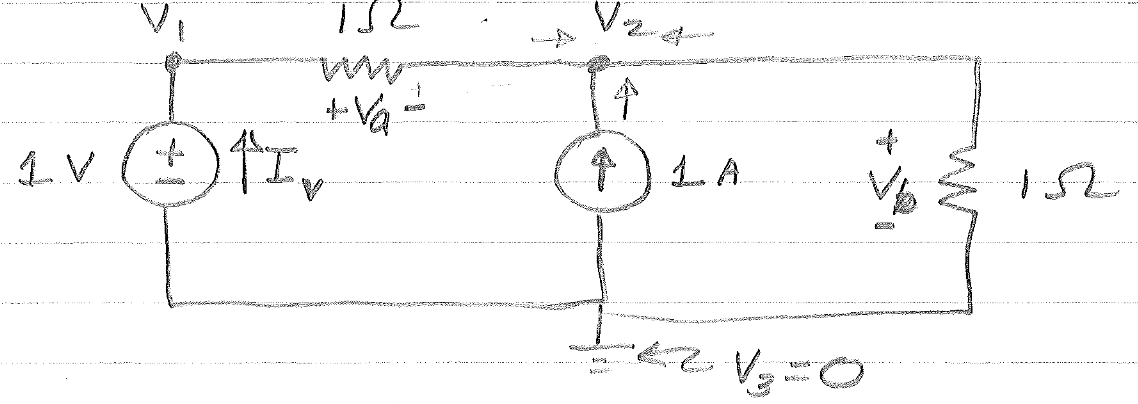
$$-1 + i_1 + (1 + i_1) = 0$$

$$2i_1 = 0 \Rightarrow i_1 = 0$$

FROM ③ $\Rightarrow i_2 = 1$ AMP

FROM ① $V_C = 1$ V

USING NODE VOLTAGES



$I_V + \frac{V_2 - V_1}{1} = 0 \Rightarrow I_V + V_2 - V_1 = 0$ ①

$1 + \frac{V_1 - V_2}{1} + \frac{0 - V_2}{1} = 0 \Rightarrow 1 + V_1 - 2V_2 = 0$ ②

$V_1 = 1$ ③

③ INTO ②

$1 + 1 - 2V_2 = 0 \Rightarrow V_2 = 1$

THIS AND ③ INTO ①

$I_V + 1 - 1 = 0 \Rightarrow I_V = 0$

$V_a = I_V (1\Omega) = 0$

$V_b = \frac{V_2 - V_3}{1\Omega}(1\Omega) = +1 V$

# ENERGY STORAGE ELEMENTS IN KIRCHHOFF'S LAWS

(SOLUTIONS RATHER DIFFICULT)

1. LOOP CURRENTS (USE VOLTAGE RELATION)

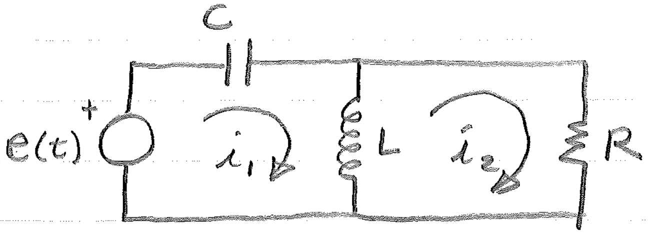
   a. R ⇒ $V_R(t) = R\,i(t)$

   b. L ⇒ $V_L(t) = L\frac{d}{dt}i_c(t)$

   c. C ⇒ RECALL $i_c(t) = C\frac{dv_c(t)}{dt}$

   $\Rightarrow v_c(t) = V_0 + \frac{1}{C}\int_0^t i_c(t)\,dt$

EXAMPLE:



$$-e(t) + \left[V_0 + \frac{1}{C}\int_0^t i_1(t)\,dt\right] + L\frac{d}{dt}(i_1 - i_2) = 0$$

$$L\frac{d}{dt}(i_2 - i_1) + R\,i_2 = 0$$

2. NODE VOLTAGE (USE CURRENT RELATION)

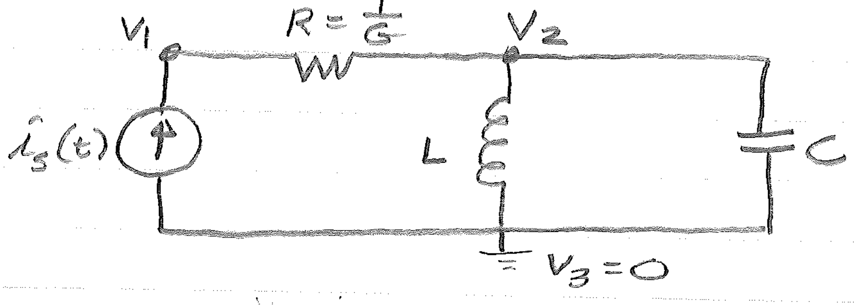
(a) $R = 1/G \quad \Rightarrow \quad i_R(t) = G\, v_R(t)$

(b) $C \quad \Rightarrow \quad i_C(t) = C \frac{d\, v_C(t)}{dt}$

(c) $L$ RECALL: $v_L(t) = L \frac{d i_L(t)}{dt}$

$$\Rightarrow i_L(t) = I_0 + \frac{1}{L}\int_0^t v_L(t)\,dt$$

EXAMPLE:



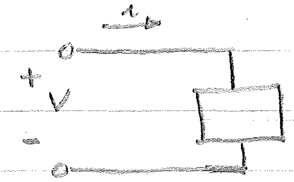
$$i_s(t) + G(v_2 - v_1) = 0$$

$$G(v_1 - v_2) + \left[I_0 + \frac{1}{L}\int_0^t (0 - v_2)\,dt\right] + C\frac{d(0 - v_2)}{dt} = 0$$

## PASSIVE NETWORK REDUCTION

### (1) PRELIMINARIES

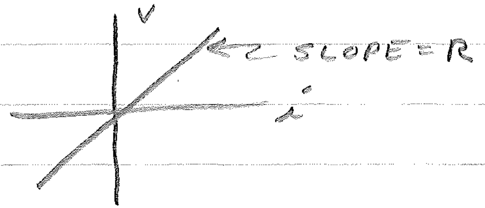
(a) V-$i$ CHARACTERISTICS



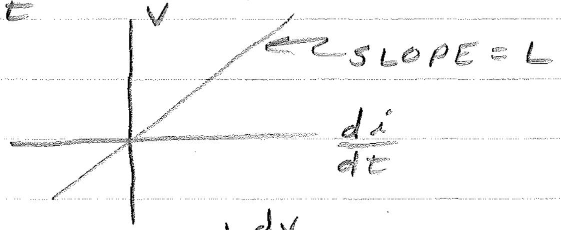
⇐ ONE PORT NETWORK

A LUMPED EVEMENT IS COMPLETELY DE TERMINED BY IT'S V-$i$ RELATION

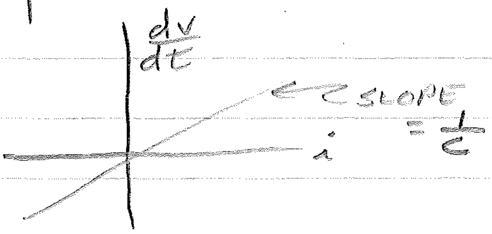
EX: $R \Rightarrow V = iR$



$L \Rightarrow V = L\frac{di}{dt}$



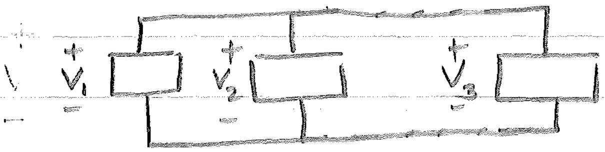
$C \Rightarrow i = C\frac{dv}{dt}$



TWO ONE-PORTS ARE EQUIVALENT IF THE HAVE SAME V-$i$ RELATION

## (b) CONNECTION DEFINITIONS

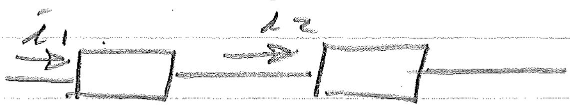
### (i) PARALLEL:



TWO OR MORE CIRCUIT ELEMENTS ARE CONNECTED IN PARALLEL IF IDENTICAL (NOT JUST EQUAL) VOLTAGES APPEAR ACROSS EACH ONE:

$$V_1 = V_2 = V_3$$

### (ii) SERIES



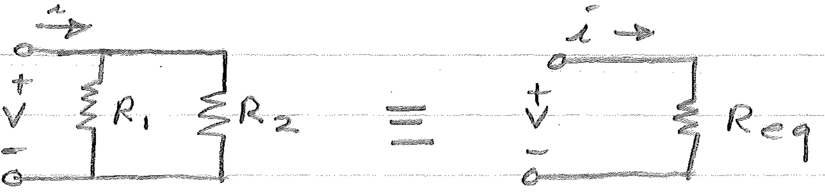
TWO OR MORE CIRCUIT ELEMENTS ARE CONNECTED IN SERIES IF IDENTICAL (NOT JUST EQUAL) CURRENT FLOWS THRU EACH ONE:

$$i_1 = i_2$$

## (2) PASSIVE ELEMENT CONNECTIONS

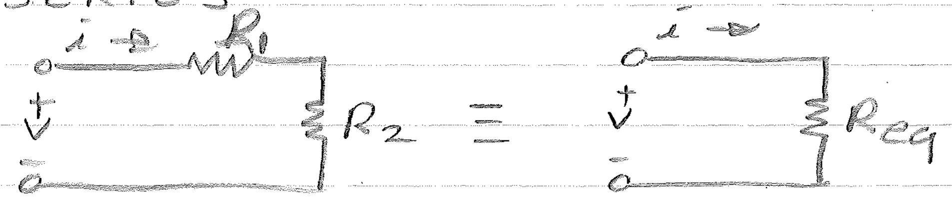
### (a) RESISTOR

(i) PARALLEL



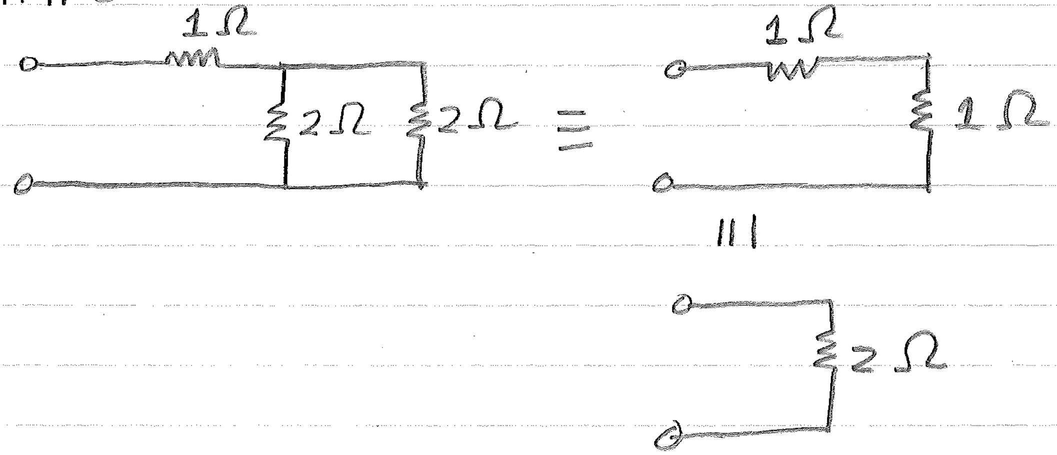
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$ (OR $G_{eq} = G_1 + G_2$)

(ii) SERIES



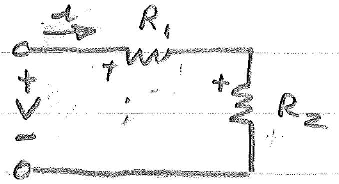
$$R_{eq} = R_1 + R_2$$

EXAMPLE:

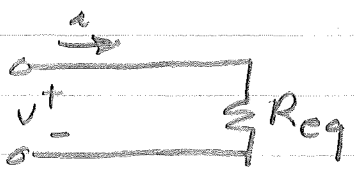


PROOF:

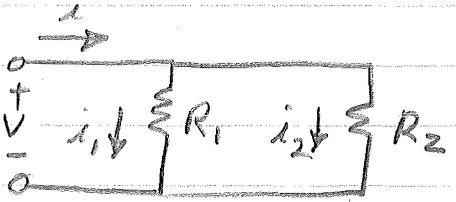
A.



$$-V + R_1 i + R_2 i = 0$$
$$V = (R_1 + R_2)\, i$$
$$= R_{eq}\, i$$



B.

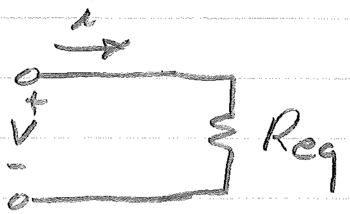


$$i_1 = \frac{V}{R_1}, \quad i_2 = \frac{V}{R_2}$$
$$i - i_1 - i_2 = 0$$

OR

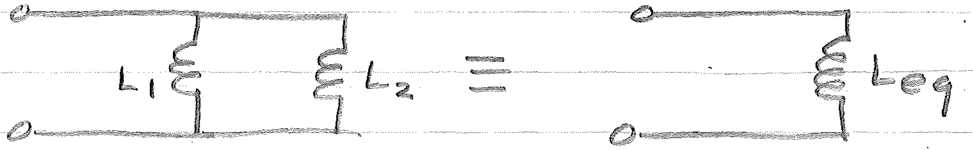
$$i = \left(\frac{1}{R_1} + \frac{1}{R_2}\right) V$$
$$V = \left[\frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}\right] i$$
$$= R_{eq}\, i$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$



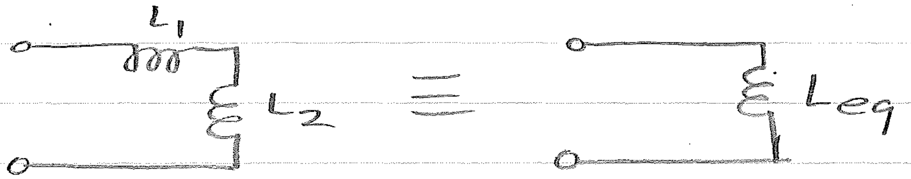
## (b) INDUCTOR

### (i) PARALLEL



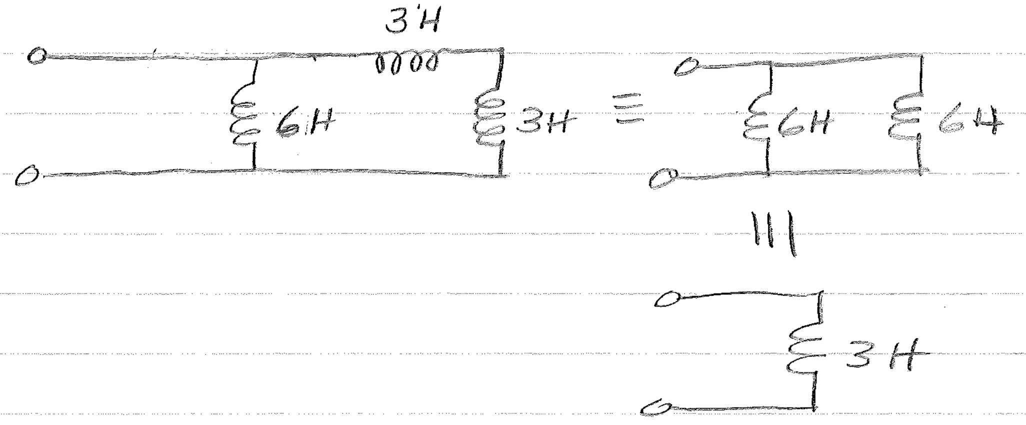
$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}$$

### (ii) SERIES



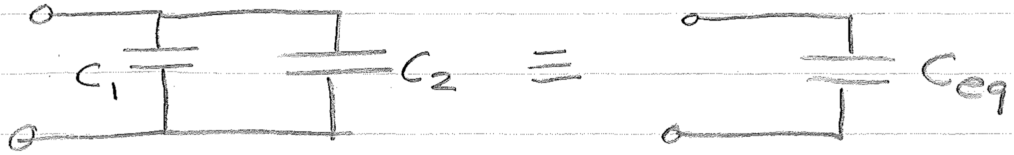
$$L_{eq} = L_1 + L_2$$

### (EX)



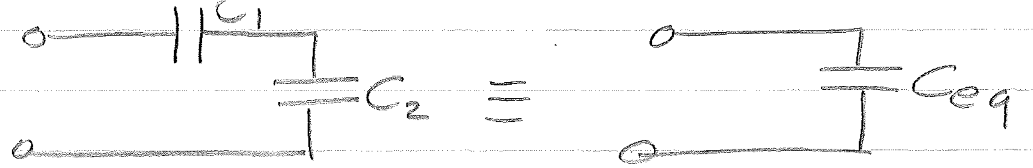
(c) CAPACITOR

(i) PARALLEL



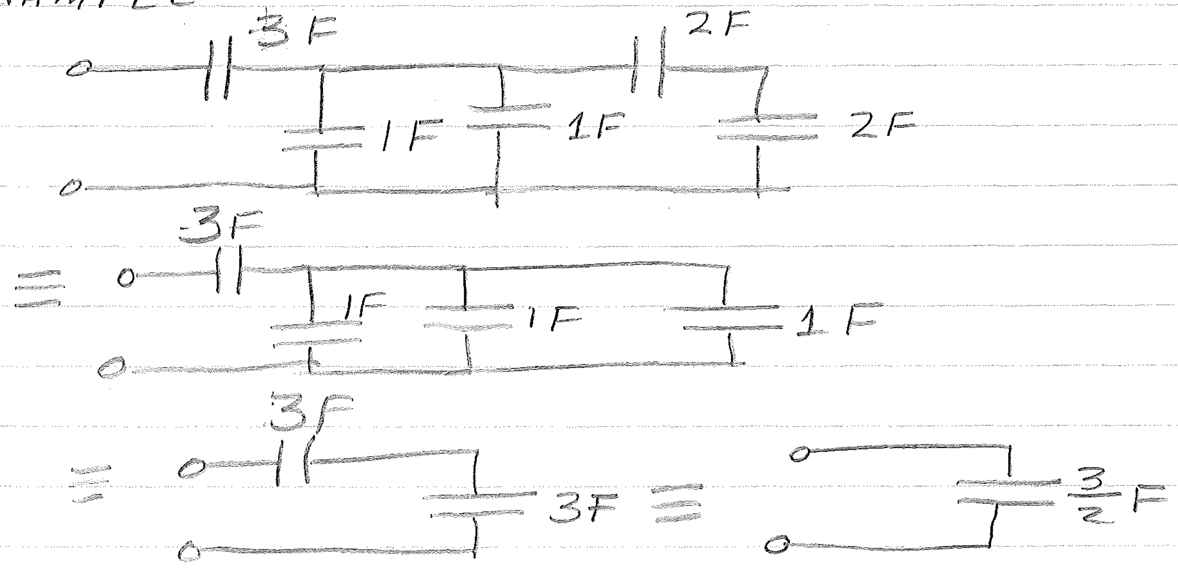
$$C_{eq} = C_1 + C_2$$

(ii) SERIES



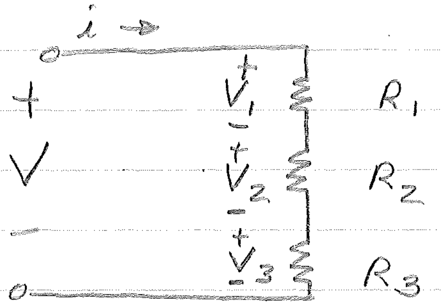
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

EXAMPLE



# CURRENT AND VOLTAGE DIVIDERS

1. VOLTAGE DIVIDER - TWO OR MORE RESISTORS IN SERIES DIVIDES THE APPLIED VOLTAGE PROPORTIONALLY



FROM KVL: $V = V_1 + V_2 + V_3$

$= (R_1 + R_2 + R_3)\, i$

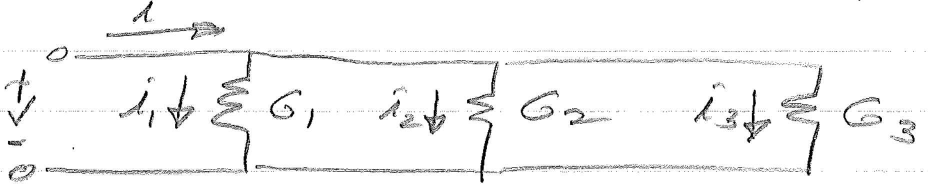
$$i = \frac{V}{R_1 + R_2 + R_3}$$

$$V_1 = iR_1 = \frac{R_1}{R_1 + R_2 + R_3} V$$

$$V_2 = iR_2 = \frac{R_2}{R_1 + R_2 + R_3} V$$

$$V_3 = iR_3 = \frac{R_3}{R_1 + R_2 + R_3} V$$

2. CURRENT DIVIDER - TWO OR MORE CONDUCTANCES IN PARALLEL DIVIDES THE APPLIED CURRENT PROPORTIONALLY



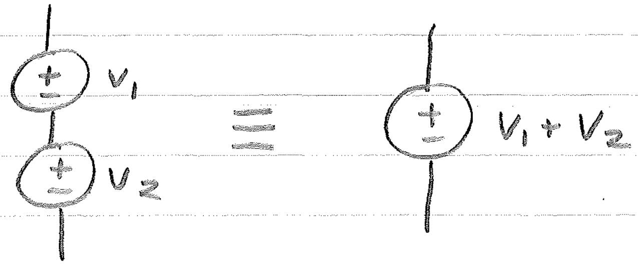
$$i_1 = \frac{G_1}{G_1 + G_2 + G_3} i$$

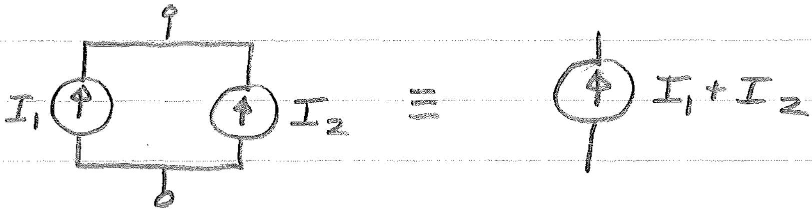
$$i_2 = \frac{G_2}{G_1 + G_2 + G_3} i$$

$$i_3 = \frac{G_3}{G_1 + G_2 + G_3} i$$

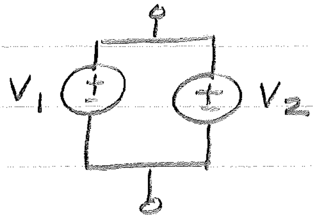
# ACTIVE NETWORK REDUCTION

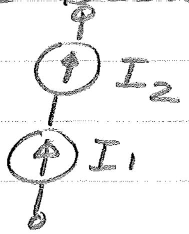
## 1. SOURCE REDUCTION



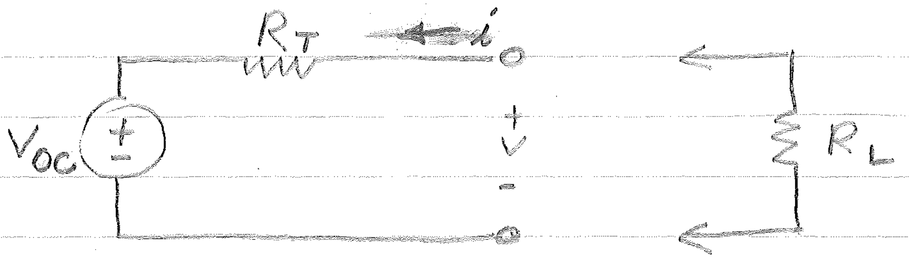


NOT ALLOWED (WILL BLOW UP)

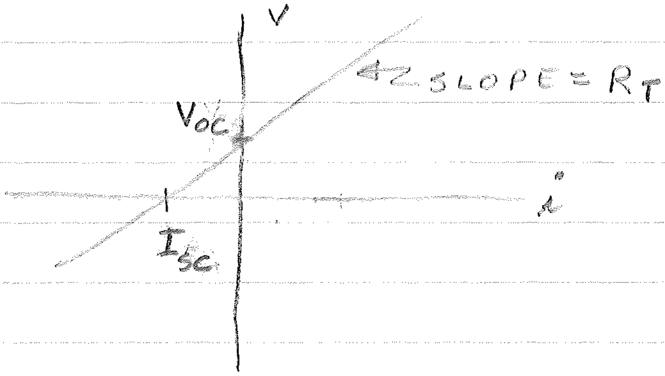




2. THÉVININ'S THEOREM: INSOFAR AS A LOAD IS CONCERNED, ANY ONE-PORT NETWORK OF RESISTORS AND ENERGY SOURCES CAN BE REPLACED BY:



v-i CURVE



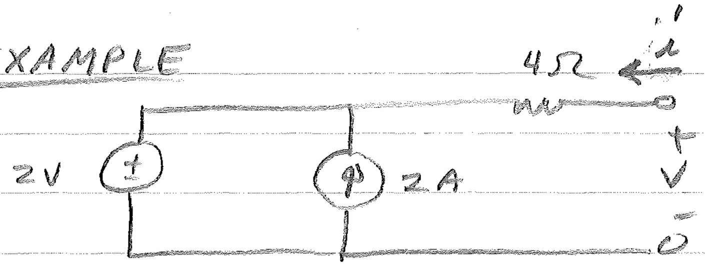
$$V = R_T\, i + V_{OC}$$

$V_{OC}$ = OPEN CIRCUIT VOLTAGE ($i$=0, $R_L = \infty$)

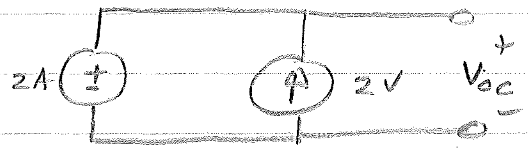
LET $I_{SC}$ = SHORT CIRCUIT CURRENT ($v$=0, $R_L$ = 0)

THEN $R_T = -V_{OC}/I_{SC}$

**EXAMPLE**

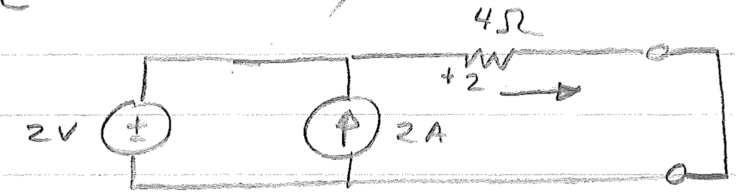


$V_{oc}$ $(i = 0)$



$V_{oc} = 2V$

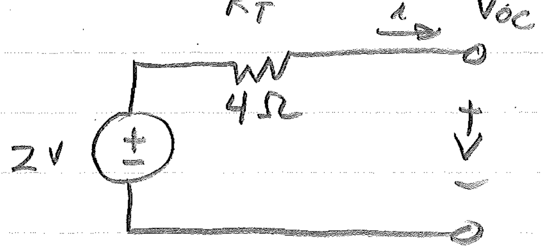
$I_{sc}$ $(v = 0)$



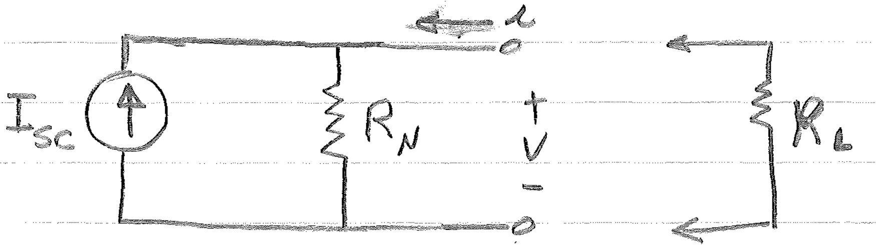
$V_{4\Omega} = 2V \Rightarrow -i_{4\Omega} = I_{sc} = -\frac{1}{2}$ AMP

$R_T = -V_{oc}/I_{sc} = 4\Omega$

$$V = \underset{\underset{R_T}{\uparrow}}{4}\; i + \underset{\underset{V_{oc}}{\uparrow}}{2}$$

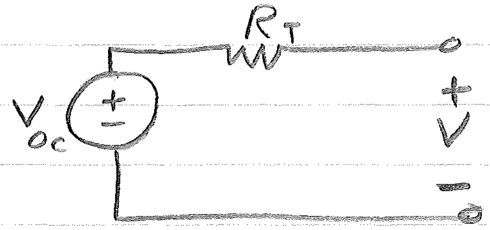


3. NORTON'S THEOREM: INSOFAR AS A LOAD IS CONCERNED, ANY ONE-PORT NETWORK OF RESISTORS AND ENERGY SOURCES CAN BE REPLACED BY

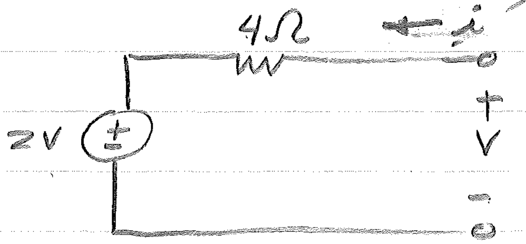


$$R_N = V_{oc}/I_{SC} \ (= R_T)$$

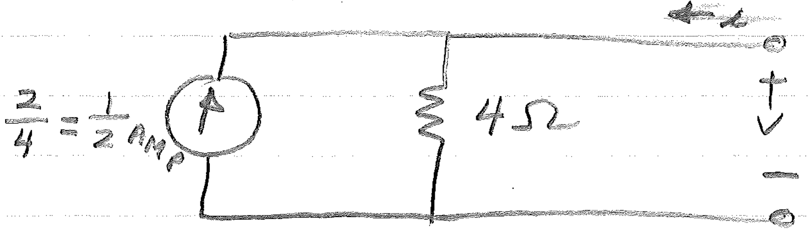
EQUIVALENT TO THEVININ'S:



IN LAST EXAMPLE, WE HAD



THE NORTON EQUIVALENT IS

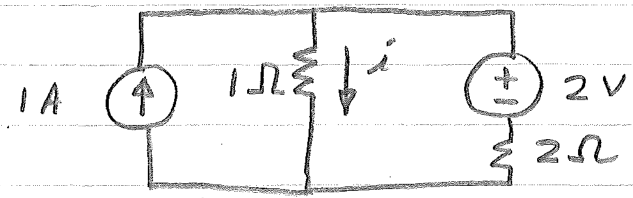


## SUPERPOSITION THEOREM

IN CIRCUITS WITH ONLY R's, L's, C's, $V_S$'s, AND $I_S$'s, THE CURRENT (VOLTAGE) THRU (ACROSS) AN ELEMENT IS THE SUM OF THE CURRENTS (VOLTAGES) INDUCED ON THAT ELEMENT BY THE CIRCUIT'S ENERGY SOURCES.

IMPLEMENTATION: WHEN VIEWING EFFECTS OF AN ENERGY SOURSE, SHORT CIRCUIT ALL $V_S$'S AND OPEN CIRCUIT ALL $I_S$'S NOT UNDER CONSIDERATION.

EXAMPLE



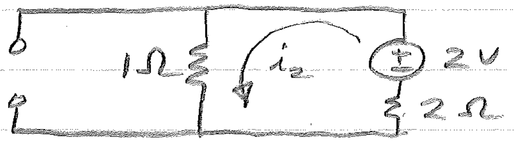
FIND $i$

① FROM 1A SOURCE:

CURRENT DIVIDER

$$i_1 = \frac{1}{1+\frac{1}{2}}(1 \text{ AMP}) = \frac{2}{3} \text{ AMP}$$

② FROM 2V SOURCE



Σ V AROUND LOOP

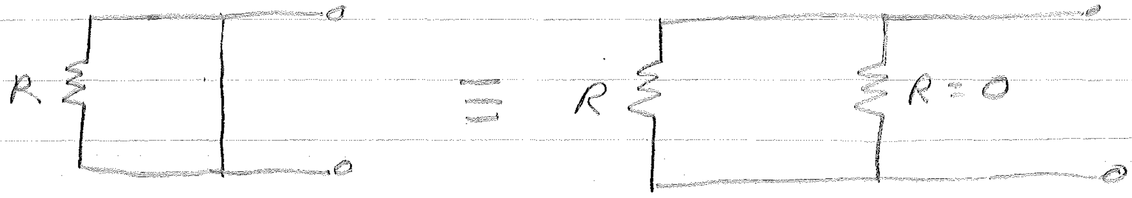
$$3i_2 = 2 \Rightarrow i_2 = \frac{2}{3} A$$

THUS

$$i = i_1 + i_2 = \frac{4}{3} A$$

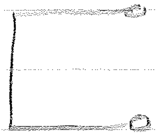
## A FEW FINAL NOTES

1.

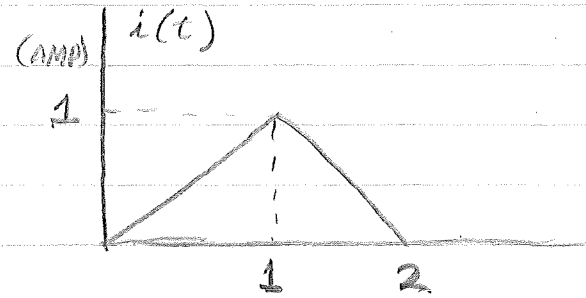


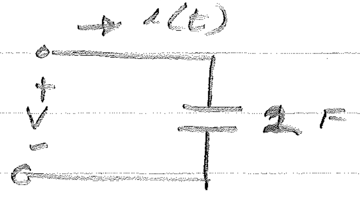
$$\frac{1}{0} + \frac{1}{R} = \frac{1}{R_{eq}} = \infty \Rightarrow R_{eq} = 0$$

≡



2.





$$v(t=2) = \cancel{v(0)}^{0} + \frac{1}{C}\int_0^2 i(t)\,dt$$

$$= \frac{1}{2}\left[1\right] = \frac{1}{2}\ V$$

TEST I

KNOW HOMEWORK & CLASS LECTURE EXAMPLES

1. V-$i$ RELATIONS OF L.C.E.
2. CONCEPT OF ENERGY CONTINUITY
3. PASSIVE & ACTIVE ELEMENT COMBINATIONS
4. KIRCHHOFF'S LOOP AND VOLTAGE-NODE METHODS
5. CURRENT AND VOLTAGE DIVIDERS
6. THEVININ'S & NORTON EQUIVALENTS & HOW TO FIND THEM
7. SUPERPOSITION THEOREM

TEST MONDAY

OPEN BOOK (TEXT, NOTES, H.W, HANDOUTS, CALC)

7 PROBLEM ⇒ 125 POINTS

B.Y.O.P. TEST

HOMEWORK GRADING

$m$ = NUMBER OF PROBLEMS ASSIGNED

$q$ = " " " NOT ATTEMPTED

$n$ = " " " GRADED $\geq m/2$

$I(d)$ = NEXT HIGHEST INTEGER $\geq d$

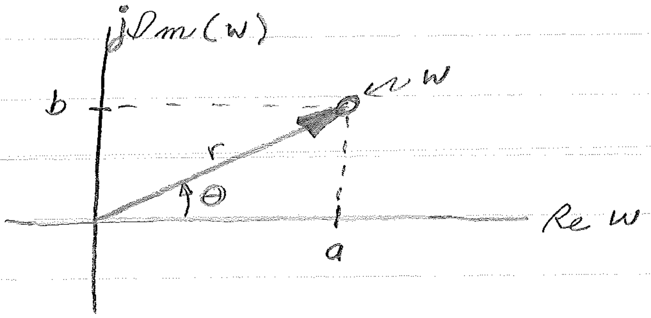
$P_i$ = POINTS ON $i^{TH}$ GRADED PROBLEM

SCORE = $I(d)$ WHERE

$$d = \left(\sum_{i=1}^{n} P_i\right)\left(\frac{m-q}{n}\right)$$

$$d_{MAX} = I_{MAX} = 10\,m$$

# COMPLEX NUMBERS



$$W = \mathcal{R}e\,W + j\,\mathcal{I}m\,W$$
$$= a + j\,b$$

WE MAY SPECIFY THE POINT W IN TWO WAYS

(1) RECTANGULAR COORDINATES

$$W = a + j\,b$$

(2) POLAR COORDINATES

$$W = r < \theta$$

"<" IS READ "AT THE ANGLE"

$\theta$ IS ALWAY MEASURED CCW FROM THE $\mathcal{R}e\,W$ AXIS

WE MAY EQUIVALENTLY WRITE

$$W = r\,e^{j\theta} = a + j b;$$

(WILL SHOW THIS LATER)

FROM GEOMETRY

$$a = r\cos\theta \qquad r = \sqrt{a^2 + b^2}$$
$$b = r\sin\theta \qquad \theta = a\tan {}^{a}\!/_{b}$$

## PROPERTIES AND NOMENCLATURE

COMPLEX CONJUGATE

$$W = a + jb = re^{j\theta}$$

$$w^* = a - jb = re^{-j\theta}.$$

ABSOLUTE VALUE & COMPONENTS

$$|W| = |a + jb| = r = \sqrt{a^2 + b^2}$$

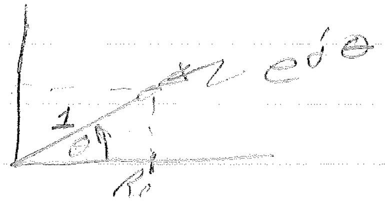
$$\arg W = \theta$$

$$\mathrm{Re}\, W = a$$

$$\mathrm{Im}\, W = b$$

EULER'S FORMULA

$$e^{\pm j\theta} = \cos\theta \pm j\sin\theta$$



$$\mathrm{Re}[e^{j\theta}] = a \qquad \mathrm{Im}[e^{j\theta}] = b$$

$$= \cos\theta \qquad\qquad = \sin\theta$$

HOMEWORK

SHOW THAT

$$|e^{j\theta}| = 1$$

$$\cos\theta = \frac{1}{2}[e^{j\theta} + e^{-j\theta}]$$

$$\sin\theta = \frac{1}{j2}[e^{j\theta} - e^{-j\theta}]$$

$$|W| = |w^*|$$

$$\arg W = -\arg W^*$$

ALWAYS VIEW $e^{j\theta}$ AS
1 AT AN ANGLE OF $\theta$.

COMPLEX ARITHMETIC

(a) X AND ÷
ALWAYS USE POLAR FORM

$$\frac{W_1}{W_2} = \frac{r_1 e^{j\theta_1}}{r_2 e^{j\theta_2}} = \frac{r_1}{r_2} e^{j(\theta_1 - \theta_2)}$$

$$= \frac{r_1}{r_2} \angle \theta_1 - \theta_2$$

$$W_1 W_2 = (r_1 e^{j\theta_1})(r_2 e^{j\theta_2}) = r_1 r_2 e^{j(\theta_1 + \theta_2)}$$
$$= r_1 r_2 \angle \theta_1 + \theta_2$$

(b) + and −
ALWAYS USE RECTANGULAR FORM

$$W_1 \pm W_2 = (a_1 + j b_1) \pm (a_2 + j b_2)$$
$$= (a_1 \pm a_2) + j(b_1 \pm b_2)$$

(c) IF $W_1 = W_2$

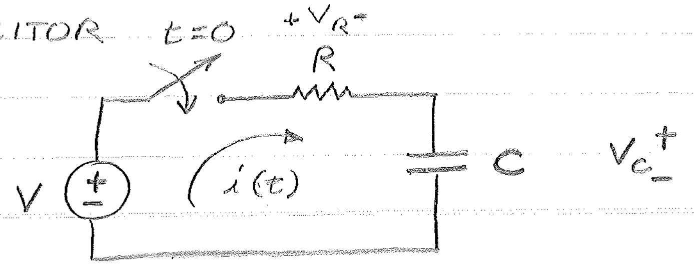
THEN $a_1 = a_2$
$b_1 = b_2$

OR $r_1 = r_2$
$\theta_1 = \theta_2$

# EXPONENTIALS

## (A) REAL ARGUMENTS

(1) CAPACITOR



ASSUME $V_c(0)=0$ , $t<0$

FOR $t>0$

$$-V + R\,i(t) + \left[\frac{1}{C}\int_{t_0}^{t} i(t)\,d\tau + V_c(t_0)\right] = 0$$

DIFFERENTIATING

$$R\frac{di}{dt} + \frac{1}{C}i = 0 \Rightarrow \frac{di}{dt} = \frac{-1}{RC}i(t)$$

SOLUTION IS

$$i(t) = a\,e^{-\frac{t}{RC}} \quad ; t>0$$

(HW: CONFIRM THIS IS A SOLUTION)

AT $t=0^+$, $V_c(0^+)=0$

⇒ ALL VOLTAGE IS ACROSS R AND

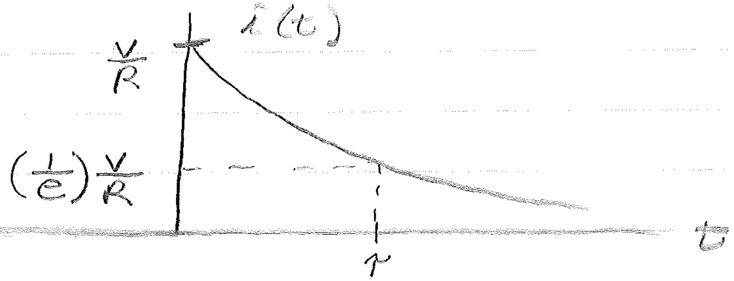
$$i(0^+) = V/R = a\,e^0$$

OR $a = V/R$ AND

$$i(t) = \frac{V}{R}e^{-t/RC}$$

$\tau = RC \Rightarrow$ TIME CONSTANT

& $i(t) = \frac{V}{R}e^{-t/\tau}$

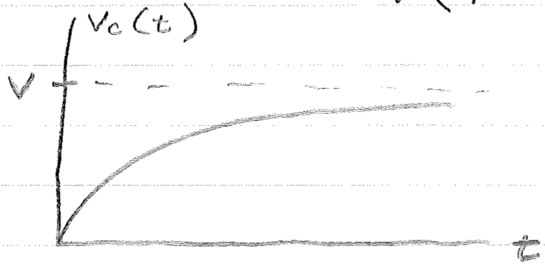


WHAT IS $V_R(t)$ ?

$$V_R(t) = R\,i(t)$$
$$= V e^{-t/\tau}$$

WHAT IS $V_C(t)$ ?

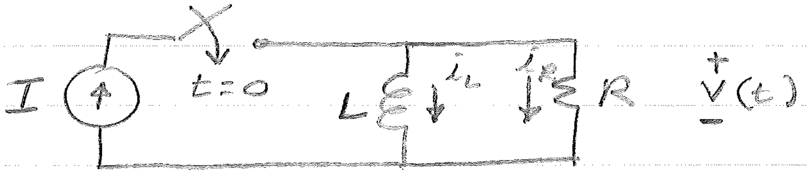
$$V = V_R(t) + V_C(t)$$
$$= V e^{-t/\tau} + V_C(t)$$
$$\Rightarrow \quad V_C(t) = V - V e^{-t/\tau}$$
$$= V(1 - e^{-t/\tau})$$



$V_C(0) = 0$

$V_C(\infty) = V$

(2) INDUCTOR



ASSUME $i_L(0^-) = 0$

$$I = i_L + i_R$$
$$= \left[\frac{1}{L}\int_{t_0}^{t} v(t)\,dt + V(t_0)\right] + \frac{1}{R} v(t)$$

DIFFERENTIATE

$$0 = \frac{1}{L} v(t) + \frac{1}{R}\frac{d}{dt} v(t) \Rightarrow \frac{dv}{dt} = \frac{-R}{L} v(t)$$

SOLUTION IS: $v(t) = a\,e^{-\frac{R}{L}t}$

$\tau = {}^{+}L/R$ = TIME CONSTANT

$$\Rightarrow \quad v(t) = a \cdot e^{-t/\tau}$$

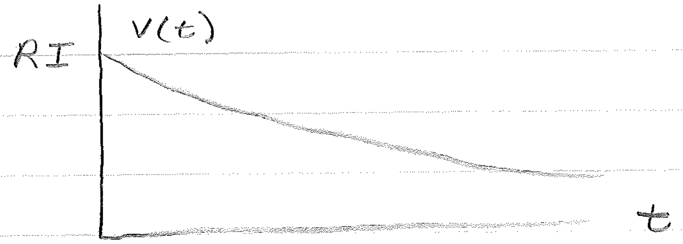
FIND $a$

$$i_L(0^+) = i_L(0^-) = 0$$

$$\Rightarrow i_R(0^+) = I$$

$$v(0^+) = RI$$

$$\Rightarrow v(t) = RI\, e^{-t/\tau}$$



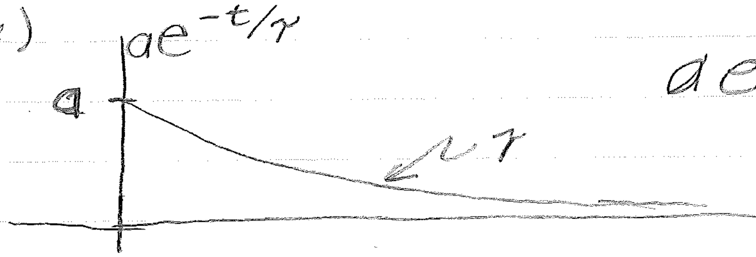
[H.W: FIND $i_L(t)$ AND $i_R(t)$]

(3) INTERPRETATION OF EXPONENTIALS

CAPACITOR $\longrightarrow$ $\tau = RC$

INDUCTOR $\longrightarrow$ $\tau = L/R$ $(= LG)$

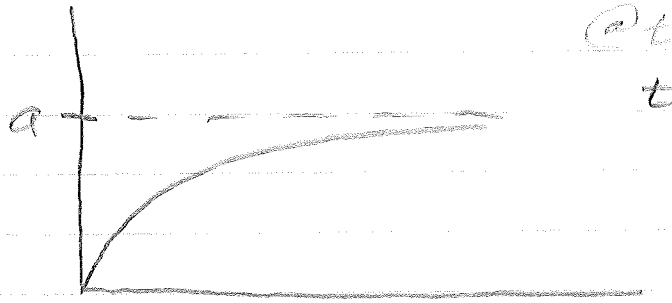
(a)



$$ae^{-t/\tau}\Big|_{t=0} = a$$

$$\lim_{t\to\infty} ae^{-t/\tau} = 0$$

(b) $a\left[1 - e^{-t/\tau}\right]$

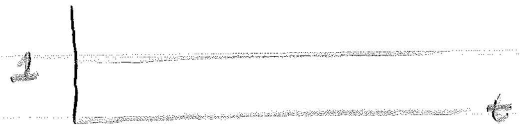


$@\, t=0 \Rightarrow 0$

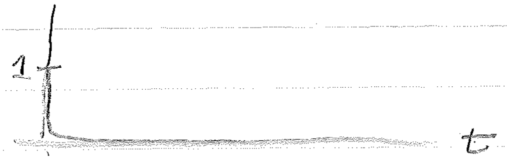
$t \to \infty \Rightarrow a$

(c) TIME CONSTANT

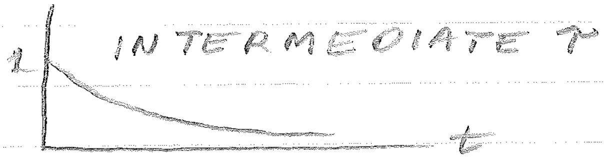
$$\lim_{\tau\to\infty} e^{-t/\tau} = e^{-0} = 1$$

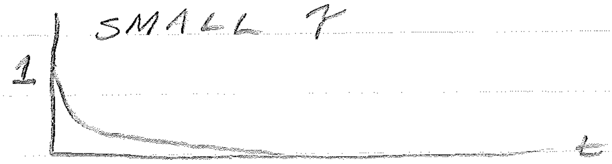


$$\lim_{\tau\to 0} e^{-t/\tau} = e^{-\infty} = \frac{1}{e^{\infty}} = \frac{1}{\infty} = 0$$



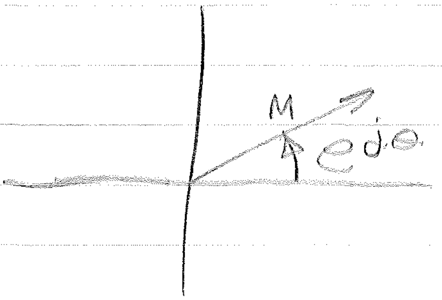
THUS





## PHASORS

$$W(t) = M e^{j(\omega t + \phi)} = Re[M \cos(\omega t + \phi)]$$
$$W(0) = M e^{j\phi}$$



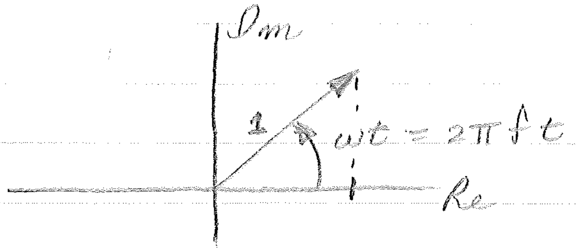
⟸ PHASOR DIAGRAM

(B) IMAGINARY ARGUMENTS
(SINUSOIDS)

$e^{j\theta} = \cos\theta + j\sin\theta$

LET $\theta = \omega t = 2\pi f t$

$e^{j\omega t} = \cos\omega t + j\sin\omega t$



THE PROJECTION OF THIS PHASOR ON THE REAL AXIS IS

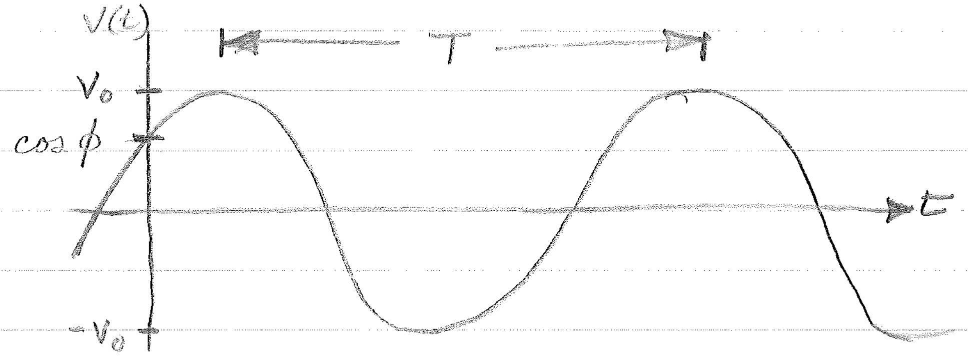
$$Re\, e^{j\omega t} = \cos\omega t = \cos 2\pi f t$$

## IDENTIFICATION AND MEASUREMENT OF PERIODIC WAVEFORMS

(A) SINUSOIDS

$$V(t) = V_0 \cos(2\pi f t + \phi)$$

$V_0$ = AMPLITUDE
$f$ = FREQUENCY (HZ)
$\phi$ = PHASE (RADIANS)
} COMPLETELY SPECIFIES SINUSOID



RELATION TO OTHER PARAMETERS:

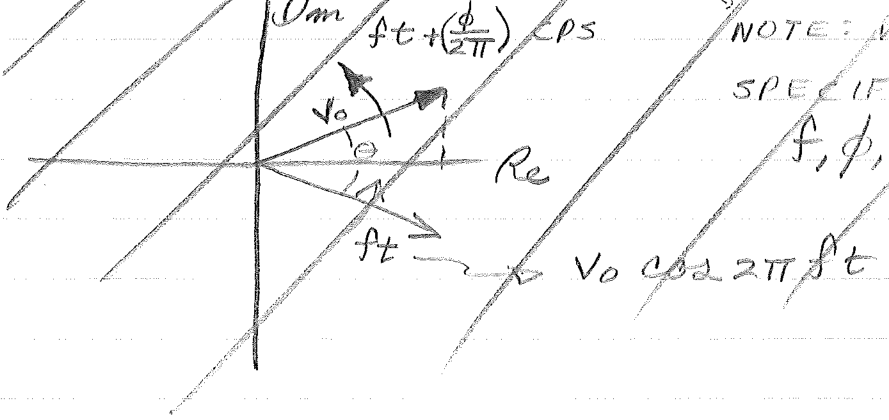
T = PERIOD = $1/f$

$\omega$ = ANGULAR FREQUENCY = $2\pi f$

$$\begin{cases} \cos(\theta - \pi/2) = \sin\theta \\ \sin(\theta + \pi/2) = \cos\theta \end{cases}$$

~~RELATION TO PHASOR~~

$$V(t) = V_0 \cos\{2\pi f t + \phi\}$$
$$= \mathrm{Re}\, V_0 e^{j(2\pi f t + \phi)}$$

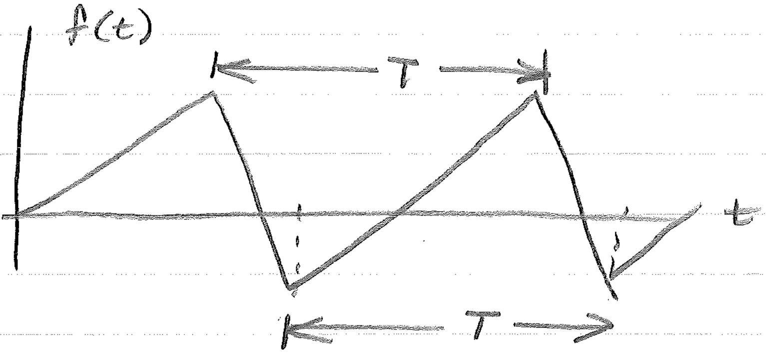


NOTE: WE'VE SPECIFIED $f, \phi,$ AND $V_0$

## (B) GENERAL PERIODIC WAVEFORMS

$f(t)$ IS PERIODIC IF $\exists\ T$

$\ni f(t+T) = f(t)\ \forall t$

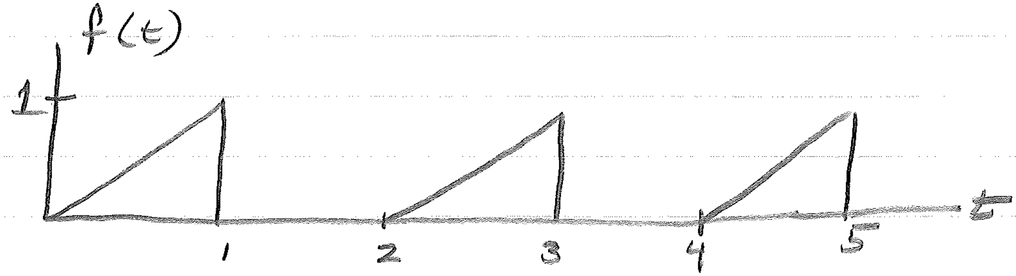


MEASURES OF PERIODIC FUNCTIONS

(1) AVERAGE VALUE

$$f_{AVE} \triangleq \frac{1}{T}\int_T f(t)dt = \frac{1}{T}\int_{t_0}^{t_0+T} f(t)dt$$

EX



$$f(t) = \begin{cases} t & ; 0 < t \leq 1 \\ 0 & ; 1 < t \leq 2 \end{cases}$$

$$f(t) = f(t+2) \Rightarrow T = 2$$

$$f_{AVE} = \frac{1}{2}\left[\int_0^1 t\,dt + \int_1^2 (0)\,dt\right]$$

$$= \frac{1}{2} \quad \frac{1}{2}t^2\Big|_0^1$$

$$= 1/4$$

(2) RMS (ROOT MEAN SQUARE) OR EFFECTIVE VALUE

$$f_{RMS} = f_{EFF} \triangleq \sqrt{\frac{1}{T}\int_T f^2(t)\,dt}$$

EX) FOR PREVIOUS EXAMPLE

$$f_{RMS} = \left[\frac{1}{2}\int_0^1 t^2 dt + \frac{1}{2}\int_1^2 (0)^2 dt\right]^{1/2}$$
$$= \left[\frac{1}{2}\,\frac{1}{3}t^3\Big|_0^1\right]^{1/2}$$
$$= 1/\sqrt{6}$$

NOTE: IN GENERAL

$$f_{RMS} \neq f_{AVE}$$

(3) PEAK TO PEAK VALUE

$$f_{PTP} = f_{MAX} - f_{MIN}$$

HOMEWORK (1) FIND $f_{RMS}$ AND $f_{EFF}$ WHEN, FOR $a$ & $\phi$ CONSTANT,

$$f(t) = a\cos(2\pi f t + \phi)$$

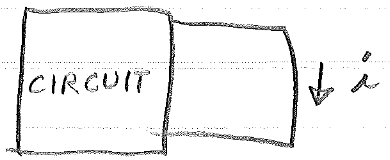
HINTS:

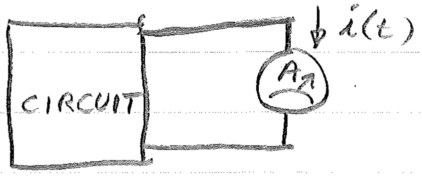
$$T = 1/f$$
$$\cos^2\theta = \frac{1}{2}\left[1 + \cos 2\theta\right]$$

(b) SHOW THAT $f(t) = a =$ CONSTANT IS "PERIODIC". COMPUTE $f_{AVE}$ AND $f_{RMS}$ AND COMMENT.

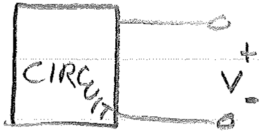
(3) METERS

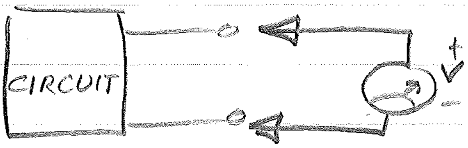
(a) AMMETER





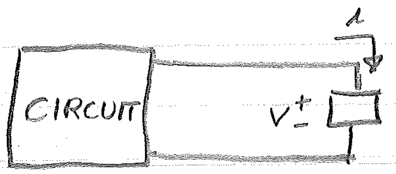
(b) VOLTMETER



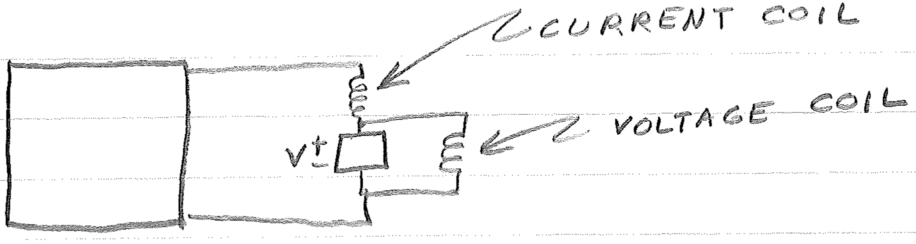


IF THE CURRENT (VOLTAGE) IS PERIODIC, THEN THE AMMETER (VOLTMETER) REGISTERS THE rms VALUE.

(3) WATTMETER (COMMON)



$P = Vi$

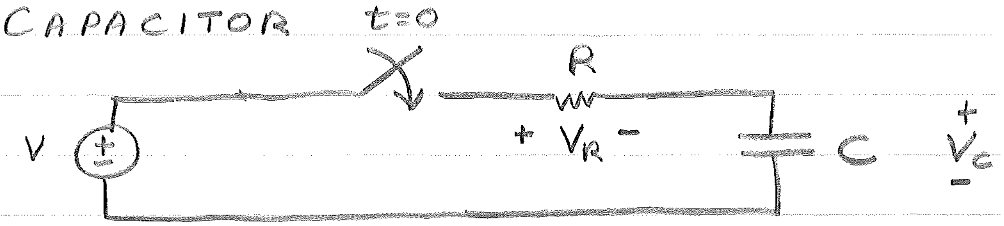


COIL'S MAGNETIC FIELD'S INTERACT TO GIVE A NEEDLE DEFLECTION PROPORTIONAL TO THE AVERAGE POWER.

## ENERGY STORAGE
## ~~CIRCUIT~~ ELEMENT D.C. RESPONSES

A. TRANSIENT RESPONSE - THE EFFECT OF AN ACTION (SUCH AS THROWING A SWITCH) ON THE V OR i OF AN ELEMENT

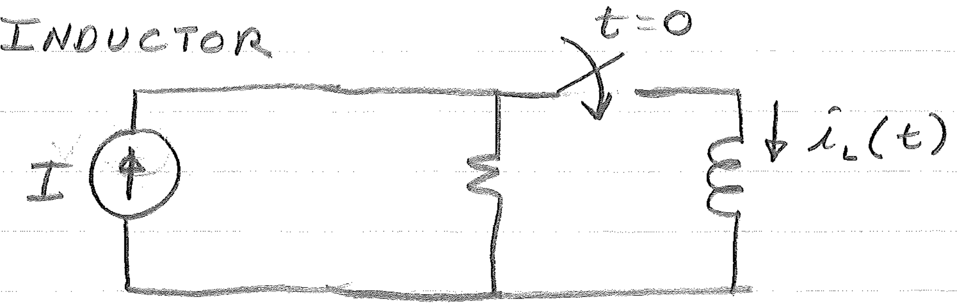
1. CAPACITOR



$$V_C(0+) = V_C(0^-)$$

VOLTAGE CAN'T CHANGE INSTANTANEOUSLY ACROSS A CAPACITOR

2. INDUCTOR

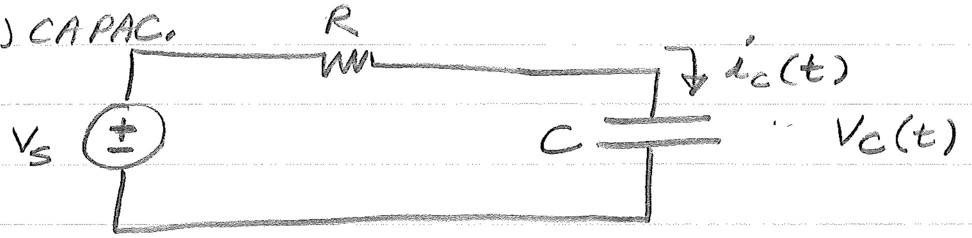


$$i_L(0+) = i_L(0-)$$

CURRENT CAN'T CHANGE INSTANTANEOUSLY ACROSS AN INDUCTOR

B. STEADY STATE RESPONSE - THE V OR $i$ OF AN ELEMENT AFTER THE CIRCUIT HAS BEEN CONNECTED FOR A "LONG TIME"

(1) CAPAC.

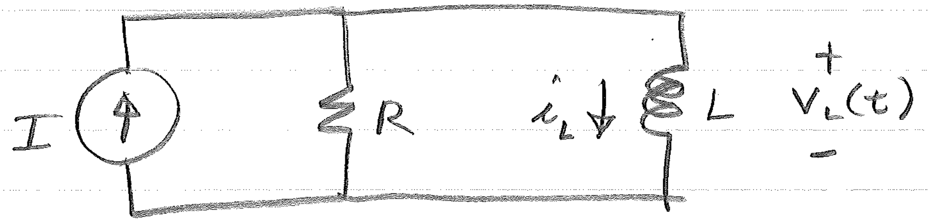


$V_C(\infty) = V_S$

$i_c(\infty) = C \frac{dV}{dt} = 0$

∴ AFTER A "LONG TIME", A CAPACITOR UNDER D.C. CONDITIONS ACTS AS AN OPEN CIRCUIT.

(2) INDUCTOR

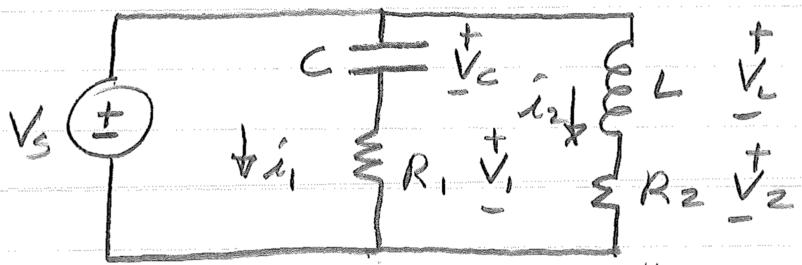


$i_L(\infty) = I$

$V_L(\infty) = C \frac{d}{dt} I = 0$

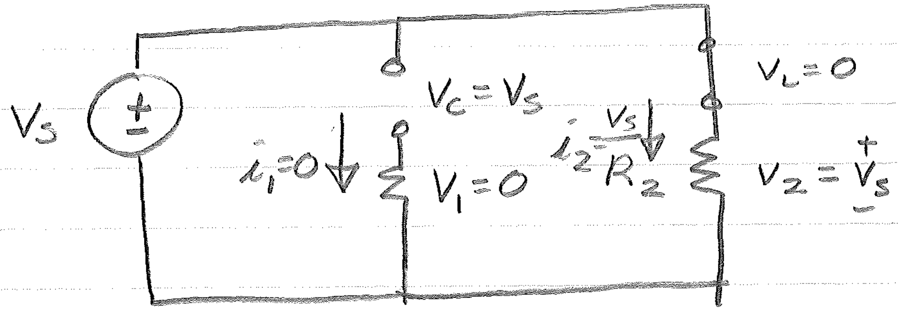
∴ AFTER A "LONG TIME", AN INDUCTOR UNDER D.C. CONDITIONS, ACTS AS A SHORT CIRCUIT.

EX

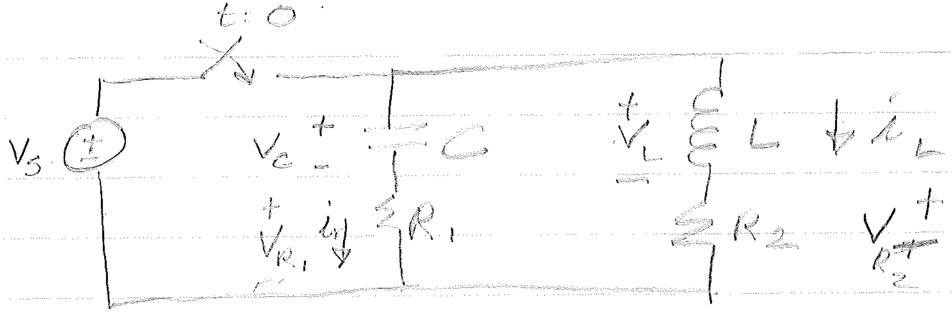


(b) AFTER "A LONG TIME", WHAT ARE ALL OF THE ABOVE $i$'s AND $V$'s?

ANS:



(a)



$V_c(0+) = V_c(0-) = 0 \Rightarrow V_R = V_s$

$\Rightarrow i_{R_1}(0+) = V_s/R_1$

$i_L(0+) = i(0-) = 0$

$\Rightarrow V_{R_2} = 0$

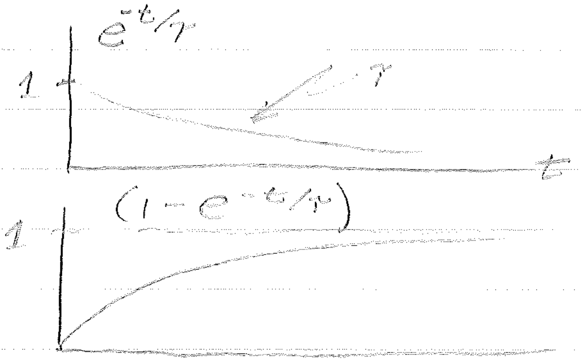
$\Rightarrow V_L = 0$

## NATURAL RESPONSE TO FIRST ORDER SYSTEM

DEF: FIRST ORDER SYSTEM: CONTAINS R's, $V_S$'s, $I_S$'s AND ONE ENERGY STORAGE DEVICE (C OR L).

WE WILL CLOSE (OR OPEN) SWITCHES IN 1st ORD. SYS.

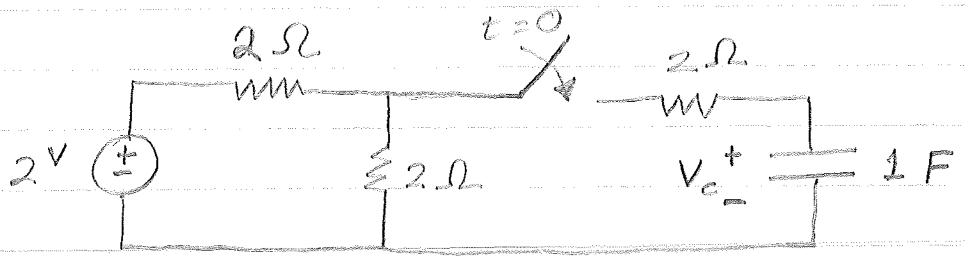
1. SOLUTION TOOLS
   1. TRANSIENT & STEADY STATE RESPONSES.
   2. EXPONENTIAL CURVES (CONNECTS 0 & $\infty$)



2. FOUR NUGGETS OF KNOWLEDGE
   1. $V(0^-)$ = VOLTAGE RIGHT BEFORE SWITCH IS CLOSED (D.C. ANALYSIS)
   2. $V(0^+)$ = VOLTAGE RIGHT AFTER SWITCH IS CLOSED (TRANSIENT RESP)
   3. $V(\infty)$ = STEADY STATE VOLTAGE
   4. $\tau$ = TIME CONSTANT $= R_{eq}C$ OR $L/R_{eq}$

WE CAN USE THE ABOVE FOR CURRENT TOO.

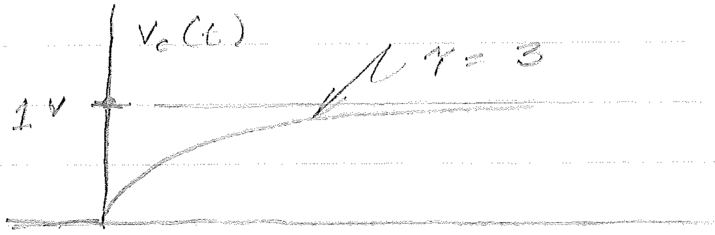
(Ex)



1. $V_c(0-) = 0$
2. $V_c(0^+) = 0$
3. $V_c(\infty) = \frac{2}{2+2} 2 = 1$ VOLT
4. $\tau = R_{eq} C$

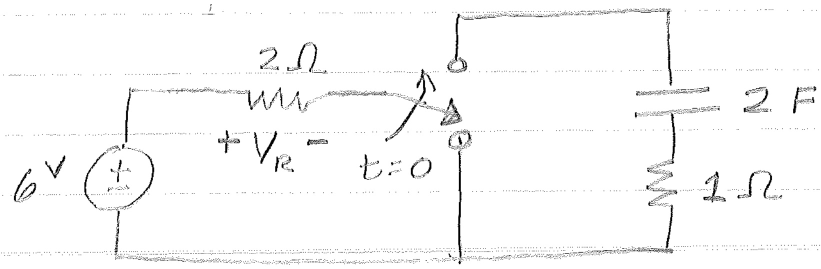
$R_{eq} = 2\Omega + 2\Omega // 2\Omega$
$= 3\Omega$

$\Rightarrow \tau = (1F)(3\Omega) = 3$ SEC



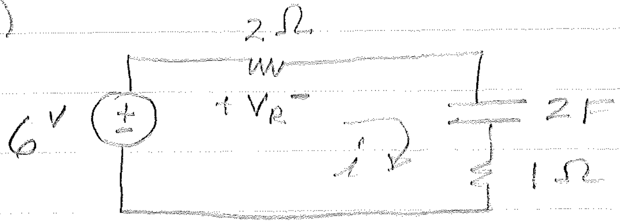
$$V_c(t) = \begin{cases} (1 - e^{-t/3}) & ; t \geq 0 \\ 0 & ; t \leq 0 \end{cases}$$

(EX)



(1) $V_R(0-) = 6^V$

(2)



C ACTS AS SHORT

VOLTAGE DIVIDER

$$V_R(0+) = \frac{2}{2+1}\,6 = 4\text{ V}$$

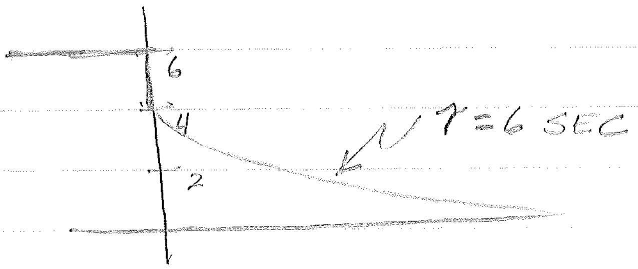
(3) @ $t=\infty$, C ACTS "OPEN"

$$\Rightarrow i = 0 \Rightarrow V_R(\infty) = 0$$

(4) $\tau = R_{eq}C$

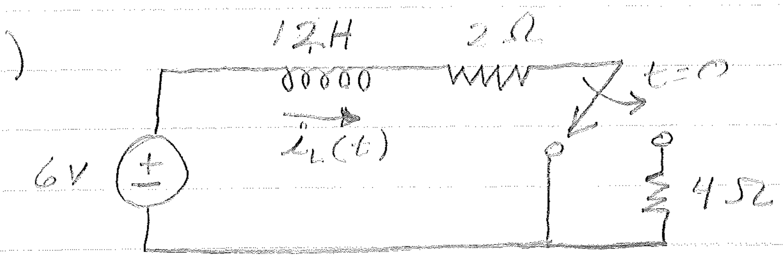
$$R_{eq} = 2+1 = 3\,\Omega$$

$$\tau = (3\,\Omega)(2F) = 6\text{ sec}$$



$$V_R(t) = \begin{cases} 6^V & ; t<0 \\ 4e^{-t/6} & ; t>0 \end{cases}$$

(EX)



(1) @ $t = 0^-$, L ACTS SHORTED

$i_L(0^-) = \frac{6V}{2\Omega} = 3$ AMPS

(2) @ $t = 0^+$

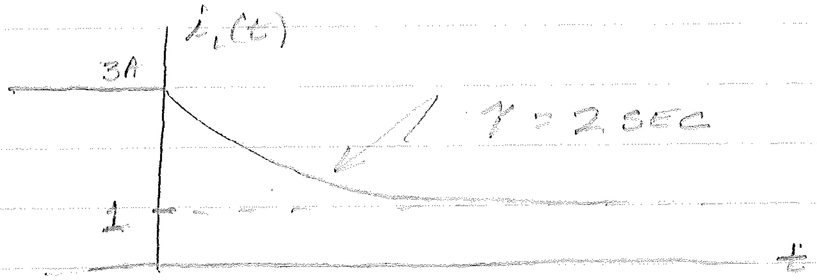
$i_L(0^-) = 3$ AMPS

(3) $i_L(\infty) = \frac{6V}{(2+4)\Omega} = 1$ AMP

(4) $\tau = L/R_{eq}$

$R_{eq} = 2 + 4 = 6\,\Omega$

$\Rightarrow \tau = 12/6 = 2$ SEC

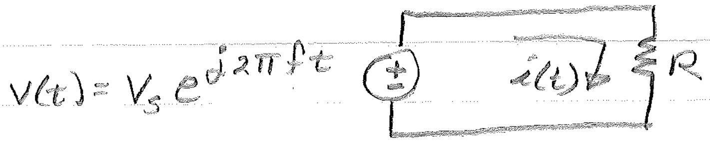


$$i_L(t) = \begin{cases} 3 & ; t < 0 \\ 1 + 2e^{-t/2} & ; t > 0 \end{cases}$$

# IMPEDENCE (SINUSOIDAL STEADY STATE RELATIONS)

## A. PASSIVE ELEMENTS

### 1. RESISTOR

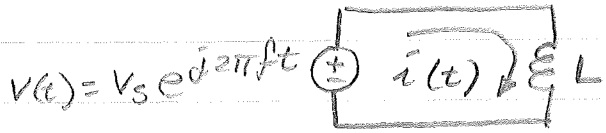


$$V_s e^{j2\pi f t} = R\, i(t)$$

$$\Rightarrow \quad i(t) = \frac{V_s}{R} e^{j2\pi f t}$$

OR $\quad V(t) = R\, i(t)$

### 2. INDUCTOR



$$V_s e^{j2\pi f t} = L \frac{di(t)}{dt}$$

$$di(t) = \frac{V_s}{L} \int^t e^{j2\pi f t}\, dt$$

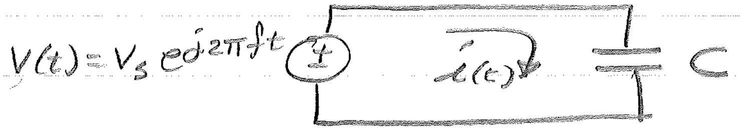
$$= \frac{V_s}{j2\pi f L} e^{j2\pi f t}$$

$$\Rightarrow V(t) = V_s e^{j2\pi f t} = j2\pi f L\, i(t)$$

$$j2\pi f = j\omega$$

$$\Rightarrow V(t) = j\omega L\, i(t)$$

### 3. CAPACITOR



$$i(t) = C \frac{dV(t)}{dt}$$

$$= C V_s \frac{d}{dt} e^{j2\pi ft}$$

$$= j2\pi fC) V_s e^{j2\pi ft}$$

$$= (j\omega C) V(t)$$

OR $$V(t) = \frac{1}{j\omega C} i(t)$$

WE HAVE GENERALIZED OHM'S LAW FOR SINUSOIDAL STEADY STATE:

$$V = Z i$$

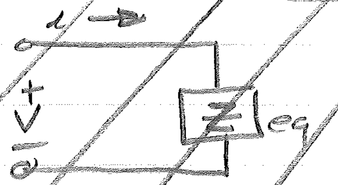
$Z$ = IMPEDANCE

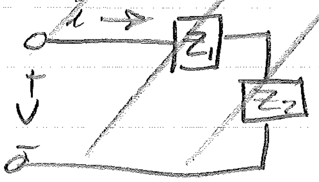
$R \implies Z = R$

$C \implies Z = \frac{1}{j\omega C} = \frac{-j}{\omega C}$

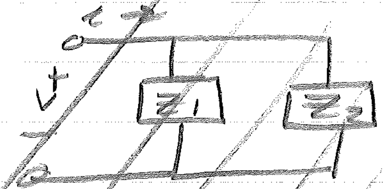
$L \implies Z = j\omega L$

~~EQUIVALENT CIRCUITS~~





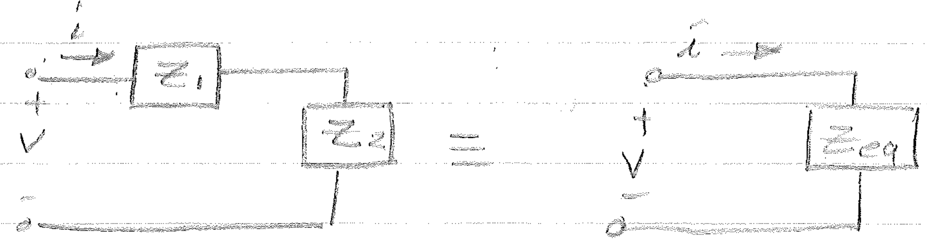
~~$Z_{eq} = Z_1 + Z_2$~~



~~$\frac{1}{Z_{eq}} = \frac{1}{Z_1} + \frac{1}{Z_2}$~~

## SERIES & PARALLEL COMBINATION OF IMPEDENCE

1. SERIES CONNECTION (SAME $i$ THRU ALL COMPONENTS)

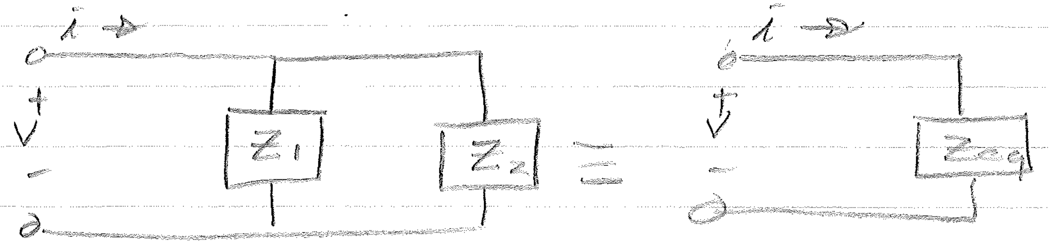


$$Z_{eq} = Z_1 + Z_2$$

2. PARALLEL CONNECTION (SAME V ACROSS ELEMENTS)

$Y = 1/Z$ = ADMITTANCE

{IMPEDANCE IN OHMS (Ω)
{ADMITTANCE IN MHOS (℧)

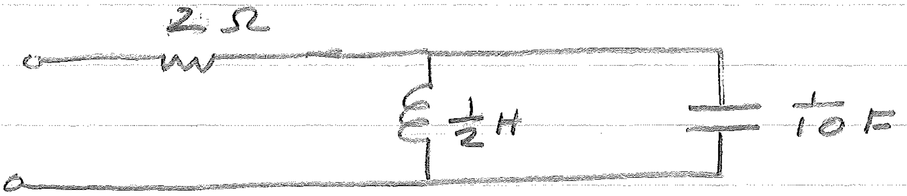


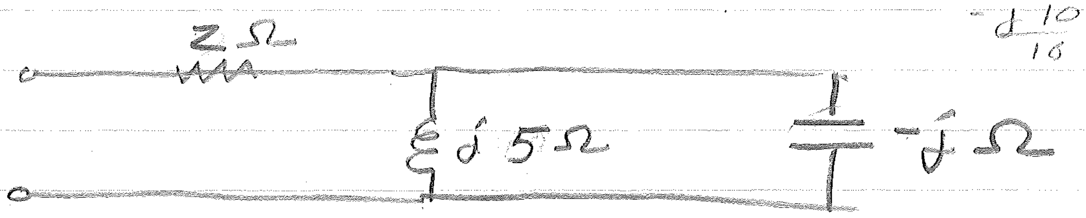
$$\frac{1}{Z_{eq}} = \frac{1}{Z_1} + \frac{1}{Z_2}$$

OR

$$Y_{eq} = Y_1 + Y_1$$

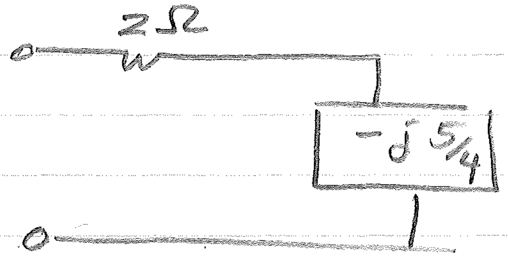
EXAMPLE : ω = 10

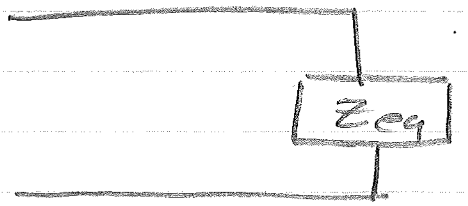




$$\frac{1}{Z_{eq}} = \frac{1}{j5} + \frac{1}{-j}$$

$$= \frac{1-5}{j5} = \frac{-4}{j5} \Rightarrow Z_{eq} = \frac{-j5}{4}$$

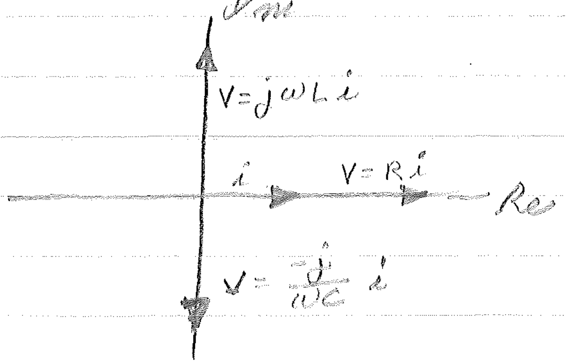




$= 2 - j\frac{5}{4}$

## B. INTERPRETATION

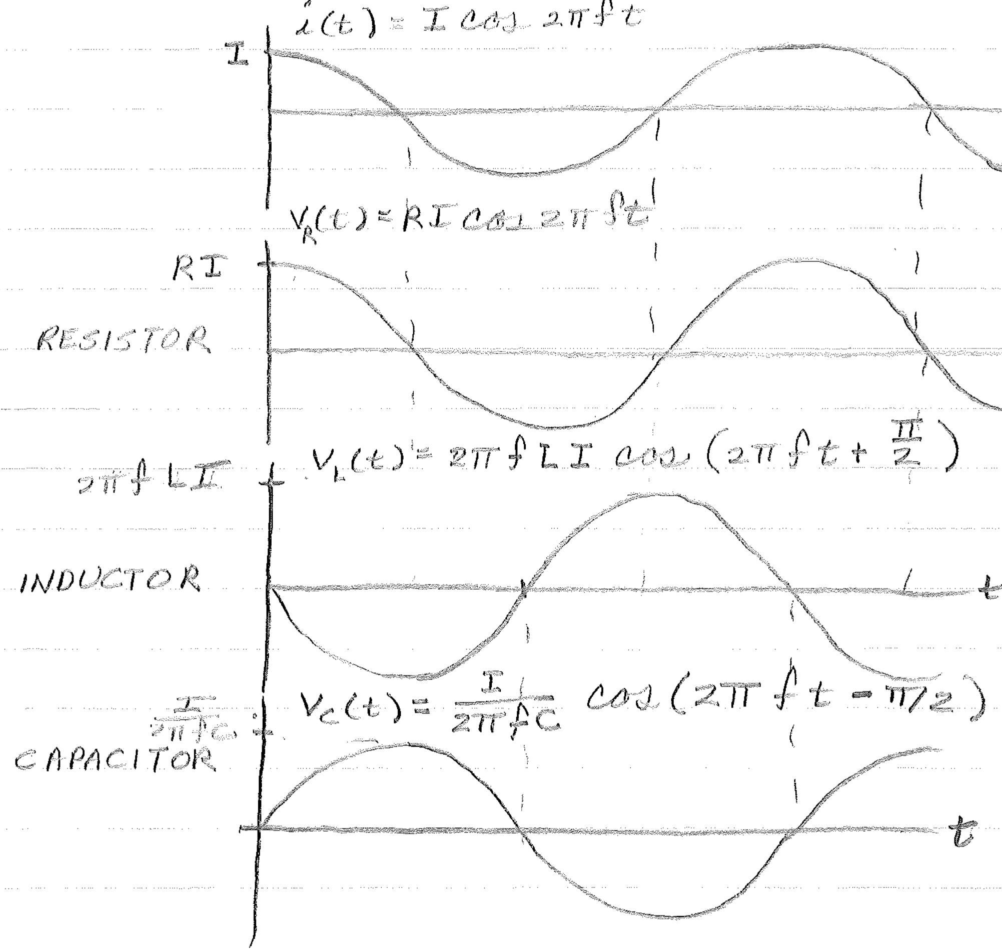
### 1. COMPLEX PLANE INTERPRETATION



USE $i$ AS REF

THE VOLTAGE THRU A CAPACITOR "LAGS" THE CURRENT BY $\frac{\pi}{2} = 90°$, AND THAT THRU AN INDUCTOR "LEADS" BY $\frac{\pi}{2}$
(NOTE 'V LEADS $i$" ≡ "$i$ LAGS V")

### 2. PHYSICAL INTERPRETATION

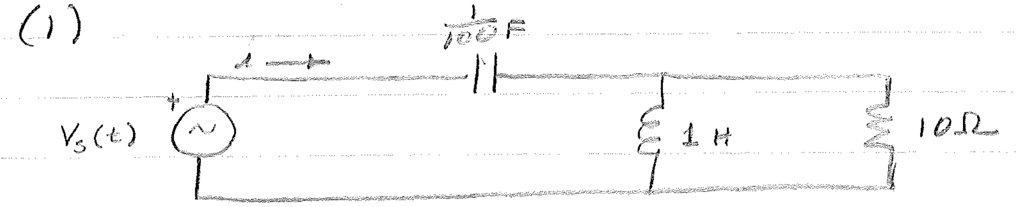


⟵ "LEADS" $i$ BY $90° = \frac{\pi}{2}$

⟸ "LAGS" $i$ BY $90° = \frac{\pi}{2}$

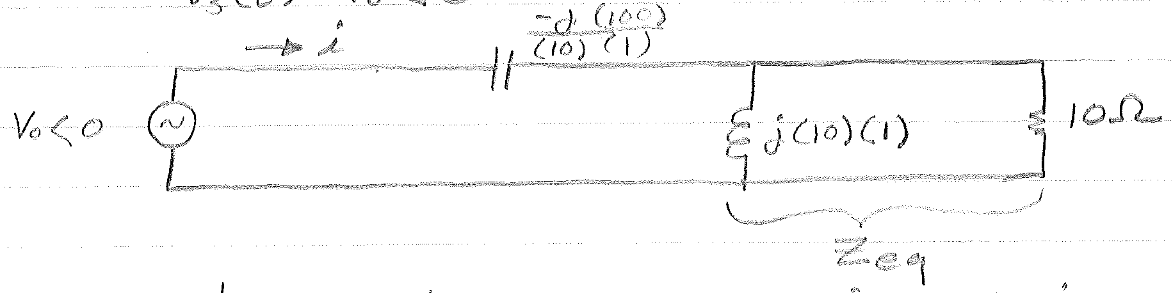
## (C) EXAMPLES

(1)



$V_S(t) = V_o \cos 10t \Rightarrow \omega = 2\pi f = 10$

$V_S(t) = V_o \angle 0$

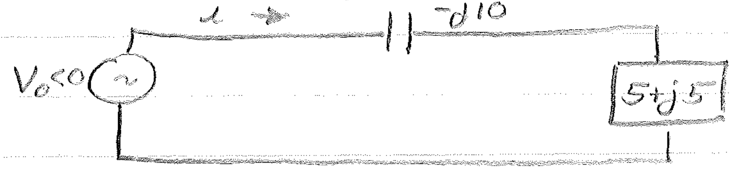


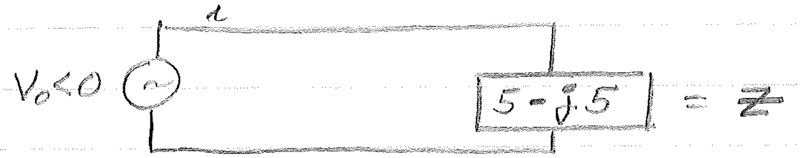
$$\frac{1}{Z_{eq}} = \frac{1}{j\,10} + \frac{1}{10} = \frac{1+j}{j\,10} = \frac{1-j}{10}$$

$Z_{eq} = \frac{10}{1-j}$ (USE COMPLEX CONJ. TRICK)

Leave in { ~~NOTE: TO REMOVE A COMPLEX # FROM THE DEN, MULTIPLY BOTH NUM. & DEN BE COMPLEX CONJUGATE OF DENOM.~~

$$Z_{eq} = \frac{10}{1-j}\;\frac{1+j}{1+j} = \frac{10+j10}{2} = (5+j5)\ \Omega$$

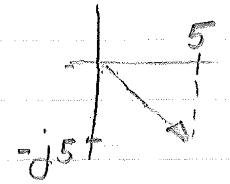


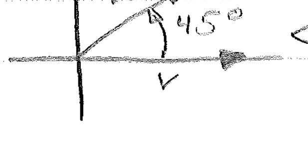


$V = Z I$

$V_o \angle 0 = (5-j5)\,i = \sqrt{2}\,e^{-j\frac{\pi}{4}}\,i$

OR $i = \frac{1}{\sqrt{2}}\,e^{j\frac{\pi}{4}}\,V$

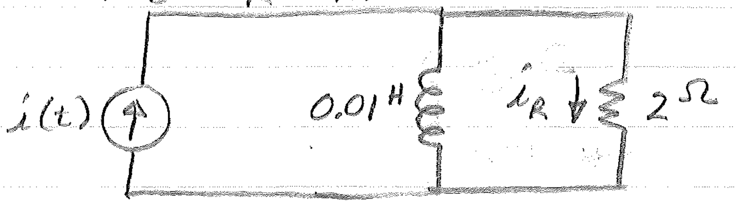




← PHASOR DIAGRAM

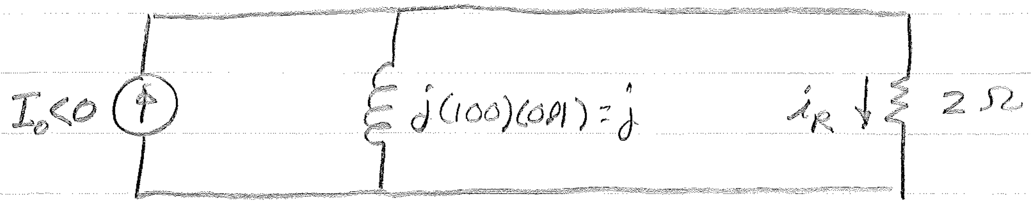
FIND $i_R$ IN THE FOLLOWING CIRCUIT

(2)



$i(t) = I_0 \cos 100t \Rightarrow \omega = 2\pi f = 100$

IN PHASOR FORM $\Rightarrow i(\ ) = I_0 < 0 = I_0$



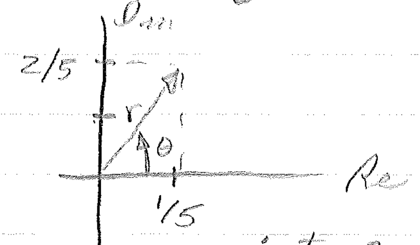
USE CURRENT DIVIDER

$$i_R = \frac{\frac{1}{2}}{\frac{1}{j} + \frac{1}{2}} I_0 = \frac{j}{2+j}(I_0)$$

USE COMPLEX CONJ. "TRICK"

$$i_R = \frac{j}{2+j}\,\frac{2-j}{2-j}(I_0)$$

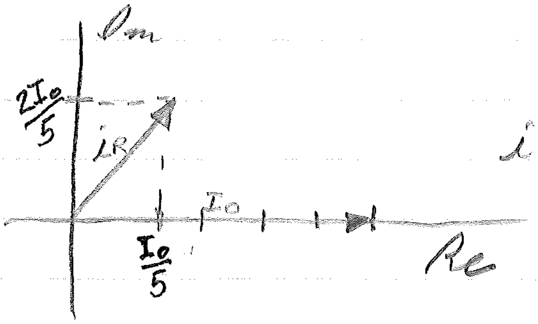
$$= \frac{1+j2}{4+1} I_0 = \left(\frac{1}{5} + j\frac{2}{5}\right) I_0$$



$$\theta = \operatorname{atan}\frac{2/5}{1/5}$$
$$= \operatorname{atan} 2 = 63.4° = 1.118$$
$$r = \sqrt{5}/5 = 1/\sqrt{5}$$

$$\Rightarrow i_R = \frac{1}{\sqrt{5}} e^{+j \operatorname{atan} 2} I_0$$

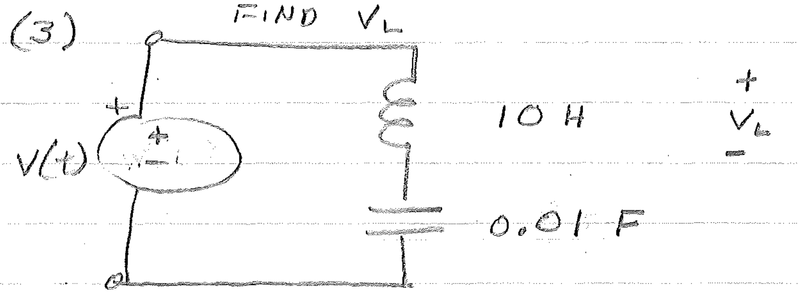
PHASOR DIAGRAM



$i_R$ "LEADS" $i$ BY atan 2 RADIANS

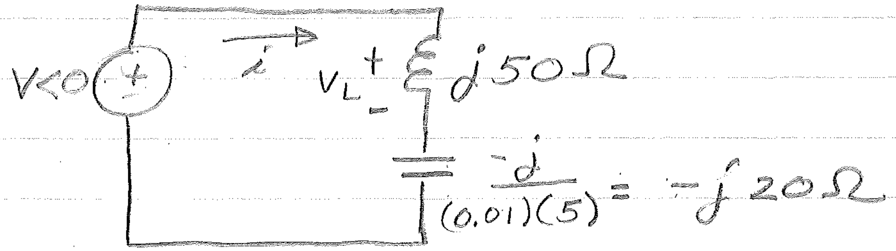
(SKIP)

(3) FIND $V_L$



$v(t) = V_0 \cos 5t$ ; $\omega = 2\pi f = 5$

$V = V_0 \angle 0$



USE VOLTAGE DIVIDER:

$$V_L = \frac{j50}{j50-j20} V_0 = \frac{j50}{j30} V_0$$

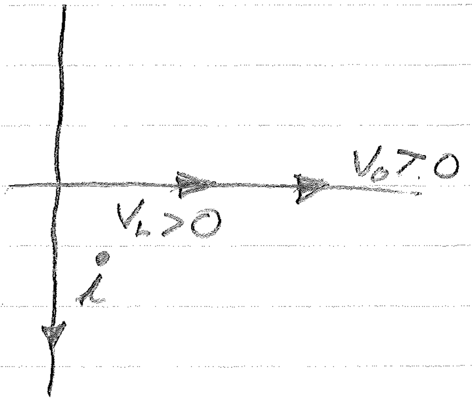
$$= 5/3\, V_0$$

$$\Rightarrow V_L = 5/3\, V_0 \angle 0$$

$$= 5/3\, V_0 \cos 5t$$

WHAT IS $i$?

$$i = \frac{V_L}{j50} = \frac{5/3\, V_0}{j50} = \frac{-j}{30} V_0$$



IMPEDANCE COMPONENTS

① REACTANCE - THE IMAGINARY COMPONENT OF IMPEDANCE

THUS

IMPEDANCE = RESISTANCE + j REACTANCE

$$Z = R + jX$$

② SUSCEPTANCE - THE IMAGINARY PART OF ADMITTANCE

THUS

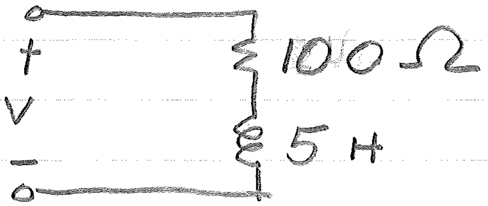
ADMITTANCE = CONDUCTANCE + j SUSCEPTANCE = $\frac{1}{\text{IMPEDANCE}}$

OR

$$Y = \frac{1}{Z} = G + jB$$

NOTE: $G \neq \frac{1}{R}$ AND $B \neq \frac{1}{X}$

**HOMEWORK:** THE IMPEDANCE OF

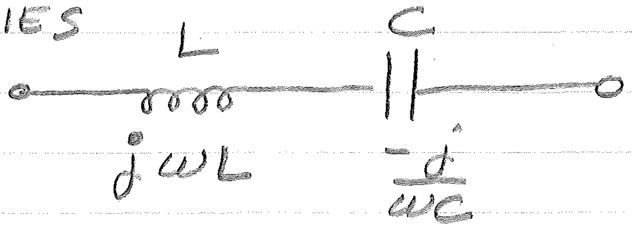


IS, AT $\omega = 10$, $Z = 100 + j50$. WHAT IS THE CORRESPONDING ADMITTANCE, CONDUCTANCE, AND SUSCEPTANCE?

## RESONANCE

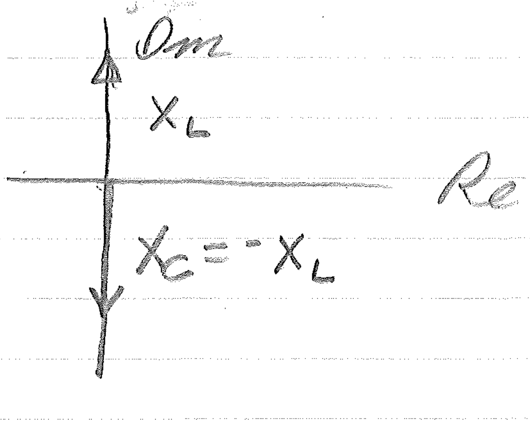
AN L & C ARE IN RESONANCE ~~AT RESONANCE~~ IF THEIR REACTANCES ARE OPPOSITE AND EQUAL. THAT IS, $X_L + X_C = 0$

(a) SERIES



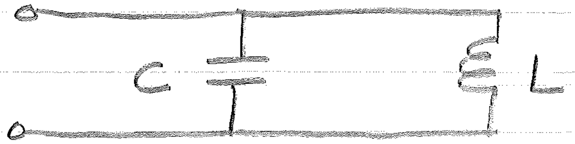
$$X_L + X_C = 0$$
$$\omega L - \frac{1}{\omega C} = 0$$
$$\omega^2 L - \frac{1}{C} = 0$$
$$\omega^2 = \frac{1}{LC}$$
$$\omega = 2\pi f = \frac{1}{\sqrt{LC}}$$
$$\Rightarrow f = \frac{1}{2\pi\sqrt{LC}} \Leftarrow \text{RESONANT FREQUENCY}$$

$\therefore$ @ $f = \frac{1}{2\pi\sqrt{LC}}$, $X_C + X_L = 0$ AND THE SERIES COMBINATION ACTS AS A SHORT CIRCUIT:



$$Z_{eq} = j(X_L + X_C) = 0$$

2. PARALLEL



$$j\omega L + \frac{-j}{\omega C} = 0 \Rightarrow f = \frac{1}{2\pi\sqrt{LC}}$$

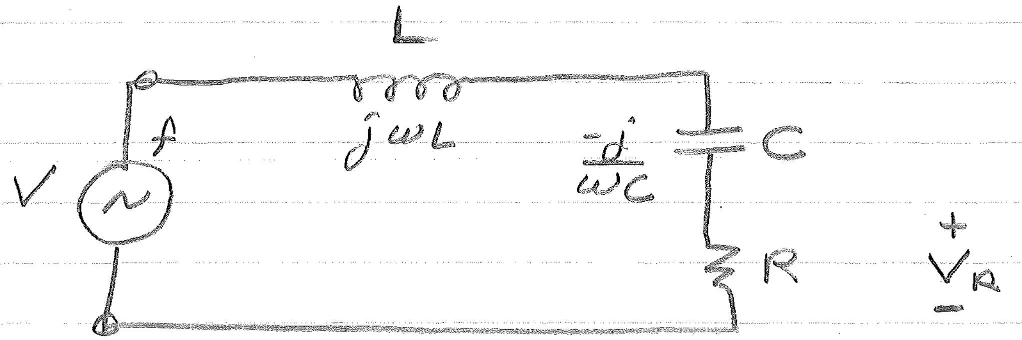
@ $f = \frac{1}{2\pi\sqrt{LC}}$, $X_L = -X_C$ AND THE PARALLEL COMBINATION ACTS AS AN OPEN CIRCUIT:

$$\frac{1}{Z_{eq}} = \frac{1}{jX_L} + \frac{1}{jX_C} = 0$$

$$\Rightarrow Z_{eq} = \frac{1}{0} = \infty$$

~~∴ @ $f = \frac{1}{2\pi\sqrt{LC}}$ THE PARALLEL COMBINATION OF AN L & C ACTS LIKE AN OPEN CIRCUIT.~~

EXAMPLE

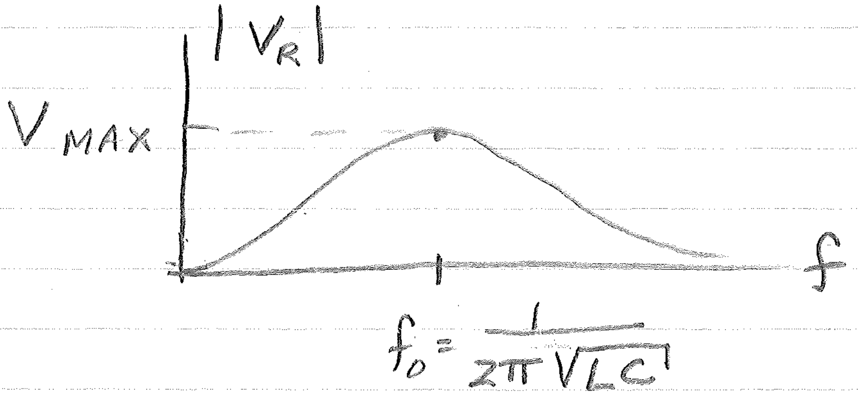


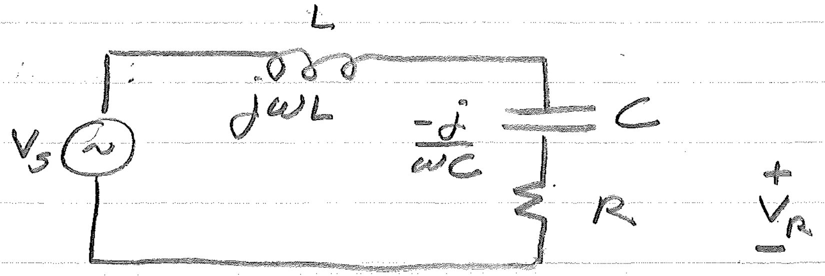
FIND $V_R$

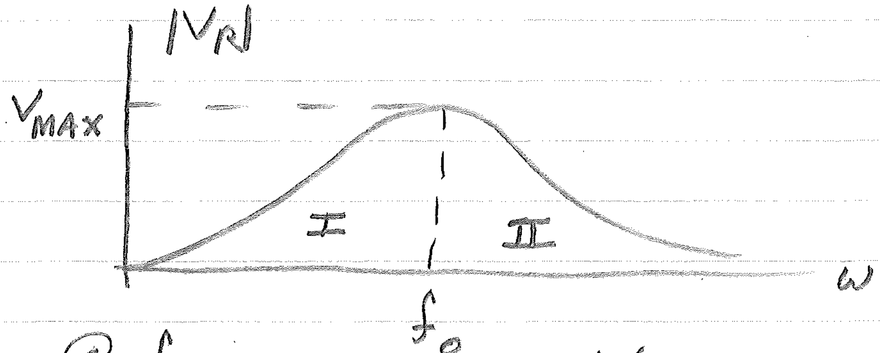
USING VOLTAGE DIVIDER

$$V_R = \frac{R}{R + j(\omega L - \frac{1}{\omega C})} V_0$$

INTUITIVELY, $V_R$ SHOULD BE MAXIMUM WHEN L & C ARE AT RESONANCE



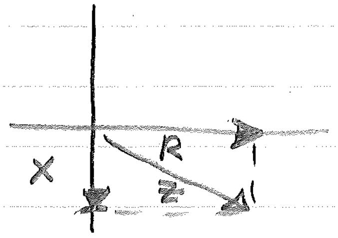




@ $f_o$, $V_R = V_{MAX} = V_s$

IN REGION I, $X_C > X_L$

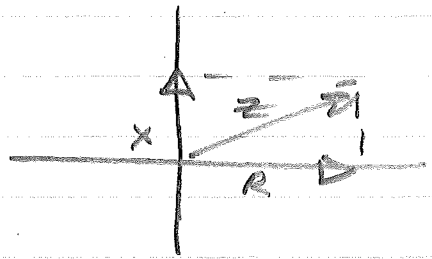
$X = X_C + X_L < 0$



CIRCUIT IS "CAPACITIVE"

IN REGION II $X_C < X_L$

$X = X_C + X_L > 0$



CIRCUIT IS "INDUCTIVE

## POWER CALCULATIONS

### A. ACTIVE & REACTIVE POWER

### 1. RESISTOR

$$\Rightarrow P = Vi$$

$$V = iR \Rightarrow P_R = i^2 R = \frac{V^2}{R}$$

FOR PERIODIC $i$, $V$ IS ALSO PERIODIC, AS IS $P$. CONSIDER AVERAGE POWER FROM PERIODIC CURRENT:

$$P_R = \frac{1}{T}\int_T P_R(t)dt$$
$$= \frac{R}{T}\int_T i^2(t)dt$$
$$= R\left[\sqrt{\frac{1}{T}\int_T i^2(t)dt}\right]^2$$
$$= R\, i_{RMS}^2$$

NOTE: AVERAGE POWER IS GIVEN BY RMS VOLTAGE.

FOR $i(t) = I_0 \cos(2\pi f t + \phi)$, WE SHOWED IN HOMEWORK THAT

$$i_{RMS} = I_0/\sqrt{2}$$
$$\Rightarrow P_R = \frac{1}{2} R I_0^2$$

SINCE $V_{RMS} = R\, i_{RMS}$

$$P_R = V_{RMS}^2/R$$

FOR SINUSOIDAL VOLTAGE, $V_{RMS} = \frac{V_0}{\sqrt{2}}$

$$\Rightarrow P_R = \frac{V_0^2}{2R} = \frac{1}{2} G V_0^2$$

$P_R$ MEASURED IN WATTS

2. REACTIVE POWER (AVERAGE)

$$P_X = I_{RMS}^2 X = V_{RMS}^2/X$$ (VOLT-AMPS-REACTIV

FOR CAPACITOR: $X_C = \frac{-1}{\omega C}$

" INDUCTOR: $X_L = \omega L$

REACTIVE POWER MEASURED IN

B. POWER COMPUTATION

$$P_{AVE} = v i = P_R + j P_X \Rightarrow \text{VOLT-AMPS} = \text{WATTS} + j$$

$$= [V_{RMS} e^{j\phi_v}][I_{RMS} e^{j\phi_i}]$$

$$= V_{RMS} I_{RMS} e^{j(\phi_v+\phi_i)}$$

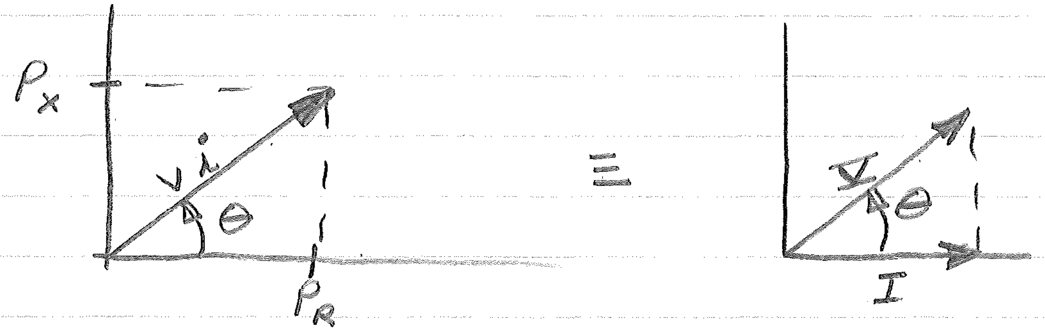
LET $\theta = \phi_v + \phi_i$

$$\Rightarrow P_R + j P_X = V_{RMS} I_{RMS} e^{j\theta}$$

THUS

$$P_R = V_{RMS} I_{RMS} \cos\theta$$

$$P_X = V_{RMS} I_{RMS} \sin\theta$$



$\cos\theta \equiv$ POWER FACTOR

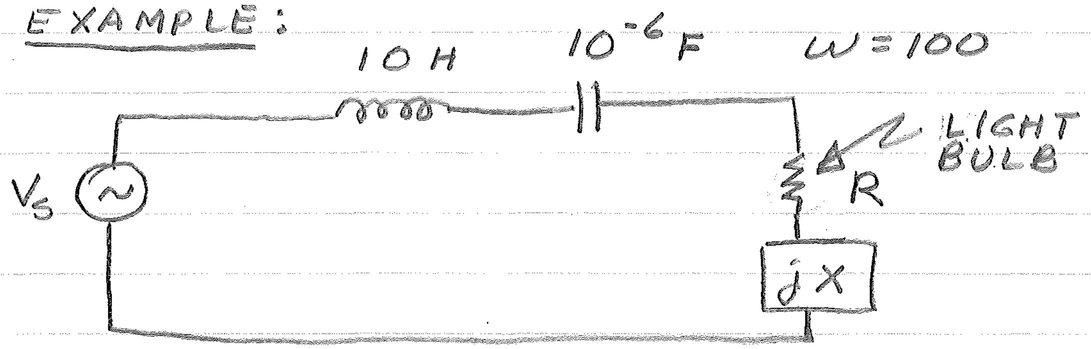
$\sin\theta \equiv$ REACTIVE FACTOR

Note: SINCE $V = Z i = [|Z|\angle\theta] I$, THE "ANGLE" OF THE IMPEDANCE CAN ALSO GIVE THE POWER FACTOR.

## C. POWER FACTOR CORRECTION

FOR A GIVEN VI, THE MAXIMUM ACTIVE (USEFUL) POWER IS $P_{X_{MAX}} = VI$. IT COSTS MONEY TO MAKE V & I, THUS, WE'D LIKE TO MAXIMIZE OUR USEFUL POWER. WE MAY DO THIS BY MAKING ALL REACTANCES CANCEL (ie, IMPOSE RESONANCE)

EXAMPLE:



FIND jX TO MAXIMIZE PWR. TO LITE BLB. WHAT VALUE OF L OR C IS REQUIRED?

SOLN: SET THE TOTAL CIRCUIT REACTANCE TO 0:

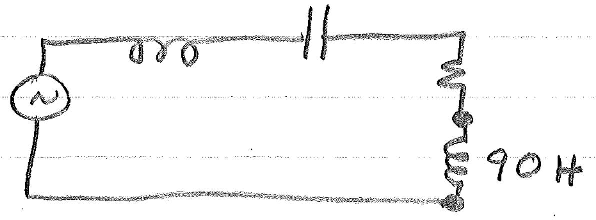
$$0 = X_L + X_C + X = (10)(100) - \frac{1}{(100)(10^{-6})} + X$$

$$= 10^3 - 10^4 + X = -9000 + X$$

THUS: $X = 9000$

SINCE $X > 0$, WE USE INDUCTOR:

$$X = \omega L \Rightarrow 9000 = 100L \Rightarrow L = 90\,H$$



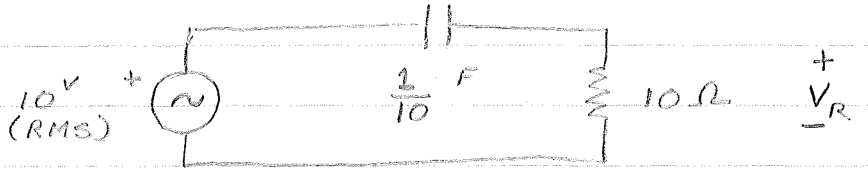
BYOP TEST ON NOV-5 - (55 min)

(15) COMPLEX ARITHMITIC
(15) SINUSOIDS, EXPONENTIALS, & PHASORS
(20) RMS, AVE, AND PEAK TO PEAK MEASURES OF PERIODIC WAVEFORMS
(20) 4 NUGGET PROBLEM
(20) RESONANCE
(20) PHASOR PROBLEM IMPEDANCE REDUCTION

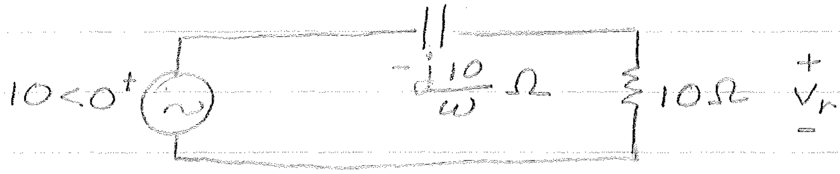
# FREQUENCY RESPONSE

THE MANNER IN WHICH A CIRCUIT IN S.S.S. PERFORMS IS DEPENDENT ON THE CIRCUIT'S FREQUENCY. "FREQUENCY RESPONSE" REFERS TO A CIRCUIT'S PERFORMANCE AS A FUNCTION OF FREQUENCY.

A SIMPLE "FILTER"



FIND $V_R$ AS A FUNCTION OF FREQ



USE VOLTAGE DIVIDER:

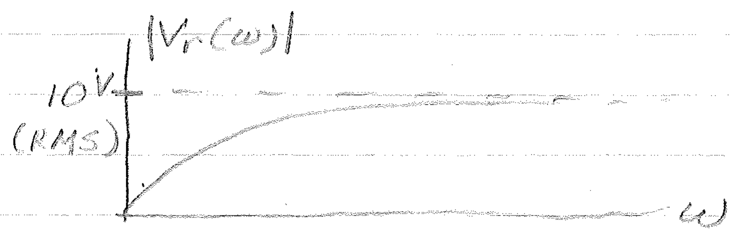
$$V_r = \frac{10\angle}{-j\frac{10}{\omega} + 10} \cdot 10 = \frac{10}{1 - (j/\omega)}$$

$$|V_r| = \frac{10}{\sqrt{1 + 1/\omega^2}}$$

LET'S SKETCH THE CURVE;

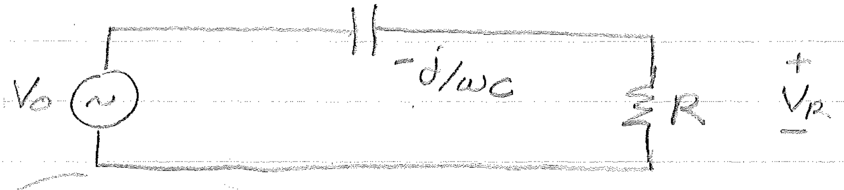
D.C ⇒ $\left|V_r\right|_{\omega=0} = \frac{10}{\sqrt{1+1/0^2}} = \frac{10}{\sqrt{\infty}} = 0$

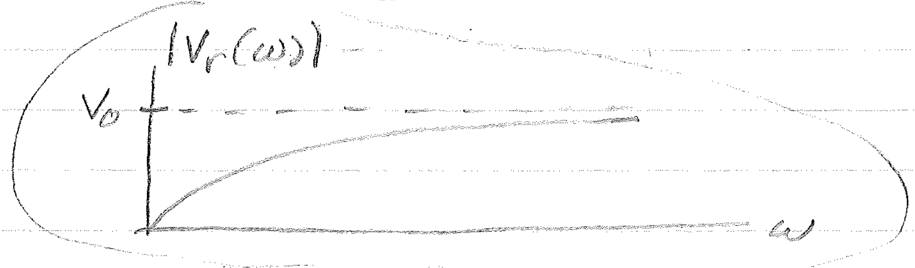
$\left|V_r\right|_{\omega=\infty} = \frac{10}{\sqrt{1+1/\infty^2}} = 10 \text{ V}$



THE CIRCUIT IS A "HIGH PASS FILTER" SINCE HI FREQ.'S ARE PASSED BETTER THAN LOW FREQUENCIES

CONSIDER MORE GENERAL CIRCUIT:





HOMEWORK: SHOW THAT

$$|V_r(\omega)| = \frac{V_0}{\sqrt{1+(1/\omega RC)^2}}$$

OBVIOUSLY, $|V_r(0)| = 0$ AND $|V_r(\infty)| = V_0$
THE MANNER IN WHICH $|V_r(\omega)|$ GOES FROM 0 TO $V_0$ IS DETER. BY THE PRODUCT, RC.

NOW

$$P_{AVE} = \frac{|V_R|^2}{R}$$

THE MAXIMUM POWER IS WHEN $|V_r|$ IS MAX, WHICH IS @ $\omega = \infty$

$$P_{MAX} = \frac{|V_{R_{MAX}}|^2}{R} = \frac{|V_0|^2}{R}$$

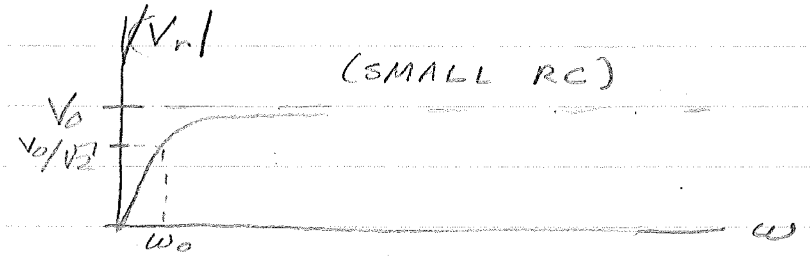
CONSIDER HALF POWER POINT:

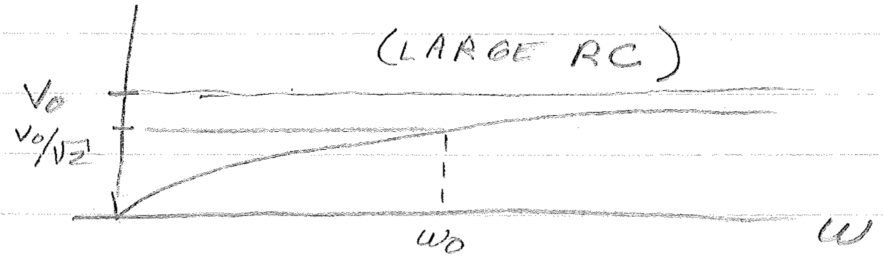
$$P_{1/2} = \frac{1}{2} P_{MAX} = \frac{|V_0|^2}{2R} = \frac{1}{R}\left|\frac{V_0}{\sqrt{2}}\right|^2$$

NOW $|V_r(\omega)| = \dfrac{V_0}{\sqrt{1 + (1/\omega RC)^2}}$

$$\left|V_r\left(\frac{1}{RC}\right)\right| = \frac{V_0}{\sqrt{2}}$$

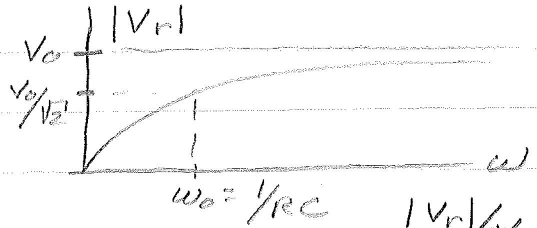
THUS, AT $\omega_0 = \frac{1}{RC}$, WE ARE AT THE "HALF POWER" POINT



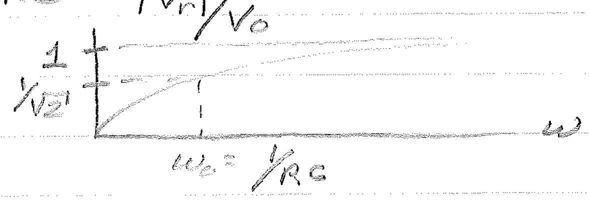


NORMALLY, FREQUENCY RESPONSES ARE EXPRESSED IN UNITLESS QUANTITIES BY NORMALIZING THE VARIABLE MEASURED QUANTITY BY THE MAXIMUM MEASURED QUANTITY:

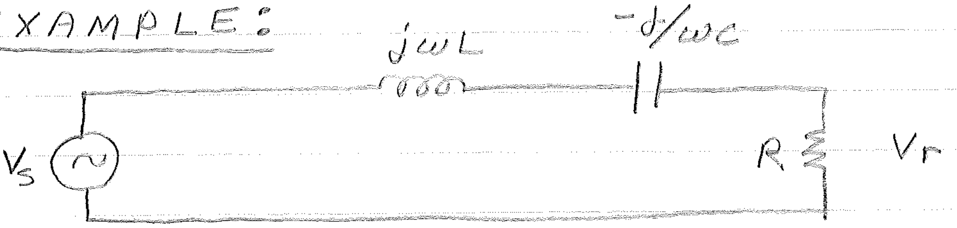
INSTEAD OF:



WE SKETCH:



EXAMPLE:



BY VOLTAGE DIVIDER:

$$V_r = \frac{R\ V_s}{j\omega L - j/\omega C + R} = \frac{V_s}{1 + \frac{j}{R}(\omega L - \frac{1}{\omega C})}$$

THUS:

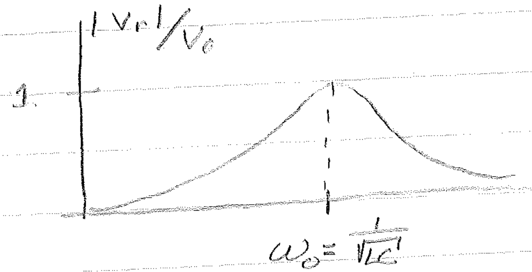
$$V_r/V_s = \frac{1}{1 + j/R\,(\omega L - \frac{1}{\omega C})}$$

$$|V_r|/V_S = \frac{1}{\sqrt{1 + \frac{(\omega L - 1/\omega C)^2}{R^2}}}$$

LET'S SKETCH THE CURVE:

$$|V_r|/V_s\Big|_{\omega=0} = 0 = |V_r|/V_s\Big|_{\omega=\infty}$$

FROM PREVIOUS CONSIRERATIONS, $|V_r|$ WILL BE MAXIMOM WHEN L & C ARE IN RESONANCE, $(\omega = 1/\sqrt{LC})$ AT WHICH TIME, $V_r = V_0 \Rightarrow |V_r|/V_0 = 1$



This IS A "BAND·PASS" FILTER ⇒ IT PASSES FREQUENCIES BEST AROUND THE BAND OF FREQUENCIES ABOUT $\omega_0$

HALF POWER POINTS ARE AT $|V_r|/V_0 = \frac{1}{\sqrt{2}}$. FROM FORMULA, THIS OCCURS WHEN

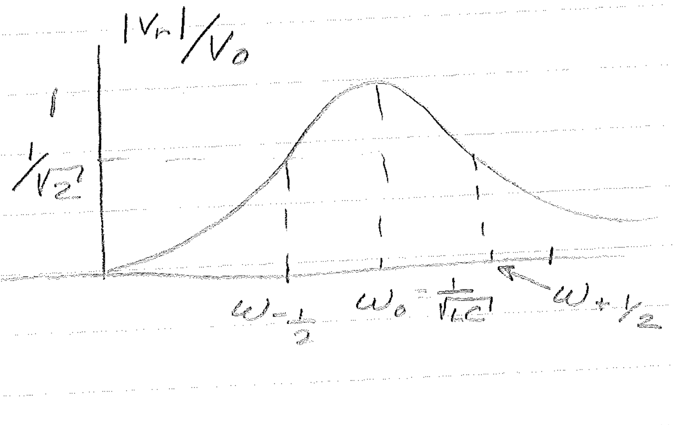
$$(\omega L - \frac{1}{\omega C})^2 = R^2$$

$$\omega L - R - \frac{1}{\omega C}$$

$$CL\omega^2 - CRW - 1 = 0$$

USE QUADRATIC FORMULA:

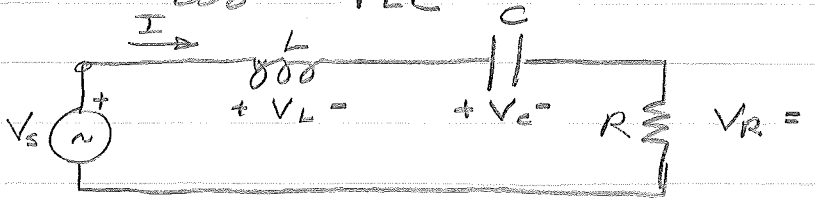
$$\omega_{\pm\frac{1}{2}} = \frac{CR \pm \sqrt{R^2C^2 - 4LC}}{2LC}$$



# THE QUALITY FACTOR

IN OUR SERIES RLC CIRCUIT, IT IS POSSIBLE TO OBTAIN VOLTAGES GREATER THAN THE SOURCE VOLTAGE. AT RESONANCE

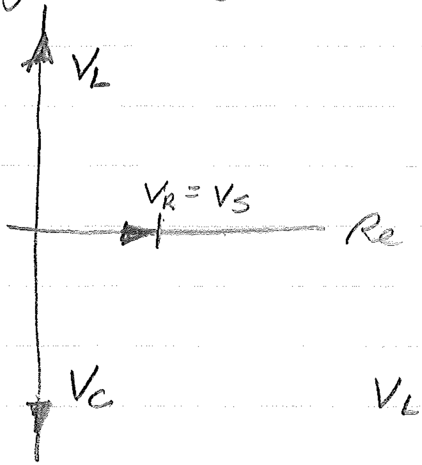
$$\omega_0 = \frac{1}{\sqrt{LC}}$$



THEN, @ RESONANCE, $V_R = V_S$

$$I = I_0 = V/R$$

$$\Rightarrow V_L = j\omega_0 L I_0 \qquad V_C = \frac{-jI_0}{\omega_0 C}$$



NOTE:

$|V_L| > V_S$

$|V_C| > V_S$

BUT

$V_L + V_C = 0$

A MEASURE OF HOW MUCH HIGHER THE C & L VOLTAGES CAN GO IS THE QUALITY FACTOR, Q. AT RESONANCE

$$|V_L| = \omega_0 L I_0 = \omega_0 L|V|/R$$

$$\Rightarrow |V_L|/|V_S| = \omega_0 L/R$$

$$|V_C| = |I_0|/\omega_0 C = |V_S|/\omega_0 RC$$

$$\Rightarrow |V_C|/|V_S| = 1/\omega_0 RC$$

BUT, AT RESONANCE, $|V_L| = |V_C|$

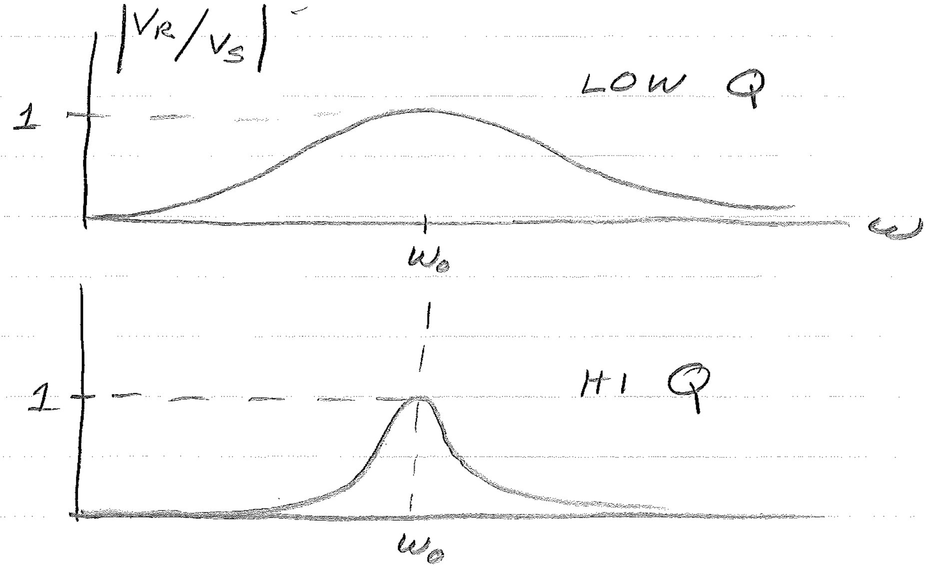
$$\Rightarrow \frac{|V_L|}{|V_S|} = \frac{|V_C|}{|V_S|}$$

OR

$$\frac{\omega_0 L}{R} = \frac{1}{\omega_0 C R} = Q$$

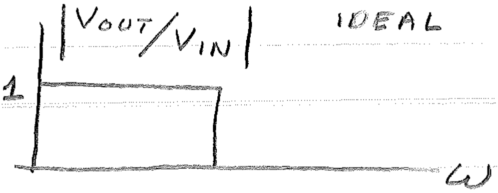
NOTE: THIS IS Q ONLY FOR THE SERIES RLC CIRCUIT UNDER INSPECTION.

THE Q ALSO IS A MEASURE OF THE DISPERSION OF THE FREQUENCY RESPONSE CURVES

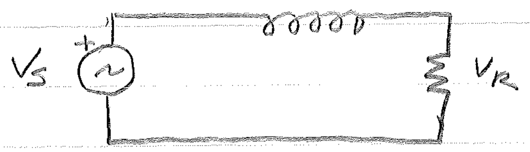


# A GENERAL VIEW OF FILTERS

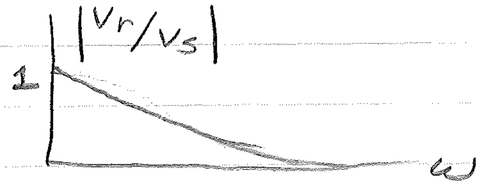
## 1. LOW PASS



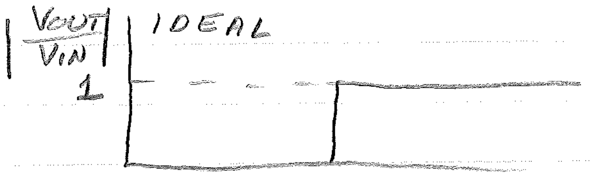
EXAMPLE



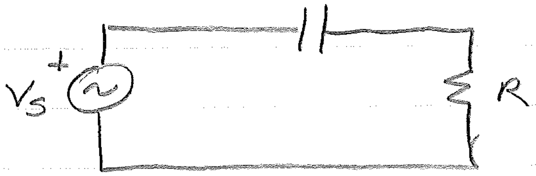
ACTUAL



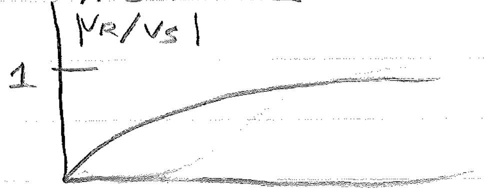
## 2. HI PASS



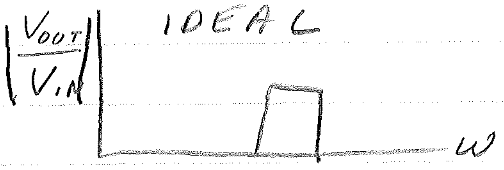
EXAMPLE



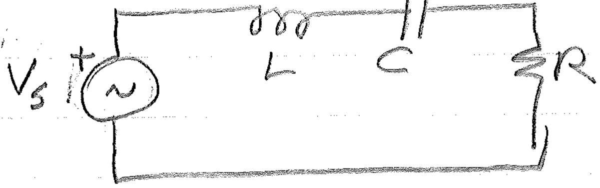
ACTUAL



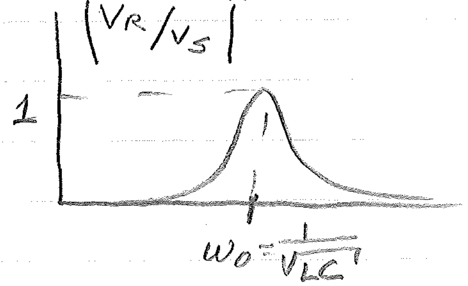
## 3. BAND PASS



EXAMPLE

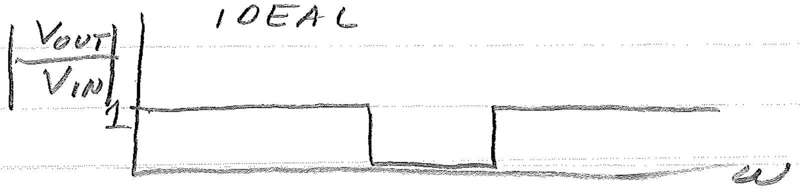


ACTUAL

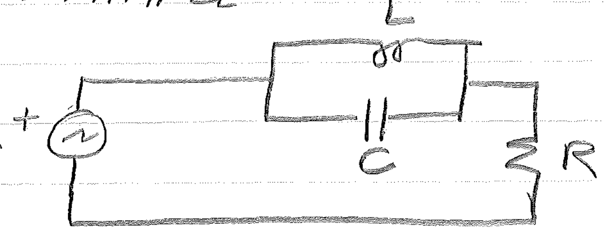


## 4. BAND STOP

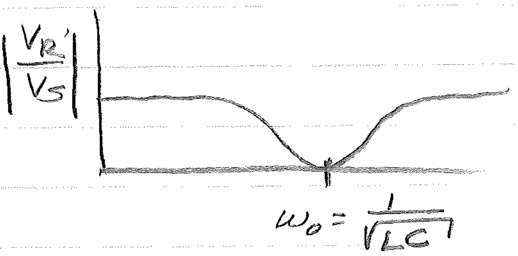
IDEAL



EXAMPLE



ACTUAL



# GENERALIZED THEVININ & NORTON THEOREMS

THEVININ: INSOFAR AS A LOAD IS CONCERNED, ANY ONE PORT NETWORK $\overset{\text{IN SSS}}{\vee}$ CONSISTING OF OF LINEAR PASSIVE ELEMENTS MAY BE REPRESENTED BY A VOLTAGE SOURCE AND IN SERIES WITH AN IMPEDANCE:

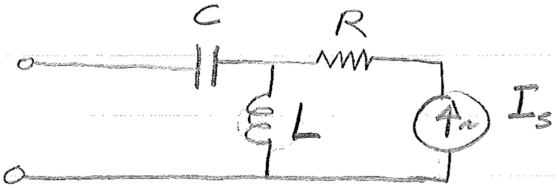
AS BEFORE:

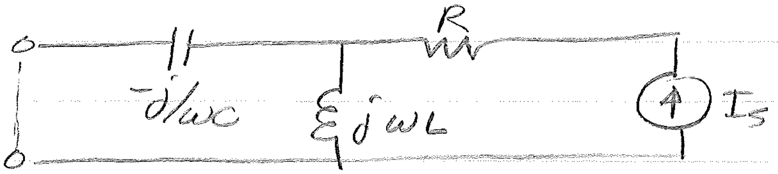
$V_{oc}$ = OPEN CIRCUIT VOLTAGE

$I_{sc}$ = SHORT CIRCUIT CURRENT

$Z_{eq} = V_{oc}/-I_{sc}$

EXAMPLE: $\omega$



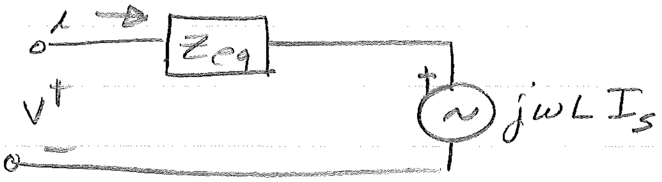


USE CURRENT DIVIDER:

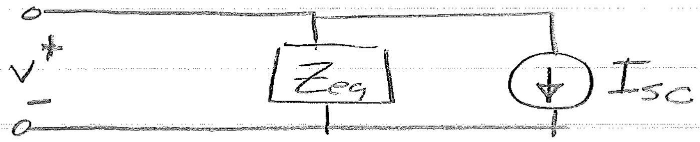
$$I_{sc} = \frac{j\omega C}{j\omega C - j/\omega L} I_s = \frac{\omega C I_s}{\omega C - 1/\omega L} = \frac{\omega^2 LC\, I_s}{\omega^2 LC + 1}$$

NOW $V_{oc} = j\omega L I_s$

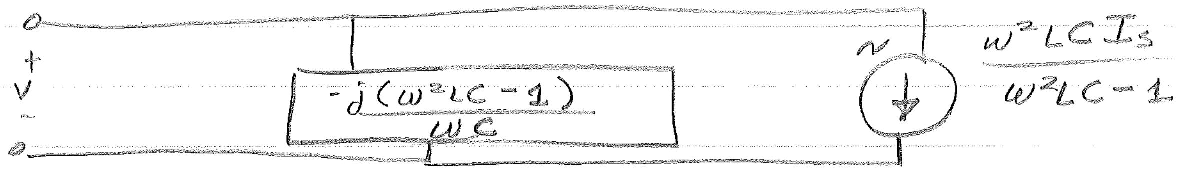
$$\Rightarrow Z_{eq} = V_{oc}/-I_{sc} = \frac{-j\omega \cancel{L} \cancel{I_s}}{\left(\frac{\omega^2 \cancel{L} C \cancel{I_s}}{\omega^2 LC - 1}\right)} = \frac{-j(\omega^2 LC - 1)}{\omega C}$$



NORTON'S EQUIVALENT FOLLOWS AS



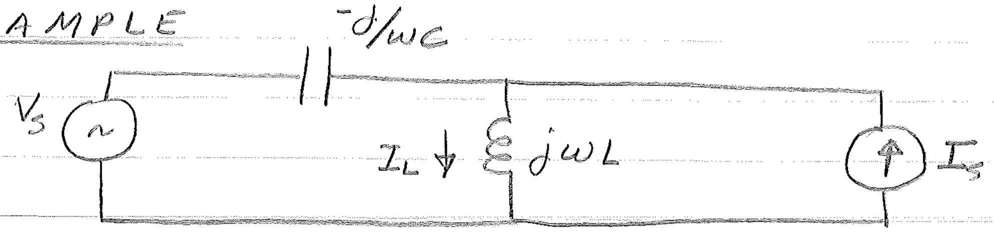
FOR PREVIOUS EXAMPLE, THE NORTON EQUIVALENT IS:



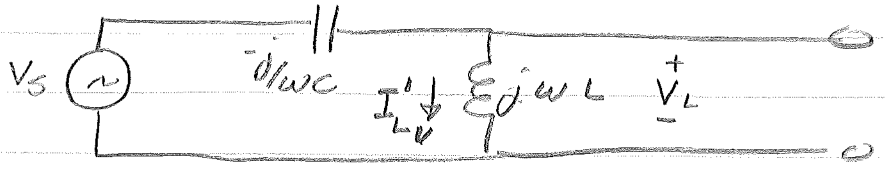
### GENERALIZED SUPERPOSITION

BY FINDING THE VOLTAGE OR CURRENT DUE TO AN INDIVIDUAL SOURCE (SHORTING ALL OTHER V SUPPLIES & OPENING ALL OTHER I SUPPLIES), ~~WE MAY FIND~~ THE RESULTING ~~CU~~ VOLTAGE OR CURRENT MAY BE FOUND FROM THE PHASER SUMS OF THE COMPONENTS.

EXAMPLE



FIND EFFECT OF $V_S$ (OPEN $I_S$):



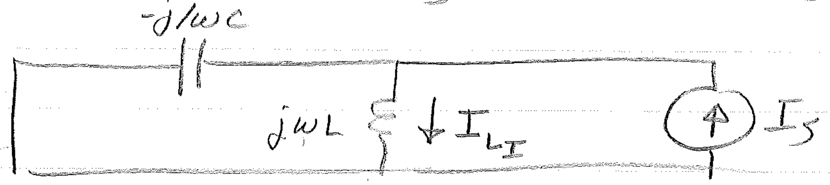
BY VOLTAGE DIVIDER

$$V_L = \frac{j\omega L}{j\omega L - j/\omega C} V_s = \frac{\omega L V_s}{\omega L - \frac{1}{\omega C}} = \frac{\omega^2 LC V_s}{\omega^2 LC - 1}$$

$$I_{L_V} = V_L / j\omega L = \frac{\omega^2 \cancel{L} C V_s}{\omega^2 LC - 1} \cdot \frac{1}{j\omega \cancel{L}}$$

$$= \frac{-j\omega C V_s}{\omega^2 LC - 1}$$

FIND EFFECT OF $I_S$ (SHORT $V_S$):



BY CURREND DIVIDER

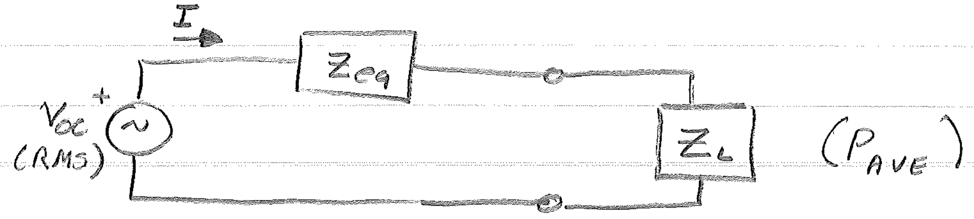
$$I_{L_I} = \frac{-j/\omega L \;\; I_S}{j\omega C - j/\omega L} = \frac{-1/\omega L \, I_S}{\omega C - 1/\omega L}$$

$$= \frac{-I_S}{\omega^2 LC - 1}$$

TOTAL CURRENT IS THEN

$$I_L = I_{L_V} + I_{I_V} = \frac{-1}{\omega^2 LC - 1}\left[ + I_S + j\omega C V_S \right]$$

# MAXIMUM POWER TRANSFER



PROBLEM: GIVEN THE THEVININ EQUIVALENT CIRCUIT WITH $V_{oc}$ AND $Z_{eq}$, FIND $Z_L$ SUCH THAT THERE IS MAXIMUM (ACTIVE) POWER IS ASSOCIATED WITH THE LOAD.

SOLUTION: MAXIMIZE $P_{AVE} = |I|_{RMS}^2 R$ WHERE

$$Z_{eq} = R_{eq} + j X_{eq}$$

$$Z_L = R_L + j X_L$$

NOW $$I = \frac{V_{oc}}{Z_{eq} + Z_L}$$

$$|I| = \frac{|V_{oc}|}{|Z_{eq} + Z_L|}$$

$$= \frac{|V_o|}{|(R_{eq} + R_L) + j(X_{eq} + X_L)|}$$

$$= \frac{|V_o|}{\sqrt{(R_{eq} + R_L)^2 + (X_{eq} + X_L)^2}}$$

THEN

$$P_{AVE} = |I|^2 R_L$$

$$= \frac{|V_o|^2 R_L}{(R_{eq} + R_L)^2 + (X_{eq} + X_L)^2}$$

IN TERMS OF REACTANCE, $P_{AVE}$ IS MAXIMUM WHEN $X_{eq} + X_L = 0$

$$\Rightarrow P_{AVE} = \frac{|V_0|^2 R_L}{(R_{eq} + R_L)^2}$$

NOTE: BY SETTING $X_{eq} + X_L = 0$, WE ARE SETTING CIRCUIT @ RESONANCE.

NOW:

$$\frac{d}{dR_L} P_{AVE} = \frac{(R_{eq}+R_L)^2 - 2(R_{eq}+R_L)R_L}{(R_{eq}+R_L)^4} |V_0|^2 = 0$$

SET NUM = 0:

$$(R_{eq}+R_L)^2 - 2(R_{eq}+R_L)R_L = 0$$

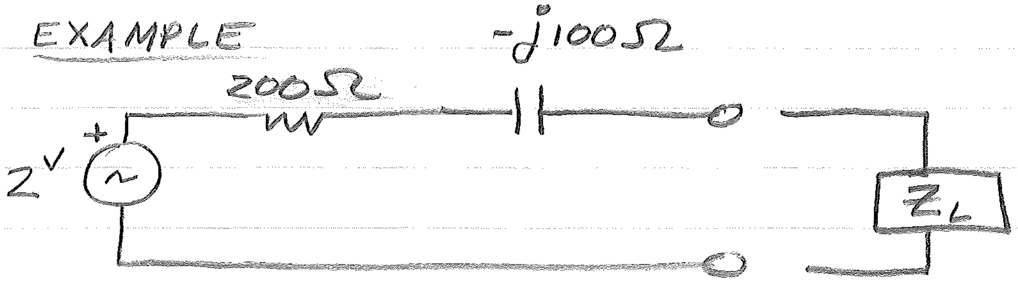
SOLVING GIVES $R_L = R_{eq}$

SUMMARY: MAXIMUM POWER IS TRANSFERED WHEN $R_L = R_{eq}$ **AND** $X_L = -X_{eq}$ OR

$$Z_L = R_{eq} - jX_{eq} = Z_{eq}^*$$

(ie, WHEN $Z_L$ AND $Z_{eq}$ ARE COMPLEX CONJUGATES)

EXAMPLE



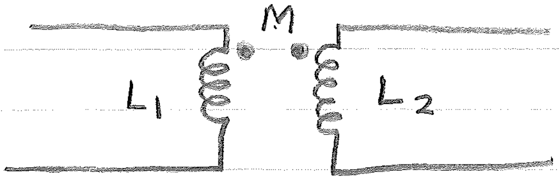
$Z_{eq} = 200 - j100$

MAXIMUM POWER IS XFERED WHEN

$Z_L = 200 + j100$

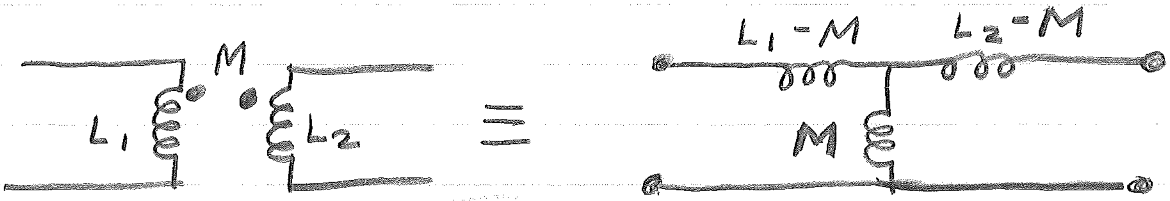
# TRANSFORMER (INDUCTIVE) COUPLING

FOR INDUCTOR: $V = L\, di/dt$
L IS "SELF INDUCTANCE"
ANOTHER TYPE OF INDUCTANCE IS
M = "MUTUAL INDUCTANCE"



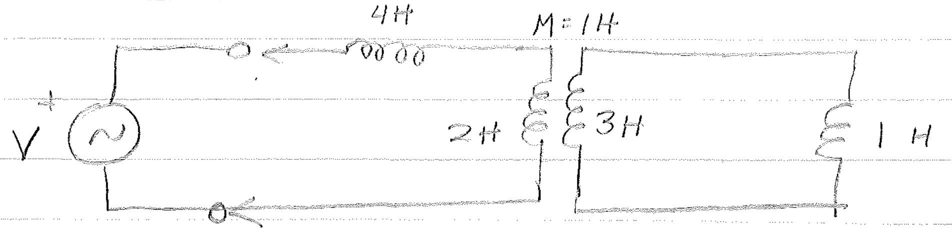
M IS DUE TO INTERACTION OF MAGNETIC FIELD OF $L_1$ ON $L_2$ AND VISA VERSA.

"T" EQUIVALENT

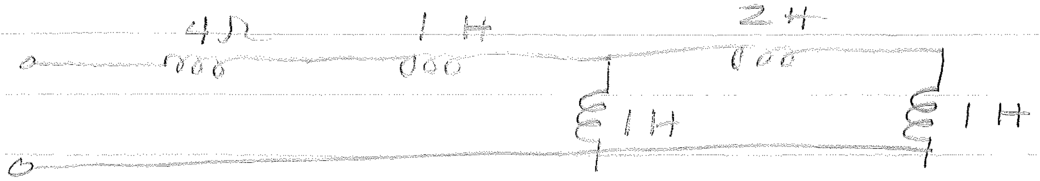


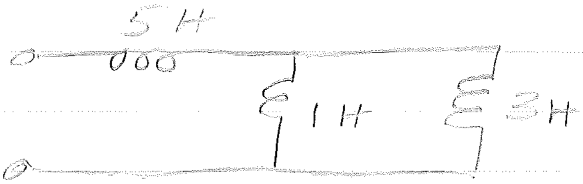
CIRCUITS OF THIS TYPE ARE "TRANSFORMERS"

## EXAMPLE

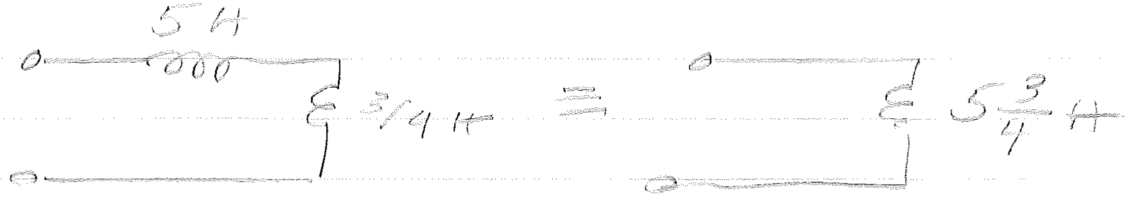


USE T EQUIVALENT





$$\frac{1}{L_{eq}} = \frac{1}{1} + \frac{1}{3} = \frac{4}{3} \Rightarrow L_{eq} = \frac{3}{4} H$$



K = COEFFICIENT OF COUPLING
= A MEASURE OF HOW WELL THE MAGNETIC FIELDS OF ~~THE~~ AN INDUCTOR INTERACT WITH THE OTHER INDUCTOR

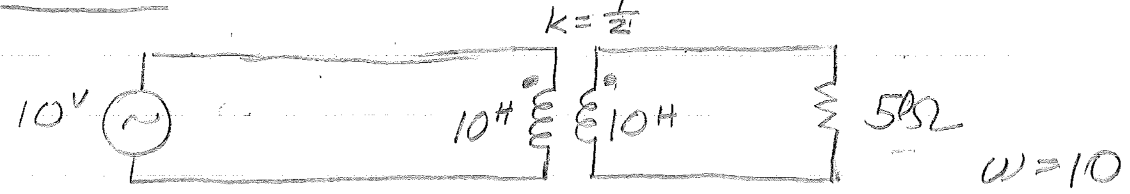
$$-1 \leq k \leq 1$$

RELATION OF M & K:

$$M = k\sqrt{L_1 L_2}$$

NOTE THAT $|M| \leq \sqrt{L_1 L_2}$

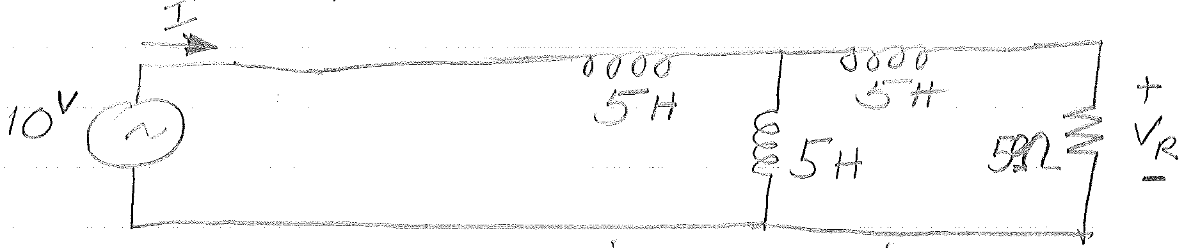
EXAMPLE

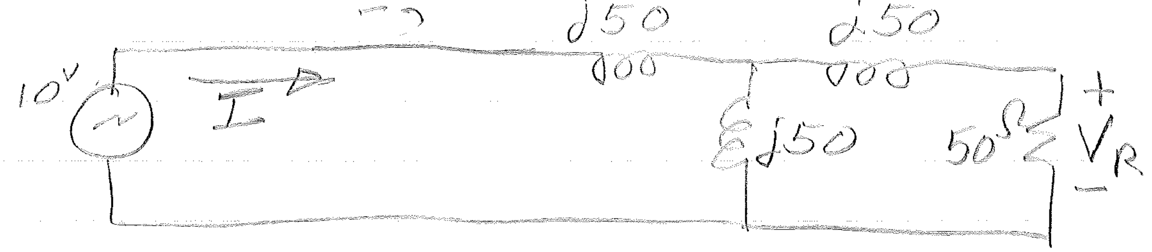


(a) FIND M

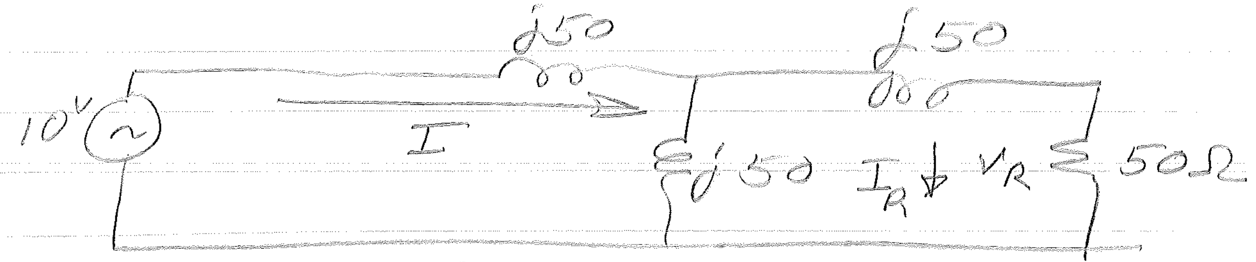
$$M = K\sqrt{L_1 L_2} = \frac{1}{5}\sqrt{10 \cdot 10} = 5\,H$$

(b) DRAW EQUIVALENT T CIRCUIT





BACK TO ORIGINAL CIRCUIT



$$I = \frac{1-j8}{65}$$

USE CURRENT DIVIDER

$$I_R = \frac{\frac{1}{50+j50}}{\frac{1}{50+j50}+\frac{1}{j50}} I$$

$$= \frac{j50}{j50+(50+j50)} \quad \frac{1-j8}{65}$$

$$= \frac{j50}{50+j100} \quad \frac{1-j8}{65}$$

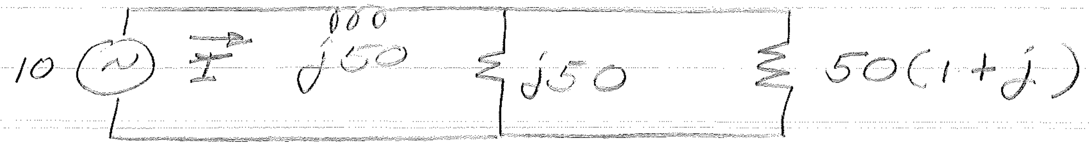
$$= \frac{j}{1+j2} \quad \frac{1-j8}{65}$$

$$= \frac{8+j}{65} \quad \frac{1}{1+j2} \quad \frac{1-j2}{1-j2}$$

$$= \frac{8-j16+j+2}{5 \cdot 65} = \frac{10-j15}{5 \cdot 65}$$

$$V_R = 50\, I_R = \frac{100-j150}{65} \text{ VOLTS}$$

FIND I BY REDUCING Z



$$\frac{1}{Z_{eq}} = \frac{1}{j50} + \frac{1}{50(1+j)}$$

$$= \frac{1}{50}\left[\frac{1}{j} + \frac{1}{1+j}\right]$$

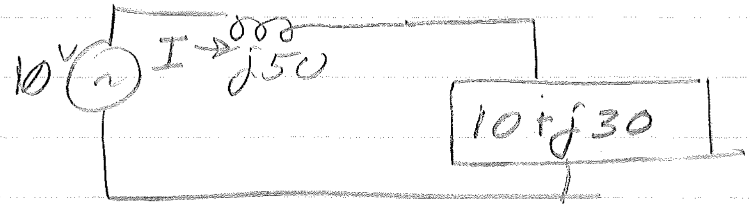
$$= \frac{1}{50} \frac{1+2j}{j(1+j)}$$

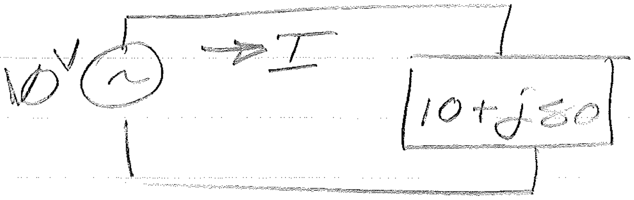
$$\Rightarrow Z_{eq} = 50 \frac{j(1+j)}{1+2j}$$

$$= 50 \frac{-1+j}{1+j2} \frac{(1-2j)}{(1-2j)}$$

$$= \frac{50(-1+j2+j+2)}{5}$$

$$= 10(1+j3)$$





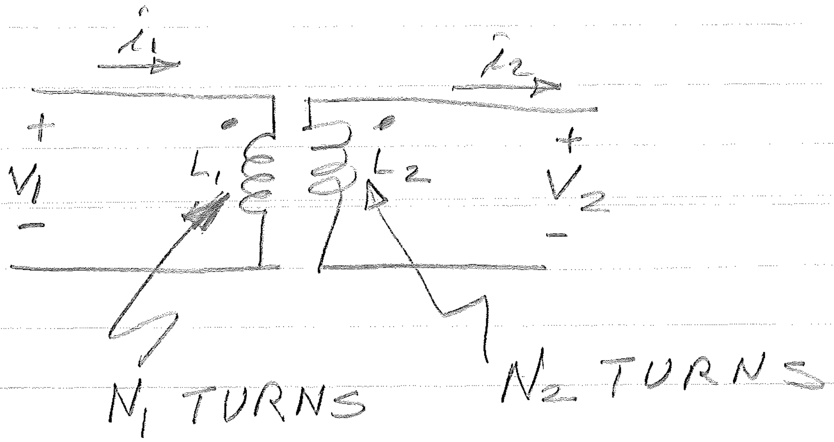
$$I = \frac{V}{Z}$$

$$= \frac{10}{10(1+j8)} \cdot \frac{1-j8}{1-j8}$$

$$= \frac{1-j8}{65}$$

THE IDEAL TRANSFORMER: $k=1$

$M = \sqrt{L_1 L_2}$

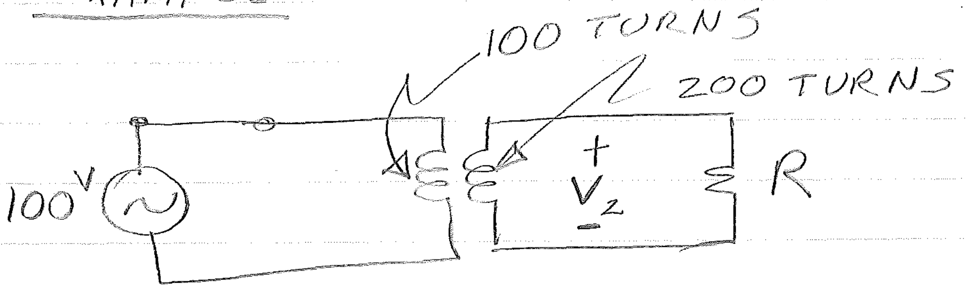


$\frac{N_1}{N_2}$ = TURNS RATIO

$$\frac{L_1}{L_2} = \left(\frac{N_1}{N_2}\right)^2$$

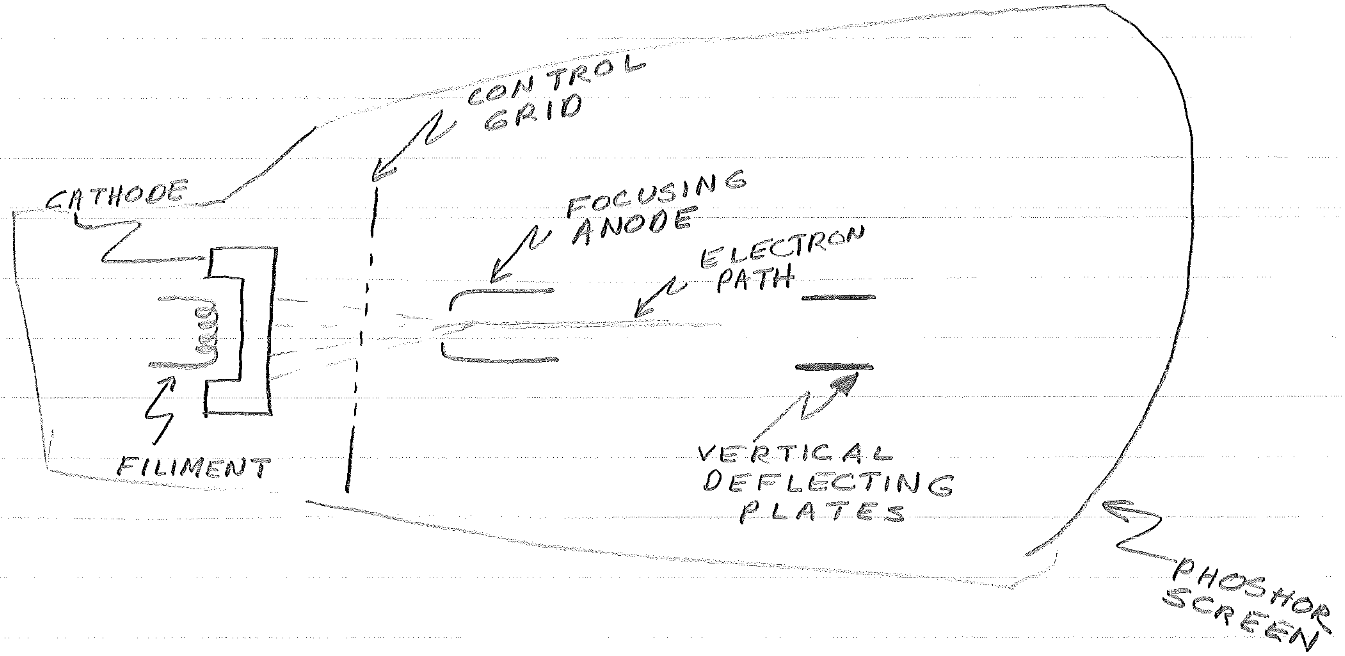
$$\frac{V_1}{V_2} = \left(\frac{N_1}{N_2}\right) \qquad \frac{i_1}{i_2} = 1 \Big/ \left(\frac{N_1}{N_2}\right) = \left(\frac{N_2}{N_1}\right)$$

EXAMPLE



$$V_2 = \frac{N_2}{N_1} V_1 = \frac{200}{100} \times 100 = 200V$$

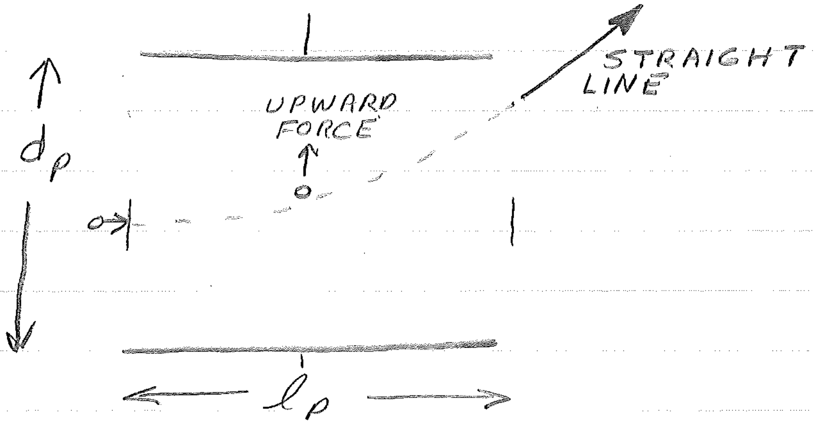
THE CATHODE RAY TUBE (CRT)



ANODE - ACCERATES & FOCUSES BEAM

HORIZONAL DEFLECTION PLATES NOT SHOWN

CONSIDER VERTICAL DEFL. PLATES

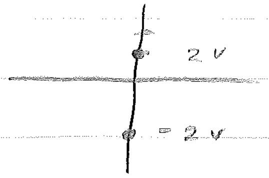


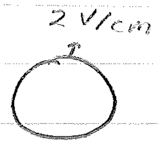
POTENTIAL ON PLATES

BY CHANGING VOLTAGE ON PLATES, WE CAN CHOOSE THE POSITION OF THE DOT ON THE SCREEN.

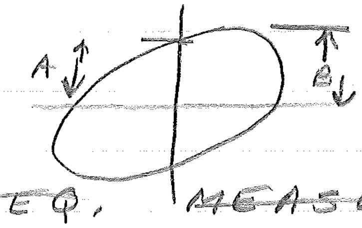
USES OF CRT

1. VOLTAGE DISPLACEMENT: DISPLACEMENT ON SCREEN IN PROPORTIONAL TO APPLIED VOLTAGE





2. TIME MEASURE-MENT (APPLY SAWTOOTH)
3. WAVEFORM PLOTTING
4. PHASE MEASUREMENTS (LISSAJOUS PATTERN)

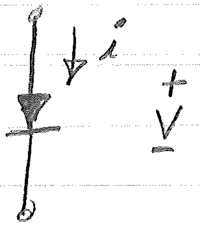


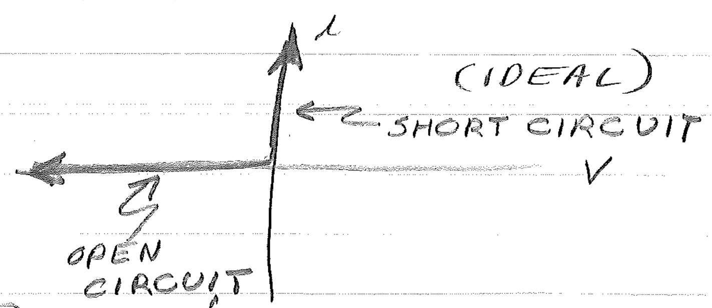
$\theta = \sin^{-1} \frac{A}{B}$

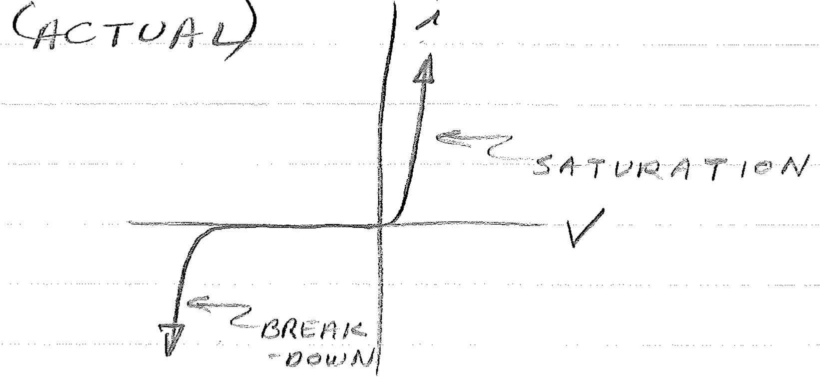
~~5. FREQ. MEASUREMENTS~~

# DIODES

V-$i$ CHARACTERISTIC

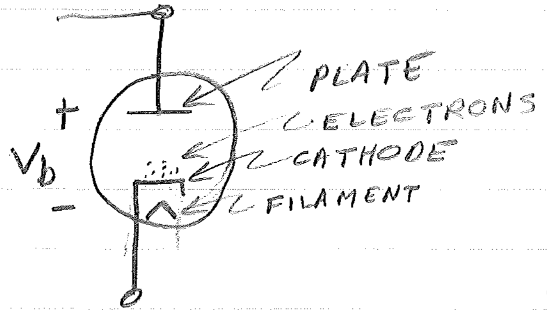






PHYSICAL DIODES

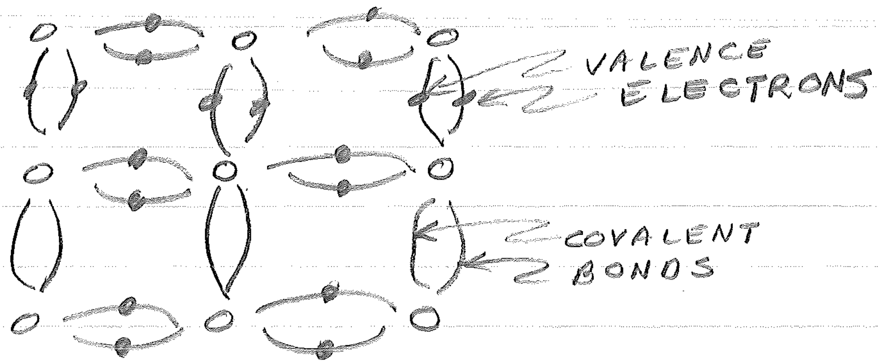
1. TUBE TYPES



FILAMENT "BOILS OFF" ELECTRONS

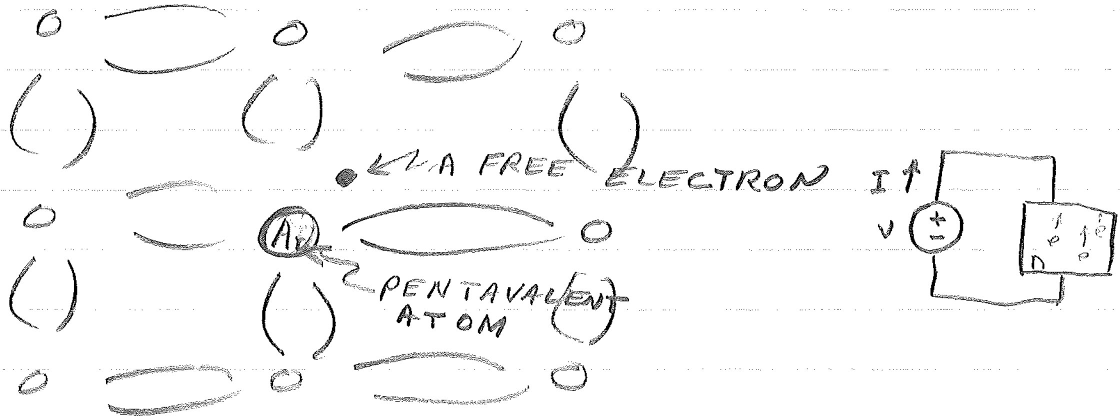
IF $V_b > 0$, THE VOLTAGE OF THE PLATE IS ~~ER~~ > THE CATHODE. AND ~~EL~~ $e^-$ ARE ATTRACTED. THUS, CONDUCTION, IF $V_b < 0$, ~~EA~~ PLATE WILL REPEL ELECTRONS ⇒ NO CONDUCTION.

2. SEMICONDUCTOR DIODES
(USUALLY SILICON & GERMANIUM)
SILICON CRYSTAL (VALENCE = 4)



DOPED SEMICONDUCTORS (IMPURITY ATOMS ARE ADDED)

a. n - DOPING - THE IMPURITY HAS MORE VALENCE ELECTRONS
(5 e ⇒ ANTIMONY, PHOSPHORUS, ARSENIC)

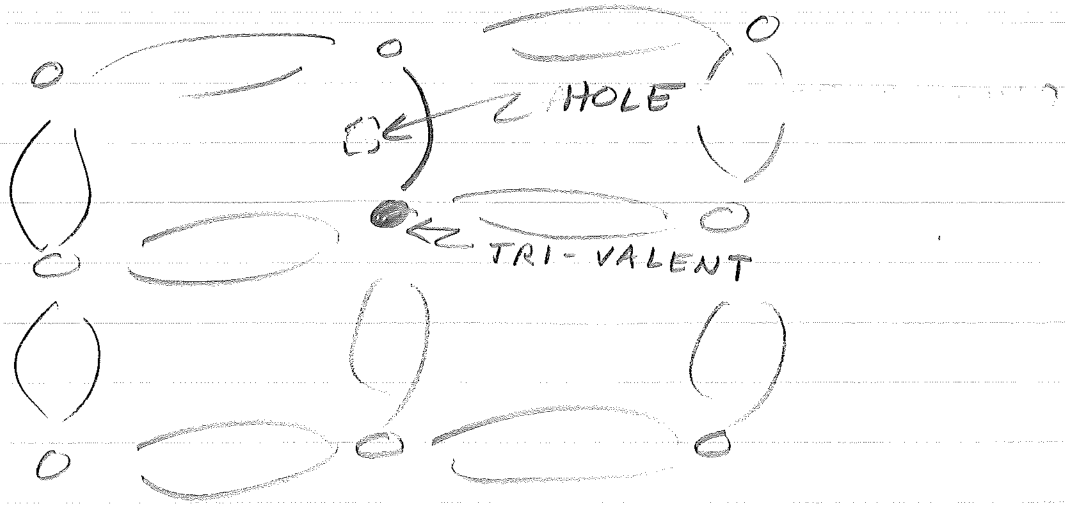


PENTAVALENT ATOMS ARE "DONORS"
THE HAVE AN EXTRA ELECTRON
TO DONE.

b. p-DOPED SEMICONDUCTORS

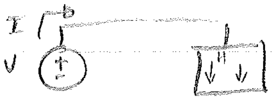
TRI-VALENT ATOM → 3 VALENCE $e^-$

(BORON, ALUMINUM, & GALLIUM)



A "HOLE" IS AN ABSENCE OF A BOND.

TRI-VALENT ATOMS ARE "ACCEPTORS" SINCE THEY HAVE A HOLE TO "ACCEPT" AN ELECTRON.



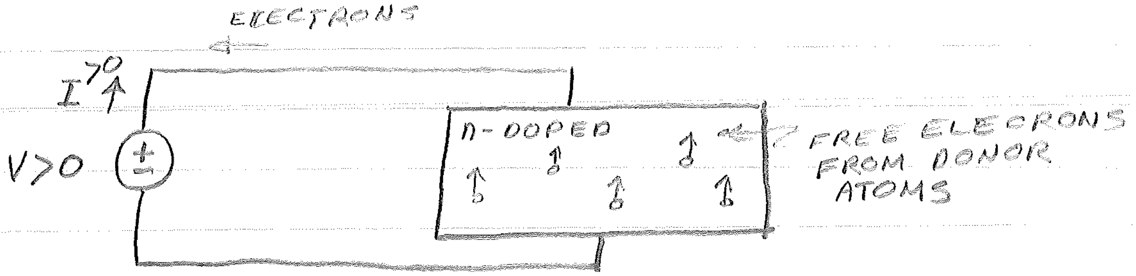
CONCEPT: JUST AS FREE ELECTRONS CAN PRODUCE CURRENT, SO CAN "FREE HOLES". THAT IS, WE CAN SPEAK OF A "HOLE CURRENT" JUST AS WE CAN AN "ELECTRON" CURRENT

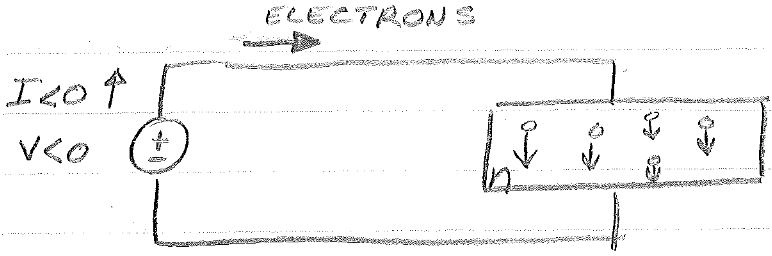
TEST # 3

20 1. DOPED SEMICOND. AND/OR TUBE DIODES
20 2. MAXIMUM POWER XFER/ LOAD MATCHING
25 3. TRANSFORMERS
20 4. FREQUENCY RESPONSE
25 5. THREE PHASE

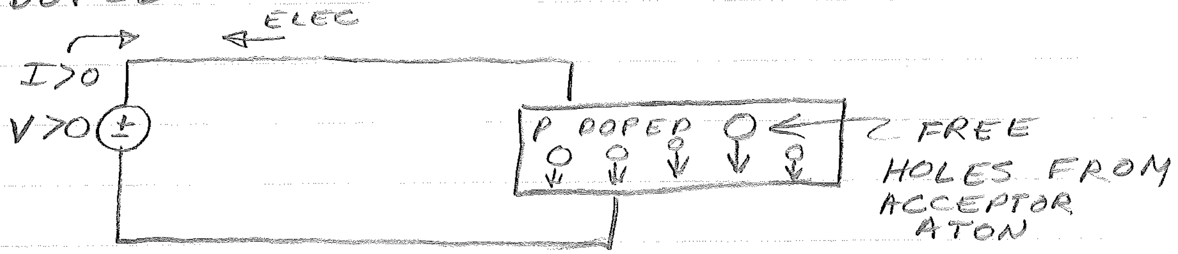
# APPLIED VOLTAGE TO DOPED SEMICONDUCTORS

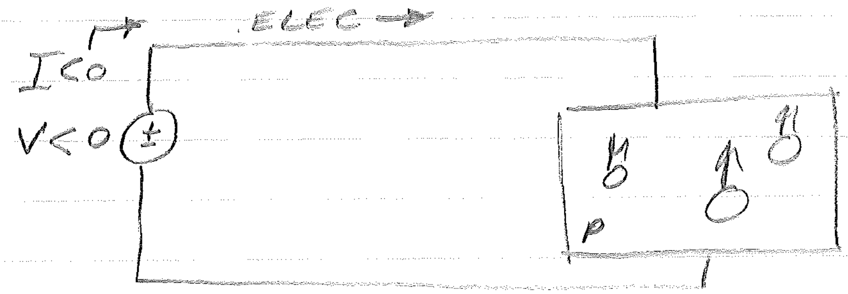
## n DOPPED



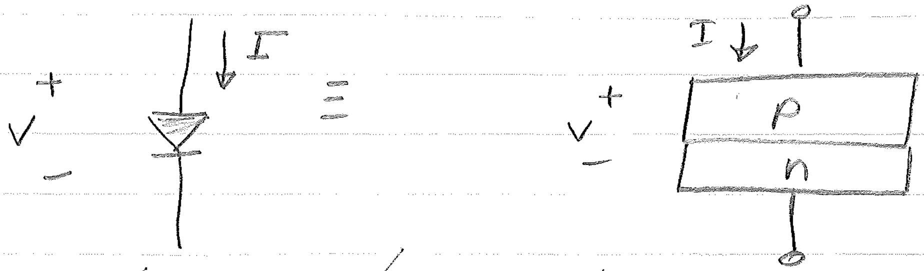


## P DOPED

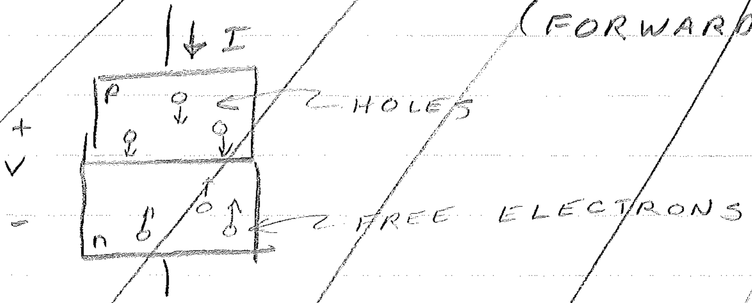




A SEMICONDUCTOR DIODE IF FORMED WHEN A p-DOPED AND n DOPED SEMICONDUCTOR ARE PLACED BACK TO BACK. CALLED "p-N" JUNCTION

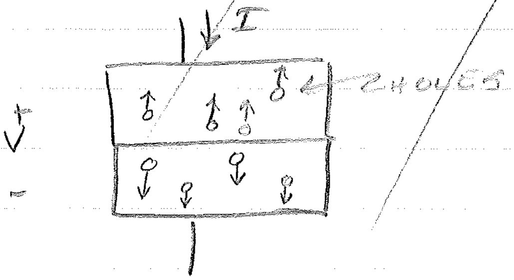


SUPPOSE WE <u>TRY</u> TO MAKE $V > 0$ (FORWARD BIASED)



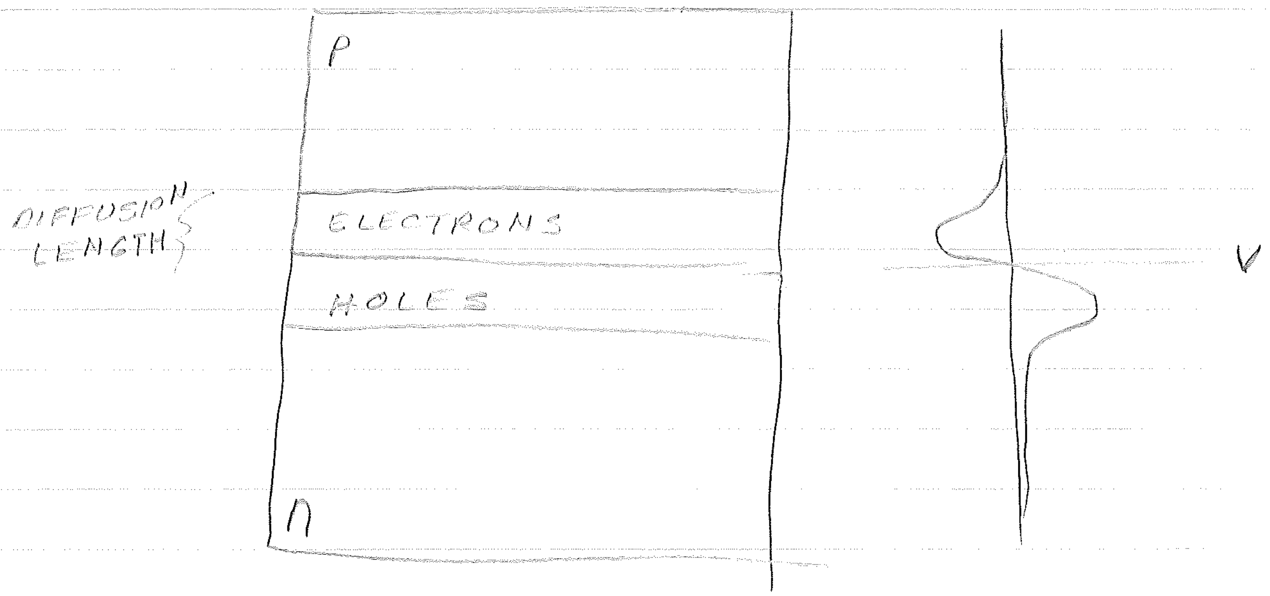
WE HAVE CONDUCTION AND THE DIODE ACTS AS A SHORT CIRCUIT

SUPPOSE $V < 0$ (REVERSE BIAS)

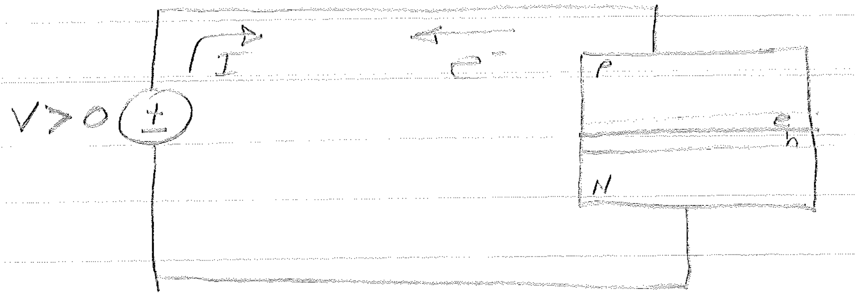


DIODE ACTS LIKE OPEN CIRCUIT

AT A P-N JUNCTION, AT ZERO VOLTS SOME OF THE FREE e's FROM THE n MATERIAL DIFFUSE INTO p MATERIAL & SOME HOLES INTO n MATERIAL:

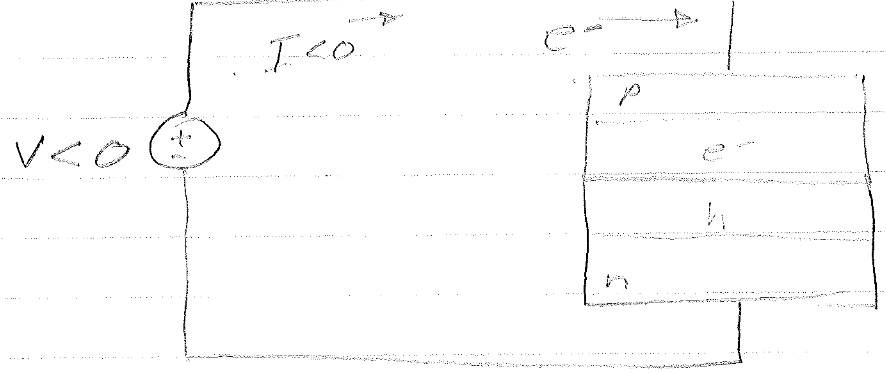


(a) IF WE "FORWARD BIAS" THE DIODE, IT CONDUCTS (SHORT CIRCUIT)



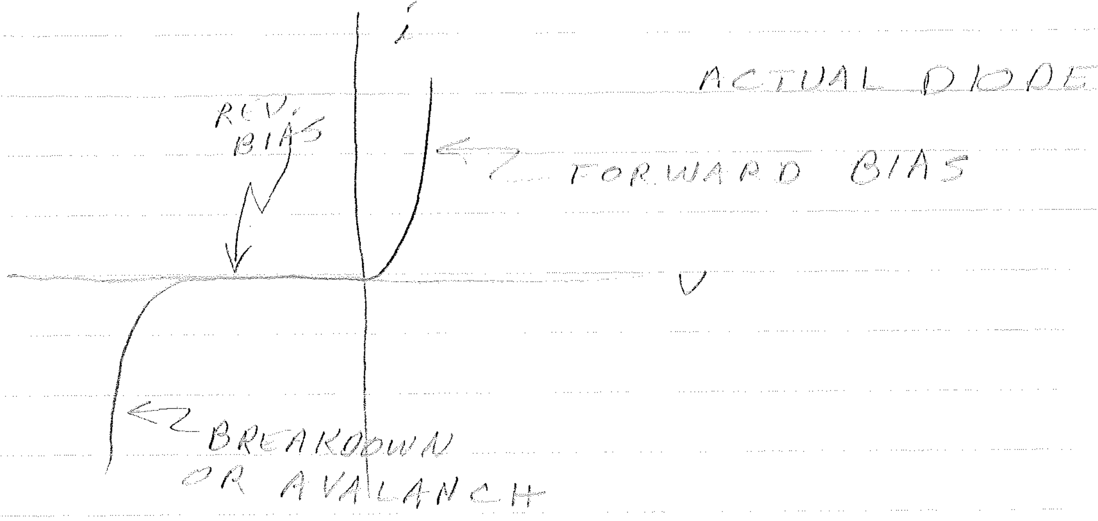
THE ELECTRONS ARE "SUCKED" FROM THE DEPLETION REGION (AS ARE HOLES) AND WE HAVE CONDUCTION. NOTE THE DIFFUSION LENGTH DECREASES

(b) IF WE "REVERSE BIAS" THE DIODE, IT DOESN'T CONDUCT (OPEN CIRCUIT



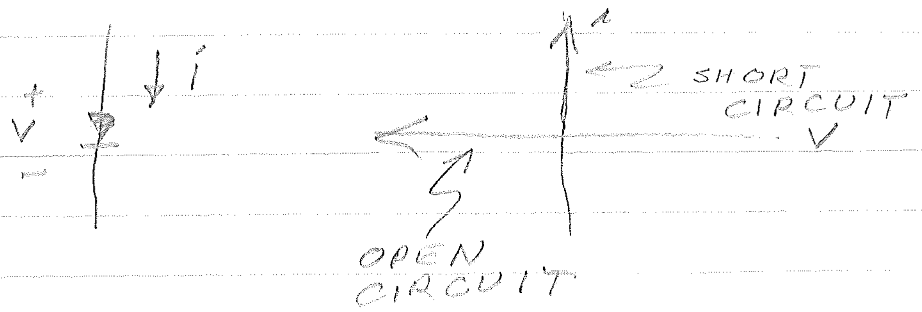
MORE e's ARE SUPPLIED TO DEPLETION REGION IN P MATERIAL & MORE HOLES TO n REGION. DIFFUSION LENGTH INCREASES

IF WE REVERSE BIAS BIG ENOUGH, THE DIODE NO LONGER HAS BIG ENOUGH DEPLETION REGION AND WE AGAIN HAVE CONDUCTION. THIS IS CALLED "BREAKDOWN" OR "AVALANCH" EFFECT



# DIODES IN CIRCUITS

FOR (FIRST ORDER) CIRCUIT ALALYSIS, WE USE IDEAL DIODE:

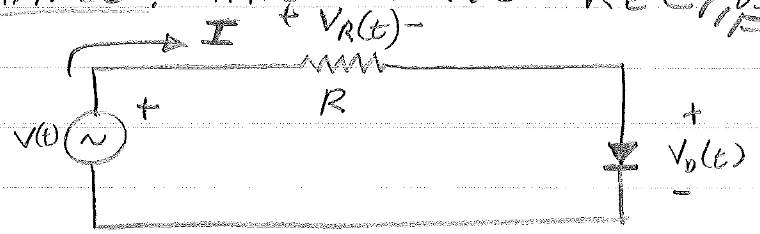


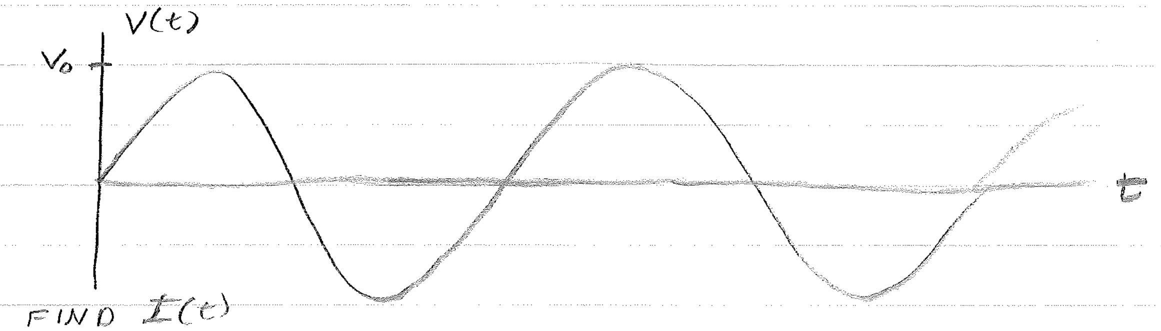
THE DIODE IS NON-LINEAR, THUS, ALL LINEAR LAWS NO LONGER APPLY (SUPERPOSITION, THEV & NORTON) LAWS WHICH STILL APPLY ARE KIRCHHOFFS LOOP AND NODE LAWS.

## DIODES IN CIRCUITS

OHM'S LAWS STILL OKAY,
KIRCHOFF'S LAWS STILL APPLY, THEV & NORT. DON'T CAN NO LONGER USE IMPEDANCE IDEAS

EXAMPLE: HALF WAVE RECTIFIER

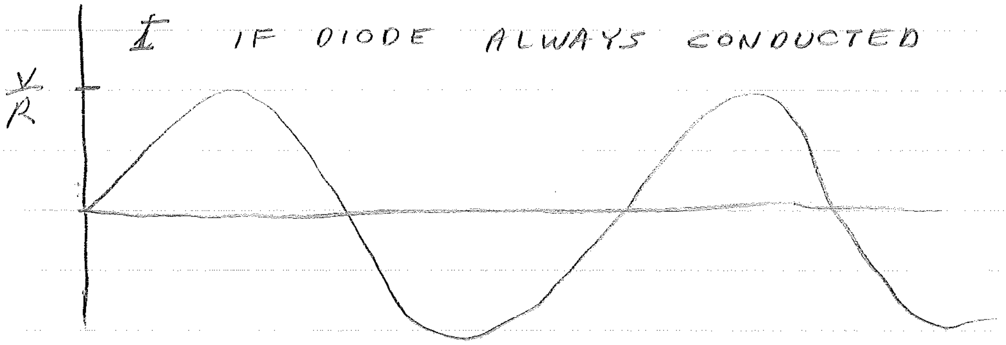


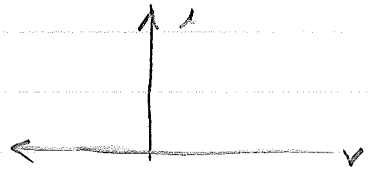


FIND $I(t)$

EITHER THE DIODE CONDUCTS OR IT DOESN'T.

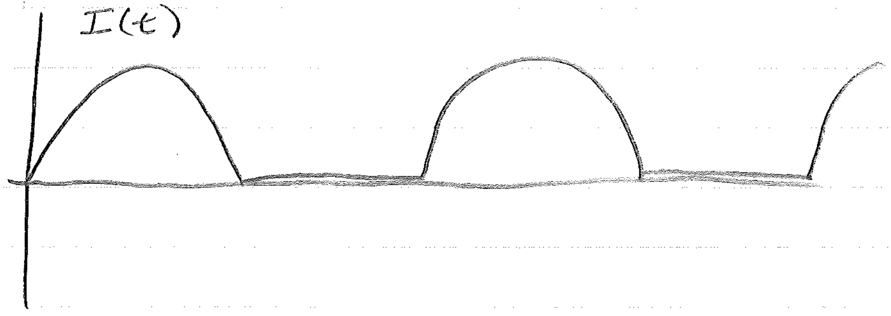
IF IT DID CONDUCT ALWAYS, THEN $I = V/R$.





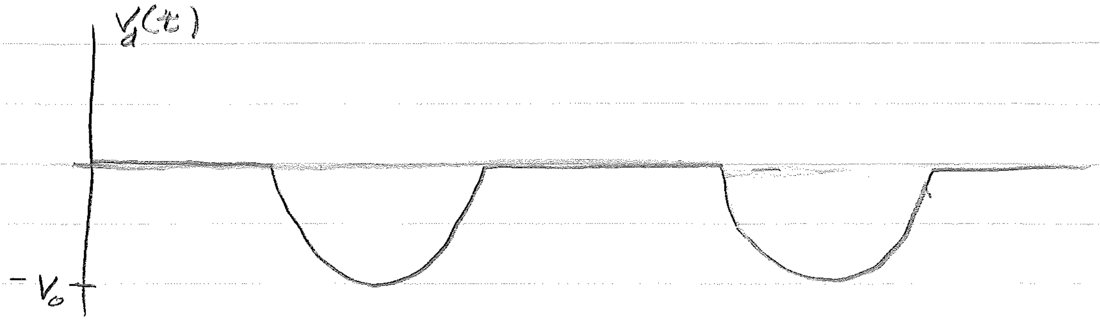
BUT, FROM $v$-$i$ CURVE, $i$ CANNOT BE NEGATIVE

SO, OUR ANSWER IS

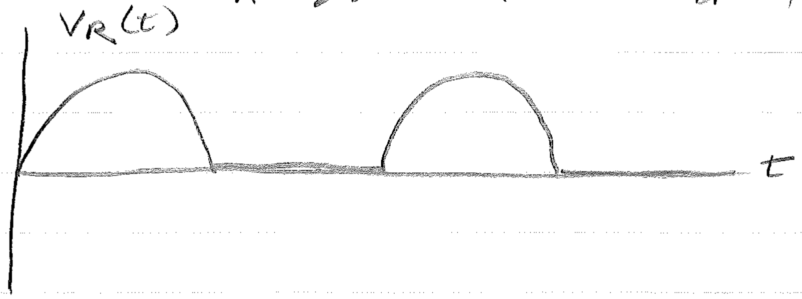


WHAT IS $V_D(t)$?

WHEN DIODE CONDUCTS, IT IS A SHORT CIRCUIT, AND $V_D(t)=0$. WHEN IT DOESN'T CONDUCT, THERE IS NO VOLTAGE ACCROSS R. THUS, USING K'S LOOP RULE, $V_D(t) = V(t)$ WHEN DIODE ISN'T CONDUCTING:



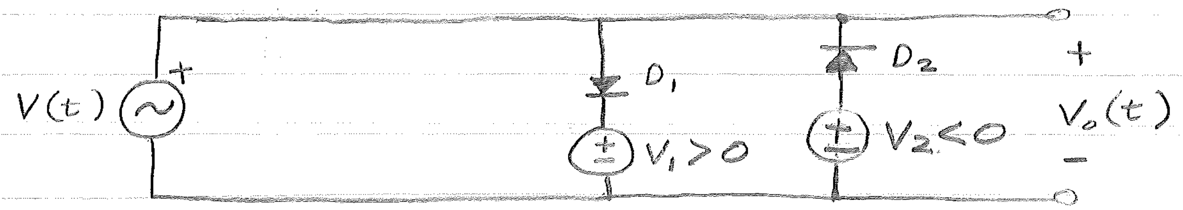
WHAT IS $V_R(t)$? $V_R = V - V_d$



NOTE THAT $V(t) = V_d(t) + V_R(t)$

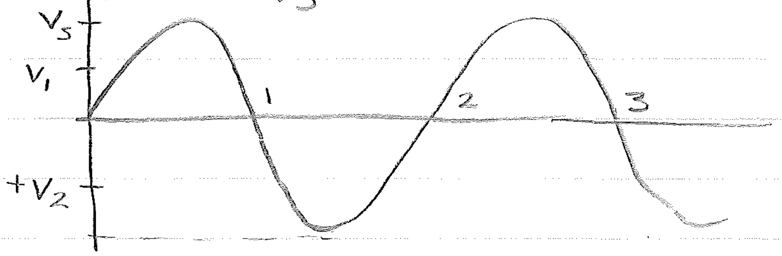
## EXAMPLE

THE DIODE LIMITER



FIND $V_0(t)$

$V(t) = V_S \sin 2\pi t$ $\quad (T = f = 1)$

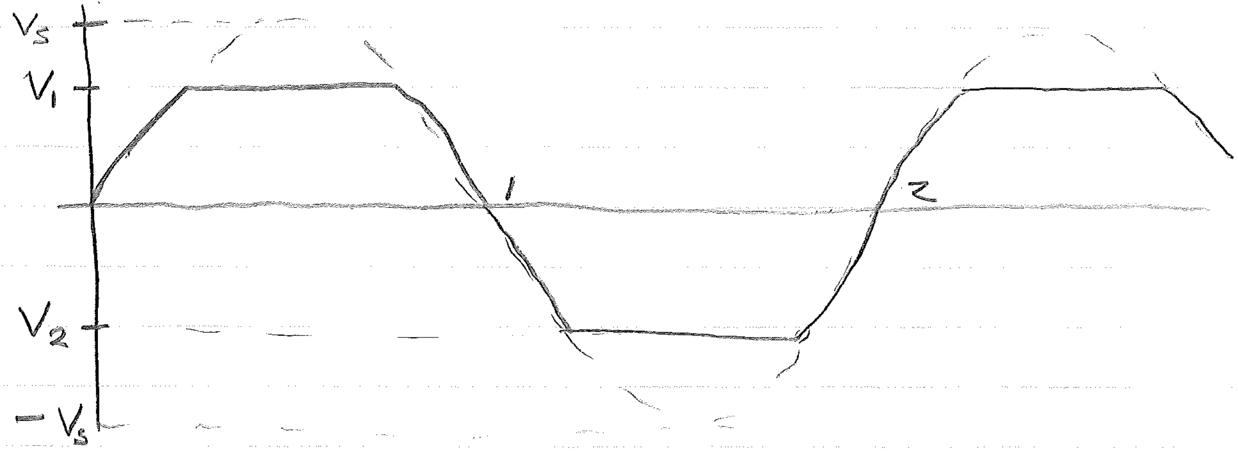


ASSUME $V_S > V_1$ ; $-V_S < V_2$

(a) WHEN $V(t) > V_1$, D1, IS FORWARD BIASED (A SHORT CIRCUIT) AND $V_o^{(t)} = V_1$

(b) WHEN $V(t) < V_1$, D2 IS FORWARD BIASED AND $V_o(t) = V_2$

(c) IN ALL OTHER CASES, $D_1$ AND $D_2$ ARE REVERSED BIASED (OPEN CIRCUITS) AND $V_o(t) = V(t)$



# GRADING

40% 1. QUIZES

$$Q = \frac{\text{TOTAL POINTS ON THE THREE QUIZES}}{300}$$

20% 2. LAB

$L =$ LAB GRADE $\quad 0 < L < 1$

10% 3. HOMEWORK

HW = TOTAL POINTS ON ALL REGULAR HOMEWORK

EC = EXTRA CREDIT POINTS

LHW = NUMBER OF LATE HOMEWORK PROBLEMS

THW = TOTAL HOMEWORK POINTS = 375

HWC = HOMEWORK COEFFICIENT

$$HWC = \frac{HW + \frac{5\,LHW}{THW}(THW - HW) + EC}{THW}$$

$$0 < HWC < 1+$$

30% 4. FINAL

$F =$ TOTAL POINTS/250.

FINAL GRADE WILL BE DETERMINED BY

$$G = (0.4)Q + (0.2)L + (0.1)HW + (0.3)F$$

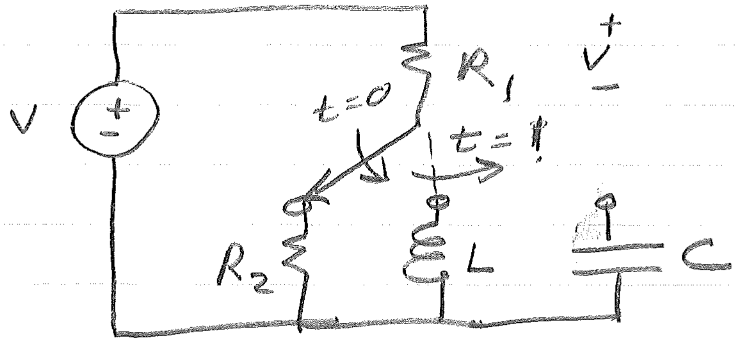
$$0 < G < 1+$$

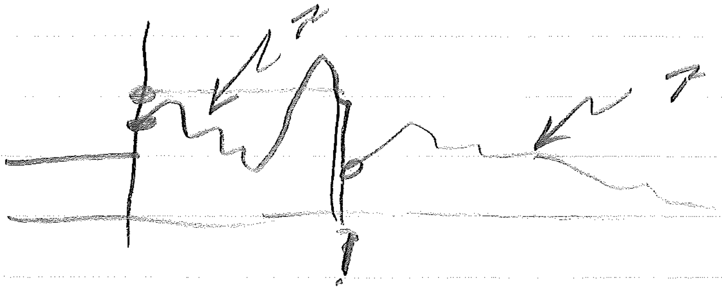
FINAL GRADES WILL BE ANALYTICALLY (NOT SUBJECTIVELY) CURVED, BUT WILL BE "CLOSE" TO

| | | |
|---|---|---|
| .9 | 1.0 | A |
| .8 | .9 | B |
| .7 | .8 | C |
| .6 | .7 | D |
| <.6 | | F |

FINAL (OPEN BOOK, PAPER SUPPLIED)
250 POINTS
(60PTS) 30 TRUE/FALSE QUESTIONS
(WITH A PENALTY FOR GUESSING)
7 PROBLEMS IN CIRCUIT ANALYSIS
(190 PTS)

SOME PROBLEMS WILL HAVE
EXTRANEOUS UNNECCESSARY INFO.
- DIODES
NO 3-PHASE
4 NUGGETS PROBLEM





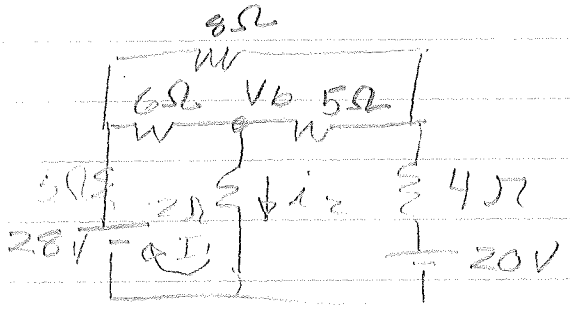
OMEWORK

| ROBLEMS | ASSIGNED | DUE |
|---|---|---|
| 26: 2, 3, 5abcd | 9/3/76 | 9/8/76 |
| 27: 12, 13, 15, 16 | 9/10/76 | 9/17/76 |

PROB 7 p 57 ADD 5Ω & 4Ω

FIND $i_2$, USING BR. CURRENTS

FIND $i_2$ USING BRANCH CURRENTS



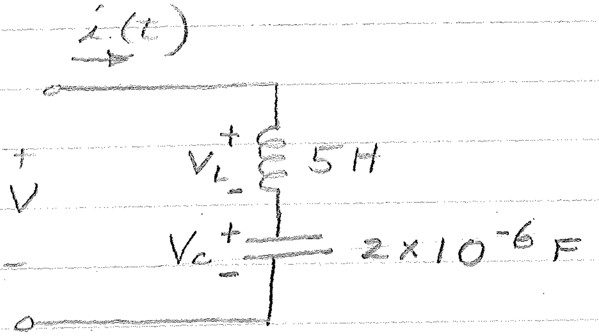
SOLVE CIRCUIT FOR I, BY LOOPS
& $V_b$ BY NODES

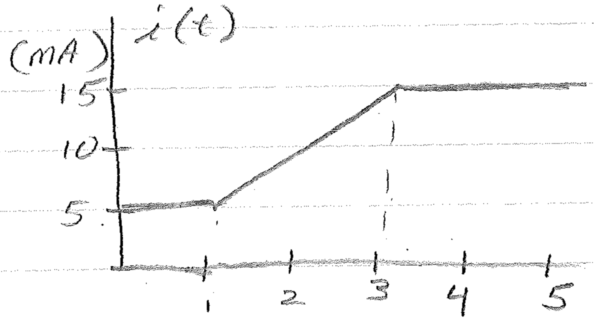
p. 57-58 # 12, 16, 17
58 18, ~~20~~, 24
p. 84 11ace, 17, 18(a)
84 19(ab) BY PHASORS
141 4b, [illegible] X
142 11, 16
143 24
144 #5 (SET UP DETER) Nov. 1-2
204 #25

202 202-3 #1, 4, 6 (11-9)
PT 203 - 11, 13
206 - 34

0.27.

2)



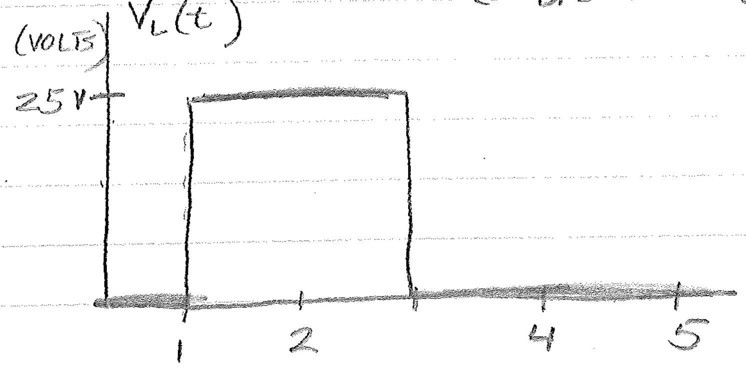


$$i(t) = \begin{cases} 0 & ;\ t<0 \\ 5\times10^{-3}\text{ A} & ;\ 0<t<10^{-3} \\ 5t & ;\ 10^{-3}<t<3\times10^{-3} \\ 15\times10^{-3} & ;\ t>3\times10^{-3} \end{cases}$$

(NOTE: IN THIS EXPRERESSION, WE ARE MEASURING $t$ IN SECONDS AND $i$ IN AMPS)

) FOR THE INDUCTOR

$$V_L = L\frac{di}{dt} = 5\frac{di}{dt} = \begin{cases} 5\times\frac{d}{dt}(0)=0 & ;\ t<0 \\ 5\times\frac{d}{dt}(5\times10^{-3})=0 & ;\ 0<t<10^{-3} \\ 5\times\frac{d}{dt}(5t)=25 & ;\ 10^{-3}<t<3\times10^{-3} \\ 5\times\frac{d}{dt}(15\times10^{-3})=0 & ;\ t>3\times10^{-3} \end{cases}$$



(b) FOR THE CAPACITOR

$$V_c = \frac{1}{C}\int_{-\infty}^{t} i\,dt = v(t_0) + \frac{1}{C}\int_{t_0}^{t} i\,dt$$

$$= V(t_0) + 5\times10^{5}\int_{t_0}^{t} i\,dt$$

$\Rightarrow 0 < t < 10^{-3}$

WE ARE GIVEN THAT THE CAPACITOR IS INITIALLY UNCHARGED $\Longrightarrow V_c(t=0)=0$

$$\Rightarrow V_c(t) = \cancel{V_c(0)}^{0} + 5\times10^{5}\int_{0}^{t}(5\times10^{-3})\,dt$$

$$= 2.5\times10^{3}\,t$$

NOTE: $V_c(t=10^{-3}) = 2.5$ VOLTS

$\Rightarrow 10^{-3} < t < 3\times10^{-3}$

$$V_c(t) = V_c(t=10^{-3}) + 5\times10^{5}\int_{10^{-3}}^{t}(5t)\,dt$$

$$= 2.5 + 25\times10^{5}\,\frac{1}{2}\,t^{2}\Big|_{10^{-3}}^{t}$$

$$= 2.5 + 12.5\times10^{5}\,(t^{2}-10^{-6})$$

$$= 2.5 - 1.25 + 12.5\times10^{5}\,t^{2}$$

$$= 1.25 + 1.25\times10^{6}\,t^{2}$$

NOTE: $V_c(t=3\times10^{-3}) = 12.5$ V

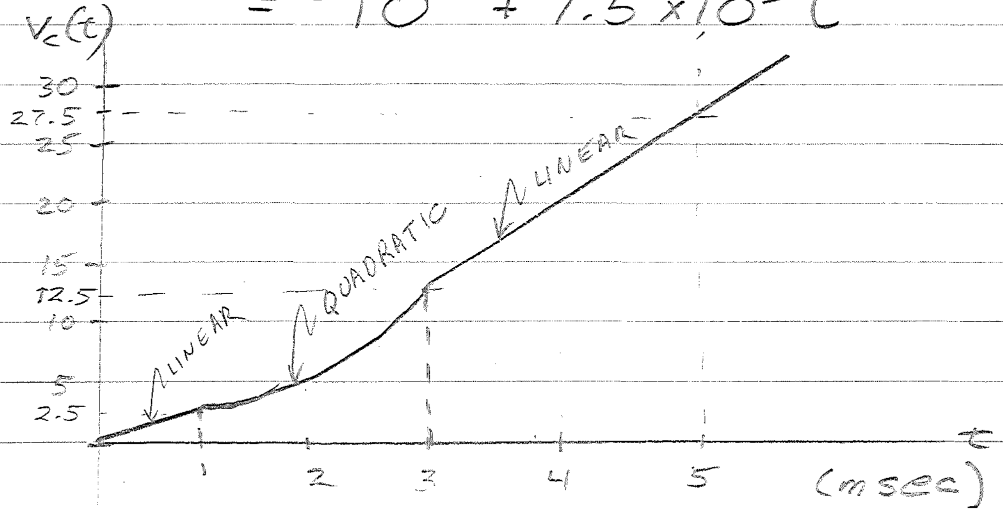
$\Rightarrow t > 3\times10^{-3}$

$$V_c(t) = V_c(t=3\times10^{-3}) + 5\times10^{5}\int_{3\times10^{-3}}^{t}(15\times10^{-3})\,dt$$

$$= 12.5 + 75\times10^{2}\,(t-3\times10^{-3})$$

$$= 12.5 - 22.5 + 7.5\times10^{3}\,t$$

$$= -10 + 7.5\times10^{3}\,t$$



(b) FOR THE CAPACITOR

$$V_c = \frac{1}{C}\int_{-\infty}^{t} i\,dt = v(t_0) + \frac{1}{C}\int_{t_0}^{t} i\,dt$$

$$= V(t_0) + 5\times10^{5}\int_{t_0}^{t} i\,dt$$

→ $0 < t < 10^{-3}$

WE ARE GIVEN THAT THE CAPACITOR IS INITIALLY UNCHARGED $\Longrightarrow V_c(t=0)=0$

$$\Rightarrow V_c(t) = \cancel{V_c(0)}^{0} + 5\times10^{5}\int_{0}^{t}(5\times10^{-3})dt$$

$$= 2.5\times10^{3}\,t$$

NOTE: $V_c(t=10^{-3}) = 2.5$ VOLTS

→ $10^{-3} < t < 3\times10^{-3}$

$$V_c(t) = V_c(t=10^{-3}) + 5\times10^{5}\int_{10^{-3}}^{t}(5t)\,dt$$

$$= 2.5 + 25\times10^{5}\,\frac{1}{2}\,t^2\Big|_{10^{-3}}^{t}$$

$$= 2.5 + 12.5\times10^{5}\,(t^2 - 10^{-6})$$

$$= 2.5 - 1.25 + 12.5\times10^{5}\,t^2$$

$$= 1.25 + 1.25\times10^{6}\,t^2$$

NOTE: $V_c(t=3\times10^{-3}) = 12.5$ V

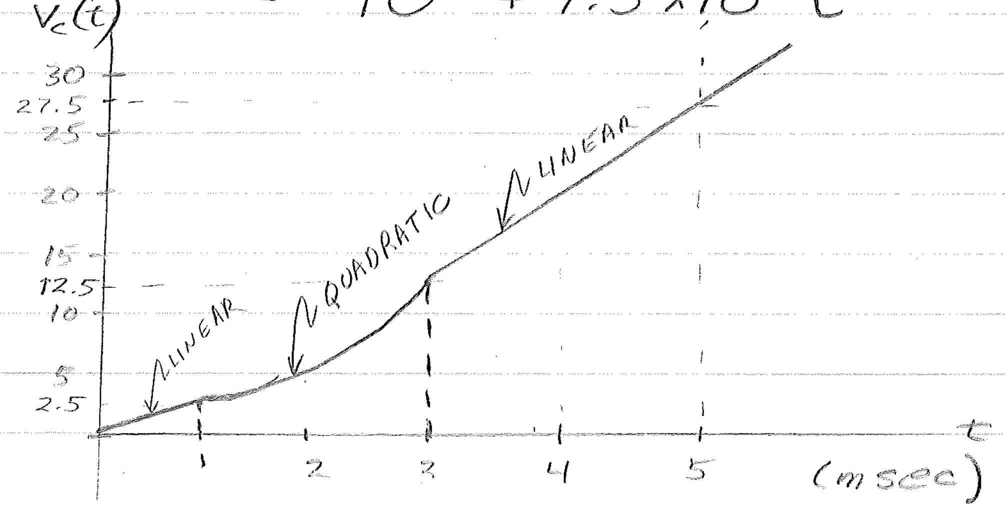
→ $t > 3\times10^{-3}$

$$V_c(t) = V_c(t=3\times10^{-3}) + 5\times10^{5}\int_{3\times10^{-3}}^{t}(15\times10^{-3})dt$$

$$= 12.5 + 75\times10^{2}\,(t - 3\times10^{-3})$$

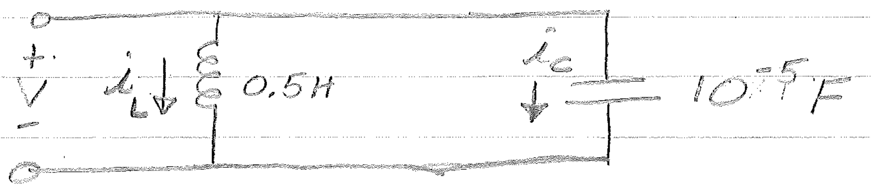
$$= 12.5 - 22.5 + 75\times10^{3}\,t$$

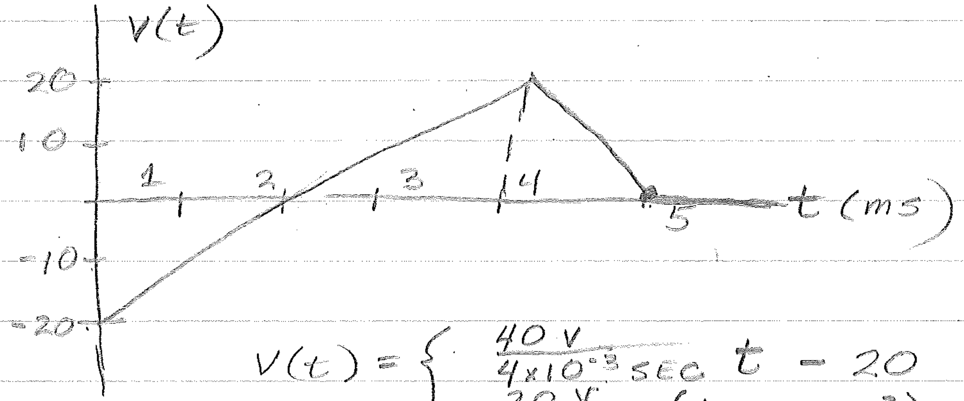
$$= -10 + 7.5\times10^{3}\,t$$



pg. 27

(13)





$$v(t) = \begin{cases} \frac{40\text{ v}}{4\times10^{-3}\text{ sec}}\, t - 20 & ; 0<t<4\text{ms} \\ -\frac{20\text{ V}}{10^{-3}\text{ sec}}\left(t-5\times10^{-3}\right) & ; 4<t<5\text{ms} \\ 0 & ; t>5\text{ms} \end{cases}$$

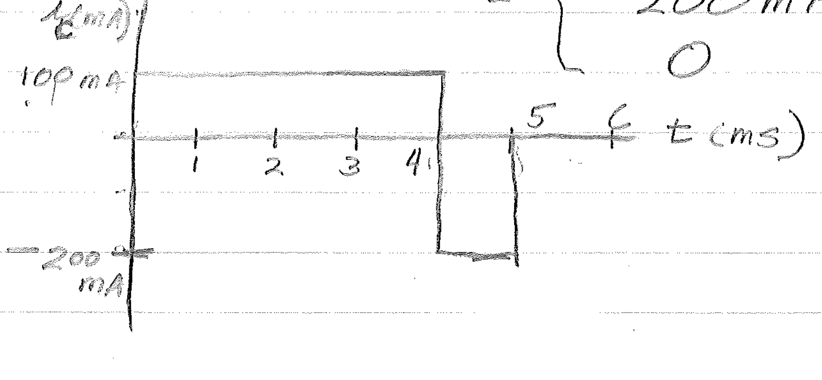
$$= \begin{cases} 10^4 t - 20 & ; 0<t<4\text{ ms} \\ -2\times10^4 t + 10^2 & ; 4<t<5\text{ ms} \\ 0 & ; t>5\text{ mS} \end{cases}$$

FOR CAPACITOR:

$$i_c = C\frac{dv}{dt} = 10^{-5}\frac{dv}{dt}$$

$$= \begin{cases} 10^{-5}(10^4) & ; 0<t<4\text{ms} \\ 10^{-5}(-2\times10^4) & ; 4<t<5\text{ms} \\ 0 & ; t>5\text{ ms} \end{cases}$$

$$= \begin{cases} 100\text{ mA} & 0<t<4\text{ ms} \\ -200\text{ mA} & 4<t<5\text{ ms} \\ 0 & t>5\text{ ms} \end{cases}$$



$$w(t) = \int_{-\infty}^{t} p(t)\,dt$$

$$= W(t_0) + \int_{t_0}^{t} p(t)\,dt$$

$0 < t < 4\ ms$

$$w(t) = \cancelto{0}{w(0)} + \int_0^t [10^3 t - 2]\,dt$$

$$= .5 \times 10^3 t^2 - 2t$$

$$w(4\times 10^{-3}) = 8\times 10^{-3} - 8 \times 10^{-3} = 0$$

$4\ ms < t < 5\ ms$

$$w(t) = \cancelto{0}{W(4\ ms)} + \int_{4\times 10^{-3}}^{t} (4\times 10^3 t - 20)\,dt$$

$$= \left[2\times 10^3 t^2 - 20t\right]_{4\times 10^{-3}}^{t}$$

$$= \left[(2\times 10^3 t^2 - 20t) - (32\times 10^{-3} - 80 \times 10^{-3})\right]$$

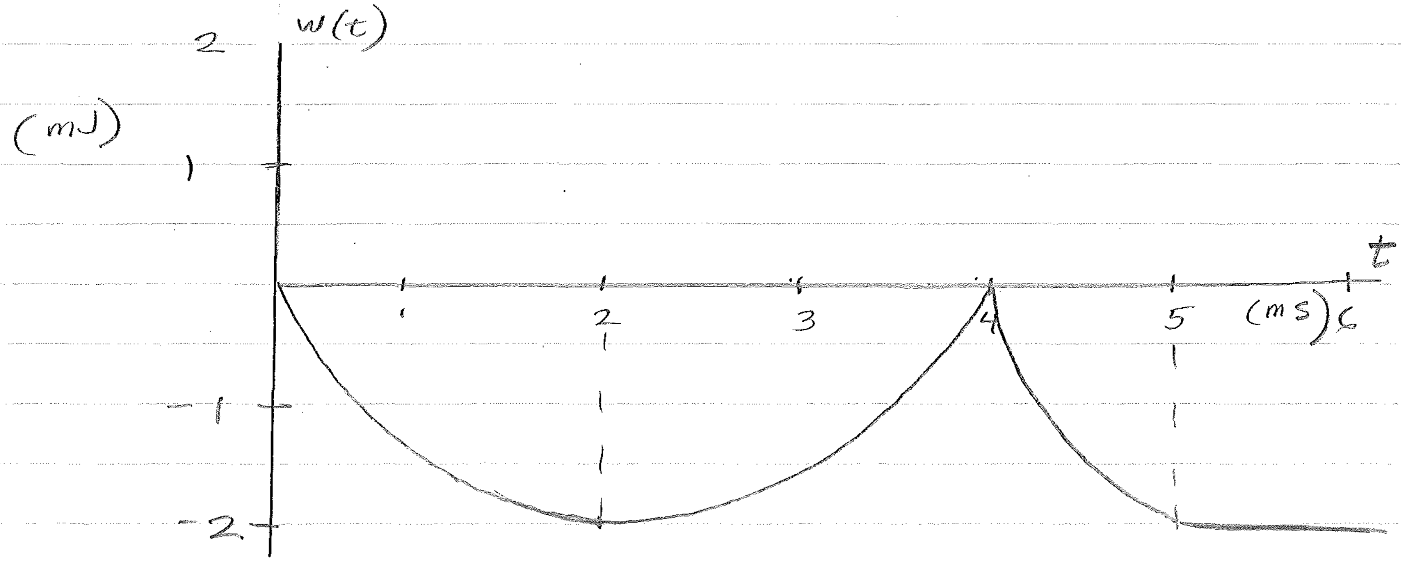
$$= 2\times 10^3 t^2 - 20t + 48\times 10^{-3}$$

$$w(t = 5\times 10^{-3}) = 50\times 10^{-3} - 100\times 10^{-3} + 48\times 10^{-3}$$

$$= -2\times 10^{-3} = -2\ mJ$$

MINIMUM @ $t = 2\times 10^{-3}$ sec

$$W(t = 2\times 10^{-3}\ sec) = -2\times 10^{-3} = -2\ mJ$$



FOR INDUCTOR

$$i_L = i(t_0) + \frac{1}{L}\int_{t_0}^{t} i(t)\,dt$$

$$= i(t_0) + 2\int_{t_0}^{t} i(t)\,dt$$

WE ARE GIVEN THAT $i_L(0) = 0$

FOR $0 < t < 4ms$

$$i_L(t) = \cancel{i(0)}^{0} + 2\int_0^t [10^4 t - 20]\,dt$$

$$= 10^4 t^2 - 40t \Big|_0^t$$

$$= 10^4 t^2 - 40t$$

MINIMIMUM @ $t = 2\times10^{-3}$

$i_L(2\times10^{-3}) = {}^-0.04$ AMPS $= {}^-40$ mA

ALSO $i_L(4ms) = 0$

FOR $4ms < t < 5ms$

$$i_L(t) = \cancel{i_L(4ms)}^{0} + 2\int_{4\times10^{-3}}^{t} [-2\times10^4 t + 10^2]\,d$$

$$= \int_{4\times10^{-3}}^{t} [-4\times10^4 t + 2\times10^2]\,dt$$

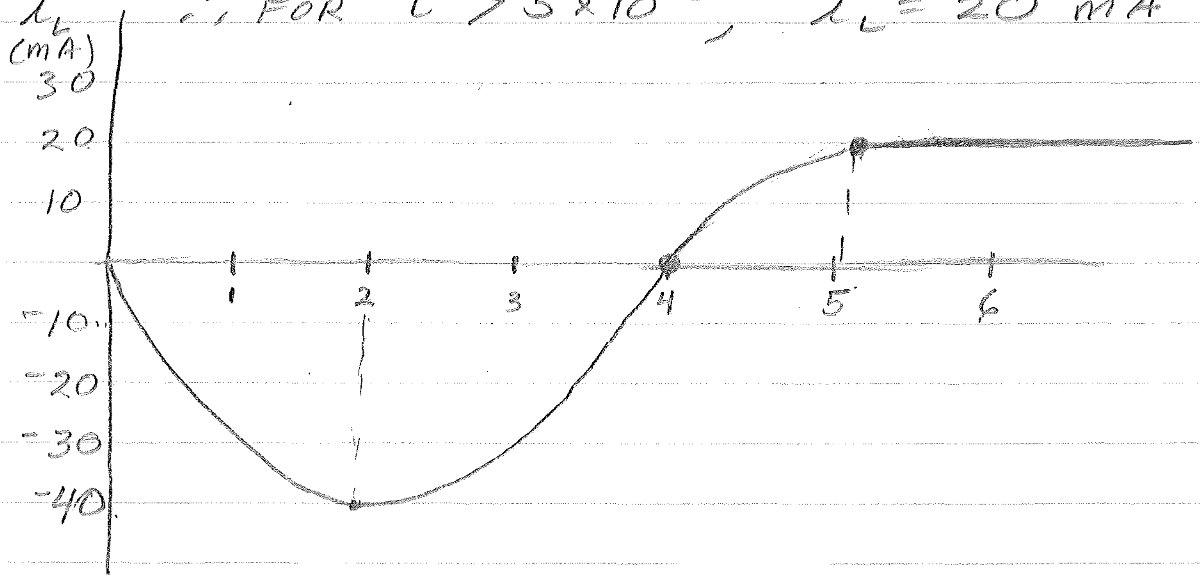
$$= -2\times10^4 t^2 + 2\times10^2 t \Big|_{4\times10^{-3}}^{t}$$

$$= (-2\times10^4 t^2 + 2\times10^2 t) - ({}^-0.32 + 0.8)$$

$$= -2\times10^4 t^2 + 2\times10^2 t - 0.48$$

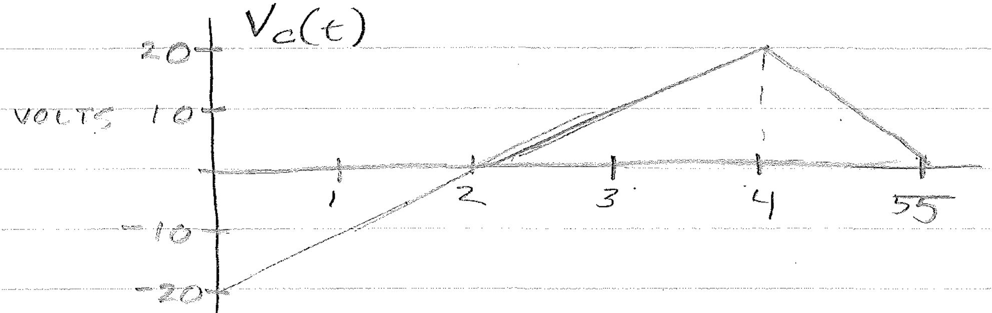
NOTE $i_L(t = 5\times10^{-3}) = {}^-0.5 + 1 - 0.48 = 0.02$ m

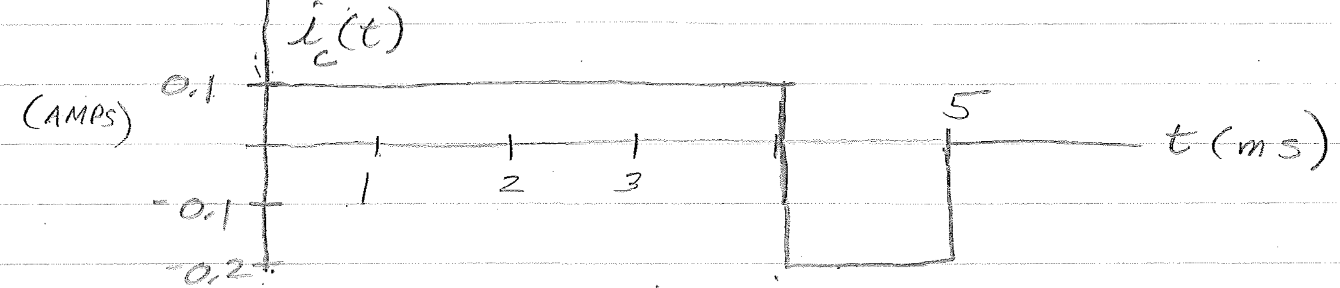
$\therefore$ FOR $t > 5\times10^{-3}$, $i_L = 20$ mA

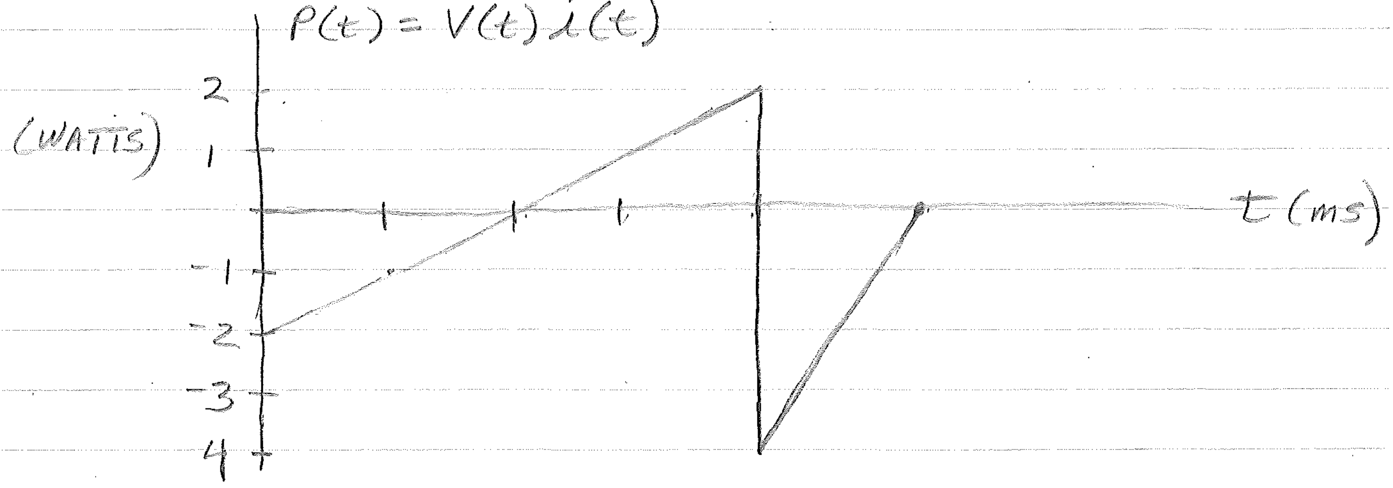


p. 27

(16) $p = v\,i$





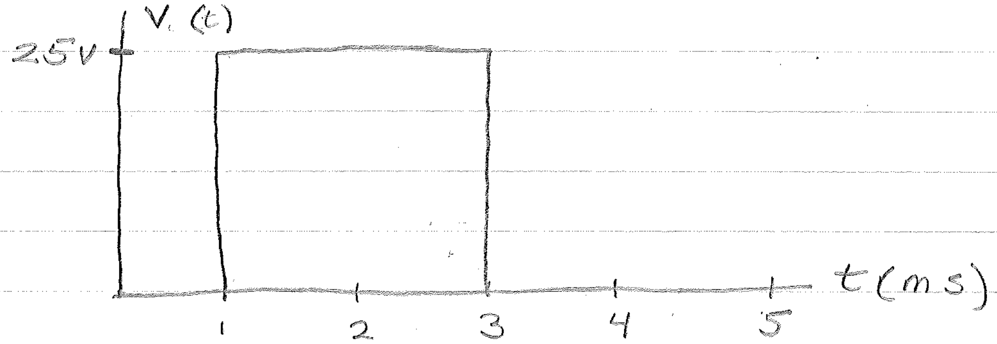


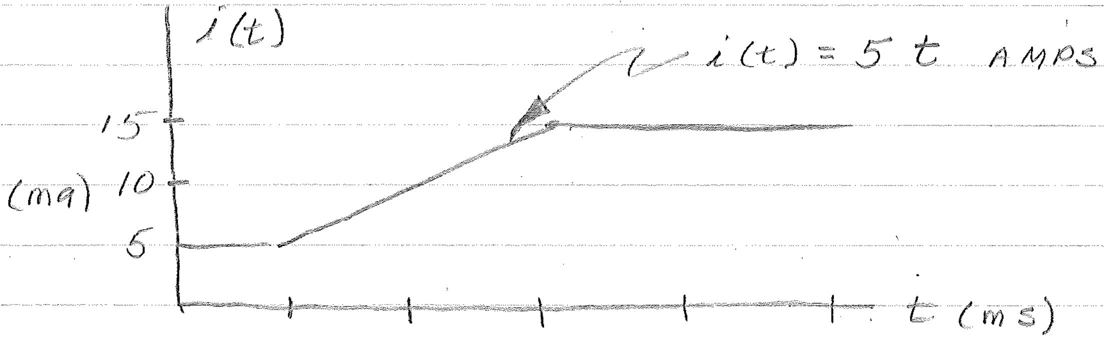
$$P(t) = \begin{cases} 10^3 t - 2 & ; \; 0 < t < 4\,ms \\ 4 \times 10^3 t - 20 & ; \; 4\,ms < t < 5\,ms \\ 0 & ; \; OTHERWISE \end{cases}$$

pg. 27

(15) $p = Vi$

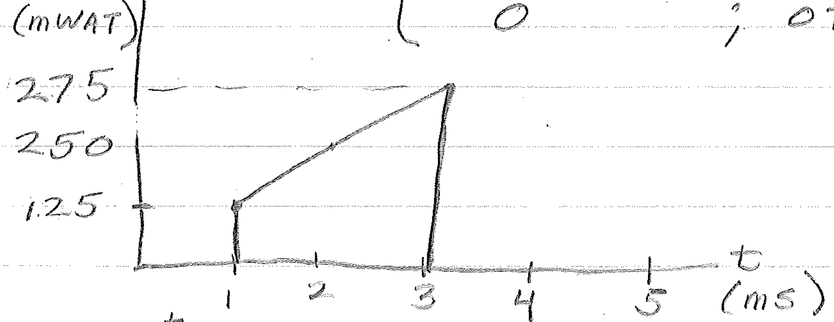
WE HAVE SHOWN IN PROBLEM 12:



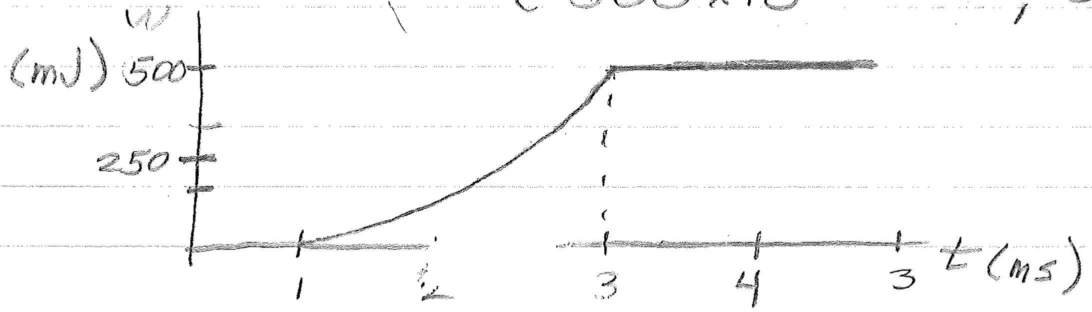


MULTIPLYING THESE TWO CURVES GIVES:

$$P(t) = \begin{cases} 125\, t & ;\ 1\ ms < t < 2\, msec \\ 0 & ;\ OTHERWISE \end{cases}$$

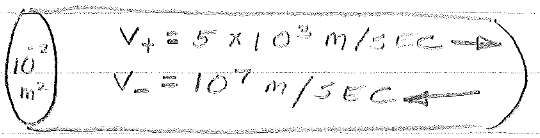


$$W = \int_{-\infty}^{t} P(t)\,dt = \begin{cases} 62.5\, t^2 - 62.5 \times 10^{-6} & ;\ 1 < t < 3\, ms \\ 500 \times 10^{-6} & ;\ t > 3 \end{cases}$$



P 26.

2.



$\rho_p = 10^{+13} \frac{\text{IONS}}{m^3}$

$\rho_e = 10^{11}\ e^-/m^3$

$I_p = (10^{+13} \frac{CH}{m^3})(10^{-2} m^2)(5\times10^3 \frac{m}{SEC})(\frac{1.602\times10^{-19} C}{CH})$

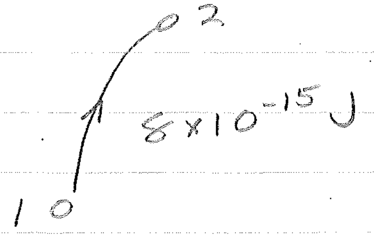
$= 8.01\times10^{-5}$ AMP $= 0.0801\times10^{-3}$ AMP

$I_e = (10^{11} \frac{CH}{m^3})(10^{-2} m^2)(10^7 \frac{m}{SEC})(\frac{1.602\times10^{-19}}{CH} C)$

$= 1.602\times10^{-3}$ AMP

$I = I_p + I_e =$ (IN DIRECTION OF +)

3.



5. $V = 12$ V  $P = 30$ W

$I = P/V = 30/12 = 15/6 = 5/2$ AMP

a. $q = It = \frac{5}{2} \times 60$ SEC $= 5\times30 = 150$ COUL

b. $1e = 1.602\times10^{-19}$ C

OR $6.24\times10^{18}$ elec $= 1$ COUL

$\Rightarrow 150$ COUL $= 9.36\times10^{20}$ elec

c. $30$ W $\times 24$ HR $= 720$ WAT HR

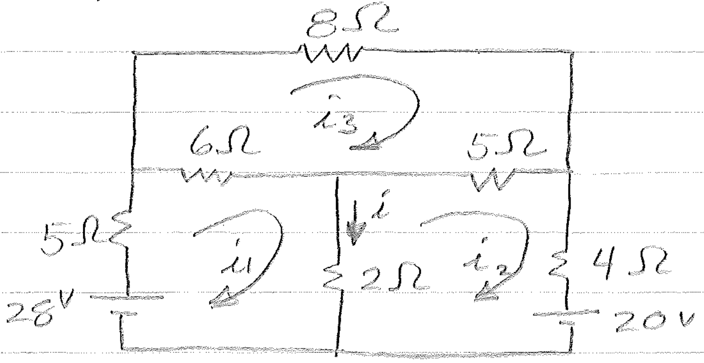
$= .72$ KWH

$.72$ KWH $\times$ 6¢/KWHR $= 4.32$¢

d. $P = I^2R = V^2/R$

$\Rightarrow R = (12)^2/30 = 4.80\ \Omega$

(2-7) (a) LOOP METHODS



MESH EQUATIONS ARE

$$13 i_1 - 2 i_2 - 6 i_3 = 28$$
$$-2 i_2 + 11 i_2 - 5 i_3 = -20$$
$$-6 i_1 - 5 i_2 + 19 i_3 = 0$$

SOLUTIONS ARE*

$i_1 = 2.106$ AMPS
$i_2 = -1.286$ AMPS
$i_3 = 0.3266$ AMPS

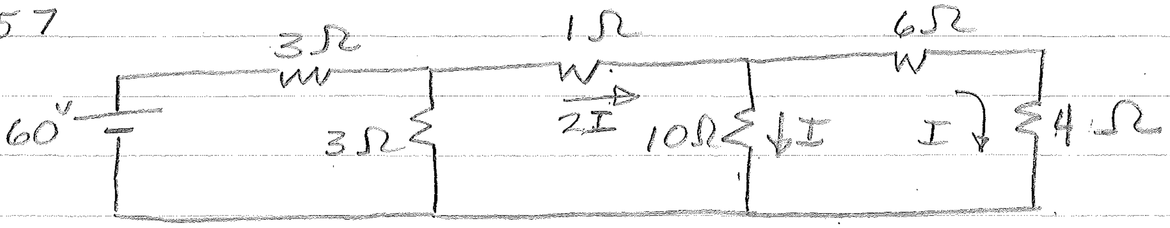
OBVIOUSLY

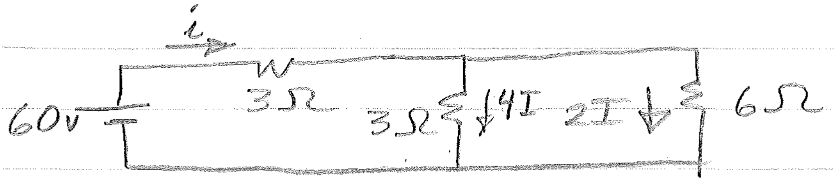
$$i = i_1 - i_2$$
$$= 2.106 + 1.286 = 3.392 \text{ AMPS}$$

*THANKS TO KINGSLEY WONG

Pg. 57

(12)

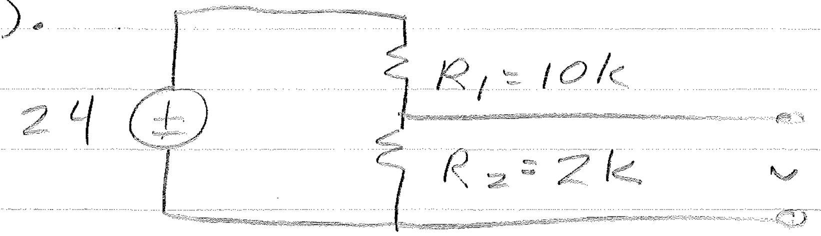




$\frac{1}{R} = \frac{1}{3} + \frac{1}{6} = \frac{3}{6} \Rightarrow R_{eq} = 2$

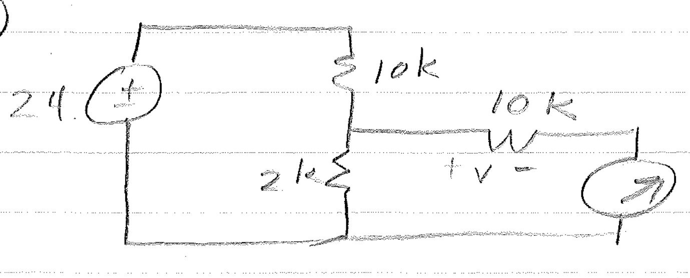
$i = \frac{60}{5} = 12$ AMPS $= 6I \Rightarrow I = 2$ AMPS

(16).



(a) $V = \frac{2}{2+10} 24 = \frac{2}{12} 24 = 4^V$

(b)



$\frac{1}{2} + \frac{1}{10} = \frac{10+2}{20} = \frac{12}{20} \Rightarrow R_{eq} = \frac{20}{12} = 5/3$ kΩ

$V = \frac{5/3}{5/3 + 10} 24 = \frac{5}{35} 24 = \frac{24}{7} V$

$$\begin{array}{r} 3.43 \\ 7\overline{)24} \\ 21 \\ 3.0 \\ 28 \\ 20 \end{array}$$

..........SEMESTER SESSION 19..........19..........

SUBJECT ..........

SECTION..........CLASS PERIOD..........ROOM..........

ASSISTANT..........

<90 F (6)
<140 D (8)
<190 C (11)
<240 B (5)
<285 A (3)

2 A+
10 A
5 B
D
2 F

0.9-1.0 3
.8-.9 4
.7-.8 4
.6-.7 6
.5-.6 4
.4-.5 3
.3-.2 4
.1-.2 3

285
90
375

HOMEWORK

|  | DATE | 30 | 40 | 50 | 20 | 20 | 40 | 35 | 50 | 285 | M10 |  | HW | LHW | EC | HWC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | [redacted] | 19 | 23 | 40 |  | 7 | 14 |  | 12 | 115 | C | 63 | 178 |  | 10 | 0.501 |
| 2 | [redacted] | 30 | 20 | 40 | 15 | 16 | 34 | 28 | 30 | 213 | A | 83 | 296 |  |  | 0.789 |
| 3 | [redacted] | 30 | 8 | 34 | 13 |  | 10 | 9 | 17 | 121 | A- | 60 | 181 |  |  | 0.483 |
| 4 | [redacted] | 23 | - | 50 | 12 | 5 | 20 |  | 5 | 115 | D- | 69 | 2[illegible]4 | 8 | 5 | 0.558 |
| 5 | [redacted] | 30 | 19 | 49 | 17 | 20 | 20 | 12 | 39 | 206 | B+ | 85 | 291 |  | 15 | 0.816 |
| 6 | [redacted] | 30 | 15 | 47 | 20 | 9 | 20 | 9 |  | 150 |  | ~~85~~ 53 | 203 | 11 | 10 | 0.635 |
| 7 | [redacted] | 30 | 25 | 50 | 20 |  | 32 |  |  | 157 | B+ | 87 | 244 | 10 |  | 0.697 |
| 8 | [redacted] | 21 | 24 | 12 |  |  |  |  |  | 57 | C+ |  | 57 |  |  | 0.152 |
| 9 | [redacted] | 24 | 24 | 50 | 20 | 20 | 38 | 35 | 47 | 234 | A | 81 | ~~315~~ 339 |  |  | 0.904 |
| 10 | [redacted] | 28 | 19 | 49 | 19 | 20 | 20 | 28 | 39 | 222 | A | 67 | 289 |  | 15 | 0.811 |
| 11 | [redacted] | 29 | 30 | 47 | 12 |  |  | 13 | 45 | 176 | A | 87 | 263 |  | 10 | 0.728 |
| 12 | [redacted] | 29 | 29 | 37 | 10 | 19 | 38 |  |  | 162 | A | 65 | 227 | 5 | 5 | 0.645 |
| 13 | [redacted] | 30 | 29 | 45 | 20 | 20 | 10 | 23 | 47 | 269 | A+ | 80 | 349 |  | 15 | 0.971 |
| 14 | [redacted] | - | - |  |  |  |  |  |  | 0 |  |  |  |  |  |  |
| 15 | [redacted] | - | - |  |  |  |  |  |  | 0 |  |  |  |  |  |  |
| 16 | [redacted] | 27 | 32 | 50 | 17 | 29 | 20 | 28 | 35 | 218 | B | 72 | 290 |  | 10 | 0.808 |
| 17 | [redacted] | 26 | 16 | 39 | 9 | 20 | 20 | 9 | 9 | 148 | C- | 76 | 224 |  | 15 | 0.637 |
| 18 | [redacted] | 24 | 28 | 49 | 20 | 20 | 38 | 35 | 44 | 258 | A- | 83 | 341 |  |  | 0.909 |
| 19 | [redacted] | 30 | 25 | 30 | 18 | 14 | 26 | 14 | 29 | 186 | A | 72 | 258 |  | 10 | 0.715 |
| 20 | [redacted] | 29 | 21 |  |  |  |  |  |  | 50 | D | 60 | 110 | 8 | 10 | 0.395 |
| 21 | [redacted] | 29 | 33 | 49 | 17 | 14 | 20 | 9 | 4 | 175 | C | 87 | 262 |  |  | 0.699 |
| 22 | [redacted] | 30 | 17 | 47 | 11 | 15 | 20 | 12 | 30 | 182 | B | 76 | 258 |  |  | 0.688 |
| 23 | [redacted] | - | 2 | 42 |  |  |  |  |  | 44 | D |  | 44 |  |  | 0.117 |
| 24 | [redacted] | 23 | 8 | 22 |  |  | 10 |  |  | 63 |  | 51 | 114 |  |  | 0.304 |
| 25 | [redacted] | - | — | 40 |  |  | 20 | 23 | 42 | 125 | C |  | 125 |  |  | 0.333 |
| 26 | [redacted] | 26 | - | 35 | 16 | 20 | 10 | 9 |  | 116 | B- | ~~15~~ 87 | 203 |  |  | 0.541 |
| 27 | [redacted] | 28 | 32 | 50 | 20 | 20 | 38 | 35 | 50 | 273 | A+ | 90 | 363 |  | 5 | 0.981 |
| 28 | [redacted] | 27 | 17 | 40 | 15 |  | 20 | 25 | 32 | 176 | A | 78 | 254 |  | 15 | 0.717 |
| 29 | [redacted] | 26 | 15 | 20 |  |  | 8 | 1 | 14 | 84 | C | 80 | 164 |  |  | 0.437 |
| 30 | [redacted] | 17 | 15 | 32 | 13 |  | 20 |  | 35 | 132 | B- | 69 | 201 |  |  | 0.536 |
| 31 | [redacted] | 18 | 22 | 50 | 10 |  |  |  |  | 100 | C |  | 100 | 11 |  | 0.374 |
| 32 | [redacted] | 26 | 15 | 32 |  | 15 | 16 | 13 | 12 | 145 | A | 13 | 158 |  |  | 0.421 |
| 33 | [redacted] | - | - | - |  |  |  |  |  | 0 |  |  | 0 |  |  |  |
| 34 | [redacted] | 30 14 | 10 | 39 | 12 | 13 |  |  |  | 118 |  |  | 118 |  |  | 0.315 |
| 35 | [redacted] | 27 | - | 42 |  |  |  |  |  | 69 | C |  | 69 |  |  | 0.184 |
| 36 | [redacted] | 13 | 21 | 45 |  |  | 10 | 11 | 45 | 145 | F | 67 | 67 |  | 10 | 0.205 |

OINTS MAXIMUM
EARNED
K PROBLEMS
POINTS

$\frac{THW-HW}{2}) + E.C.$

L 4
+
CL 2
+
CL 1
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TO 00

..........................SEMESTER

SUBJECT ..........................

SECTION..........................CLASS

ASSISTANT..........................

TEXT BOOKS

100-110 1 | 40-50 2 | 10   100-110
90-100 1
80-90 3 | 30-40 0 | 4   90 100
70-80 1 | 20-30 2 | 6   80 90
60-70 7   3   70 80
50-66 13   1   60 70
4   50 60
40 50

TESTS

| | DATE | 115 PTS | 110 | 110 | Q |
|---|---|---|---|---|---|
| 1 | [redacted] | ~~81~~79 | 77 | 54 | 210 |
| 2 | [redacted] | 99 | 101 | 97 | 297 |
| 3 | [redacted] | 92 | 92 | 65 | 249 |
| 4 | [redacted] | 70 | ~~64~~ 20 | 65 | 155 |
| 5 | [redacted] | 110 | 89 | 65 | 264 |
| 6 | [redacted] | 76 | ~~109~~85 | 29 | 190 |
| 7 | [redacted] | 81 | 109 | 63 | 253 |
| 8 | [redacted] | 76 | 106 | 50 | 232 |
| 9 | [redacted] | 98 | 101 | 67 | 266 ✓ |
| 10 | [redacted] | 110 | 103 | 53 | 266 ✓ |
| 11 | [redacted] | 110 | 107 | 83 | 300 ✓ |
| 12 | [redacted] | 92 | 92 74 | ~~58~~ | ~~252~~ 258 |
| 13 | [redacted] | 98 | 104 | 51 | 253 ✓ |
| 14 | [redacted] | 30 | WP | | WP |
| 15 | [redacted] | | | | |
| 16 | [redacted] | 78 | 83 | 50 | 211 ✓ |
| 17 | [redacted] | 91 | 50 | 60 | 201 ✓ |
| 18 | [redacted] | 96 | 82 | 58 | 236 ✓ |
| 19 | [redacted] | 101 | 97 | 83 | 281 ✓ |
| 20 | [redacted] | 87 | ~~58~~64 | 51 | 203 ✓ |
| 21 | [redacted] | 68 | 85 | 58 | 211 ✓ |
| 22 | [redacted] | 70 | 95 | 68 | 233 ✓ |
| 23 | [redacted] | 79 | ~~64~~71 76 | 51 | 201 ✓ |
| 24 | [redacted] | 80 | 70 | 23 | 177 ✓ |
| 25 | [redacted] | 82 | 74 | 50 | 206 ✓ |
| 26 | [redacted] | 83 | ~~75~~85 | 56 | 224 ✓ |
| 27 | [redacted] | 101 | 108 | 101 | 310 ✓ |
| 28 | [redacted] | 105 | 101 | 80 | 286 ✓ |
| 29 | [redacted] | 89 | 73 | 52 | 214 ✓ |
| 30 | [redacted] | 80 | 86 | 50 | 216 ✓ |
| 31 | [redacted] | 75 | 86 53 | 47 | ~~208~~ ✓213 |
| 32 | [redacted] | 100 | 100 | 74 | 274 |
| 33 | [redacted] | | | | |
| 34 | [redacted] | 77 | | | |
| 35 | [redacted] | ~~88~~91 | 60 | 69 | ~~215~~220 |
| 36 | [redacted] | 51 | 50 | 47 | 148 |

## GRADE COMPUTATION

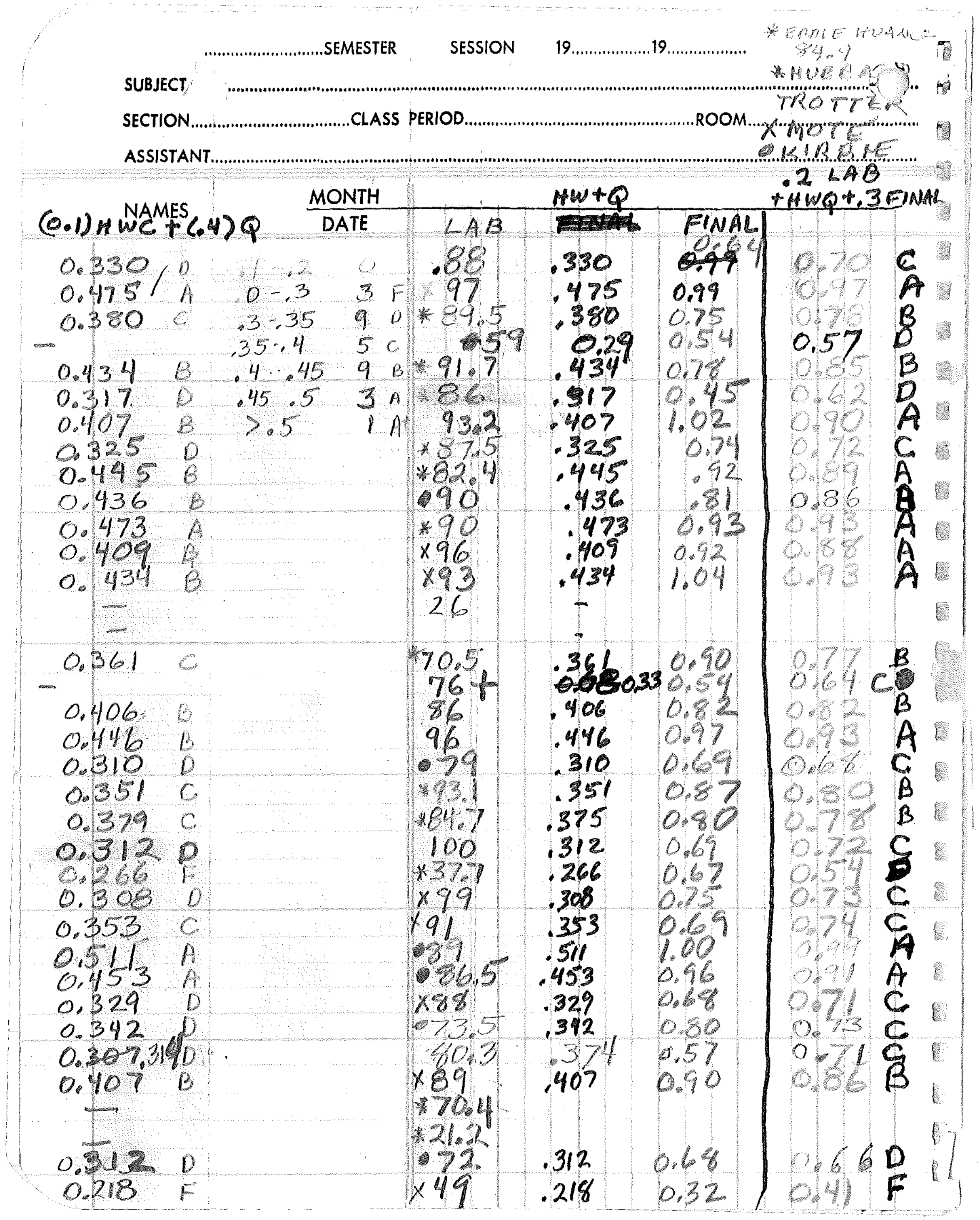
1. HOMEWORK

THW = TOTAL HOMEWORK POINTS MAXIMUM
HW = HOMEWORK POINTS EARNED
LHW = # LATE HOMEWORK PROBLEMS
EC = # EXTRA CREDIT POINTS

$$HW\% = \frac{HW + \frac{10 LHW}{THW}\left(\frac{THW-HW}{2}\right) + E.C.}{THW}$$

THW = 375 STO → 1

```
STO 2   (HW)        RCL 4
STOP                  +
STO 3   (LHW)       RCL 2
STO P                 +
STO 4   (EC)        RCL 1
RCL 1                 ÷
RCL 2               GTO 00
  -
  2
  ÷
 RCL 3
  ×
  1
  0
  ×
 RCL 1
  ÷
```



..........SEMESTER SESSION 19..........19..........

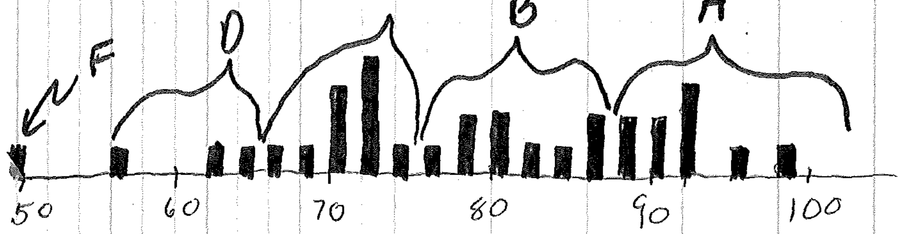
SUBJECT..........

SECTION..........CLASS PERIOD..........ROOM..........

ASSISTANT..........

*EDDIE HUANG 84.4
*HUBBA
TROTTER
X MOTE
• KIRBIE

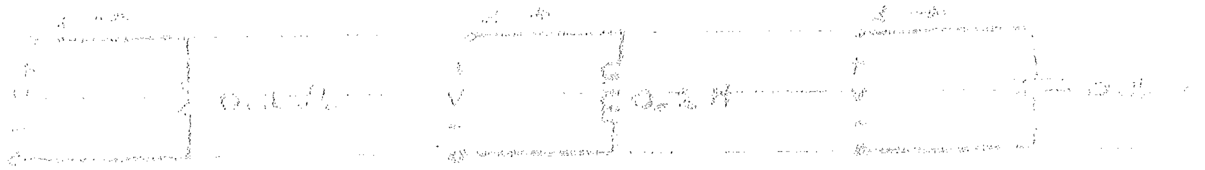
| NAMES<br>(0.1)HWC+(.4)Q | | MONTH<br>DATE | | | LAB | HW+Q<br>~~FINAL~~ | FINAL | .2 LAB<br>+HWQ+.3FINAL | |
|---|---|---|---|---|---|---|---|---|---|
| 0.330 / | D | .1 - .2 | 0 | | .88 | .330 | ~~0.99~~ 0.64 | 0.70 | C |
| 0.475 / | A | 0 - .3 | 3 | F | *97 | .475 | 0.99 | 0.97 | A |
| 0.380 | C | .3 - .35 | 9 | D | *89.5 | .380 | 0.75 | 0.78 | B |
| — | | .35 - .4 | 5 | C | •59 | 0.29 | 0.54 | 0.57 | D |
| 0.434 | B | .4 - .45 | 9 | B | *91.7 | .434 | 0.78 | 0.85 | B |
| 0.317 | D | .45 .5 | 3 | A | *86 | .317 | 0.45 | 0.62 | D |
| 0.407 | B | >.5 | 1 | A | 93.2 | .407 | 1.02 | 0.90 | A |
| 0.325 | D | | | | *87.5 | .325 | 0.74 | 0.72 | C |
| 0.445 | B | | | | *82.4 | .445 | .92 | 0.89 | A |
| 0.436 | B | | | | •90 | .436 | .81 | 0.86 | B |
| 0.473 | A | | | | *90 | .473 | 0.93 | 0.93 | A |
| 0.409 | B | | | | x96 | .409 | 0.92 | 0.88 | A |
| 0.434 | B | | | | x93 | .434 | 1.04 | 0.93 | A |
| — | | | | | 26 | — | | | |
| — | | | | | | - | | | |
| 0.361 | C | | | | *70.5 | .361 | 0.90 | 0.77 | B |
| — | | | | | 76 + | ~~0.08~~ 0.33 | 0.54 | 0.64 | C |
| 0.406 | B | | | | 86 | .406 | 0.82 | 0.82 | B |
| 0.446 | B | | | | 96 | .446 | 0.97 | 0.93 | A |
| 0.310 | D | | | | •79 | .310 | 0.69 | 0.68 | C |
| 0.351 | C | | | | *93.1 | .351 | 0.87 | 0.80 | B |
| 0.379 | C | | | | *84.7 | .375 | 0.80 | 0.78 | B |
| 0.312 | D | | | | 100 | .312 | 0.69 | 0.72 | C |
| 0.266 | F | | | | *37.7 | .266 | 0.67 | 0.54 | D |
| 0.308 | D | | | | x99 | .308 | 0.75 | 0.73 | C |
| 0.353 | C | | | | x91 | .353 | 0.69 | 0.74 | C |
| 0.511 | A | | | | •89 | .511 | 1.00 | 0.99 | A |
| 0.453 | A | | | | •86.5 | .453 | 0.96 | 0.91 | A |
| 0.329 | D | | | | x88 | .329 | 0.68 | 0.71 | C |
| 0.342 | D | | | | •73.5 | .342 | 0.80 | 0.73 | C |
| 0.~~307~~.314 | D | | | | 40.3 | .374 | 0.57 | 0.71 | C |
| 0.407 | B | | | | x89 | .407 | 0.90 | 0.86 | B |
| — | | | | | *70.4 | | | | |
| — | | | | | *21.2 | | | | |
| 0.312 | D | | | | •72 | .312 | 0.68 | 0.66 | D |
| 0.218 | F | | | | x49 | .218 | 0.32 | 0.41 | F |



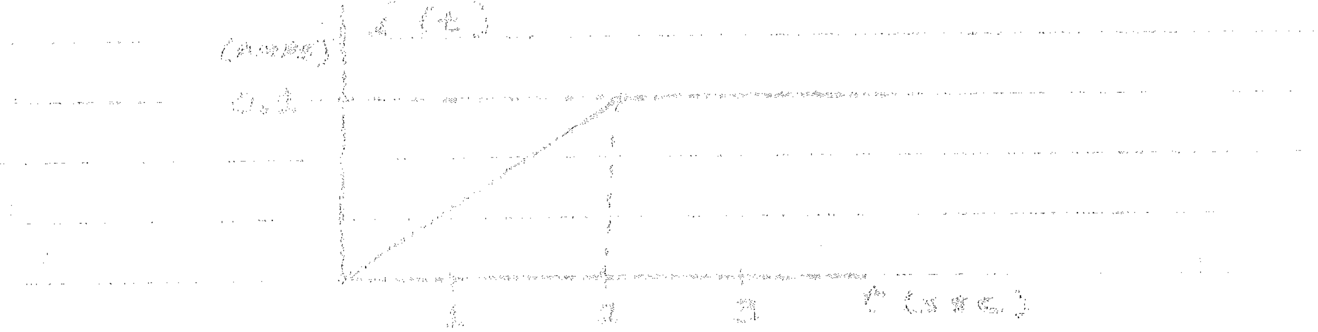
9 A's
9 B's

10 C's
3 D's
1 F

EE 232 - [illegible] 9-21-76

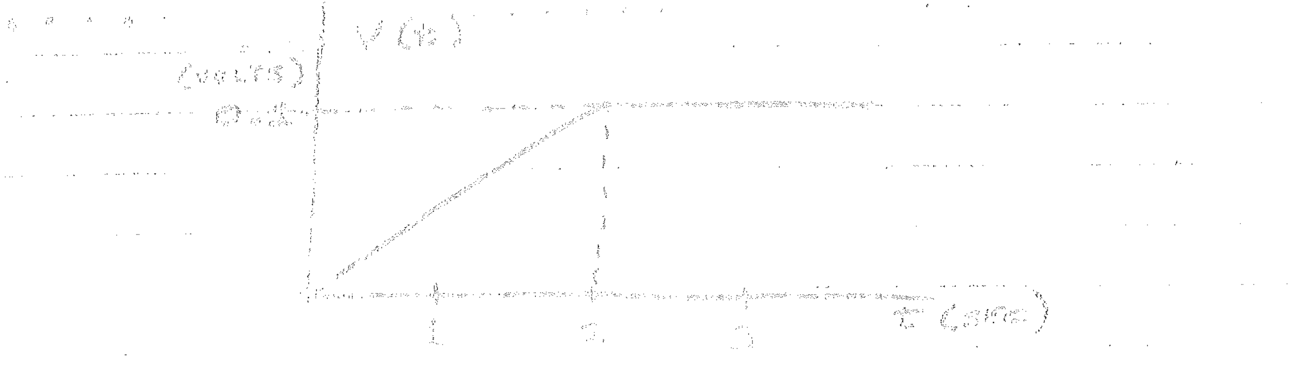


(1) GIVEN THE FOLLOWING $i(t)$, COMPUTE AND SKETCH $v(t)$, $P(t) = v(t)\,i(t)$, AND $w(t) = \int_{-\infty}^{t} P(t)\,dt = w(t_0) + \int_{t_0}^{t} P(t)\,dt$ FOR (a) R (b) L AND (c) C



(ASSUME $V_c(t=0) = 0$)

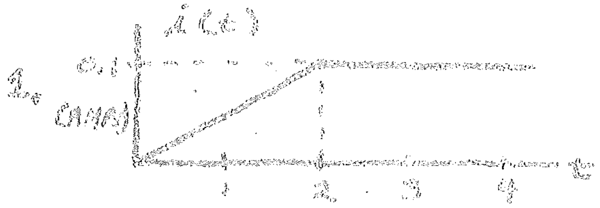
(2) GIVEN THE FOLLOWING $v(t)$, COMPUTE AND SKETCH $i(t)$, $P(t)$, AND $w(t)$ FOR (a) R (b) L AND (c) C



(3) COMPARE THE RESULTS IN (1) AND (2) AND COMMENT.

EXTRA CREDIT PROBLEM - EE 233 (MARTIN)
DUE: 10/1/76

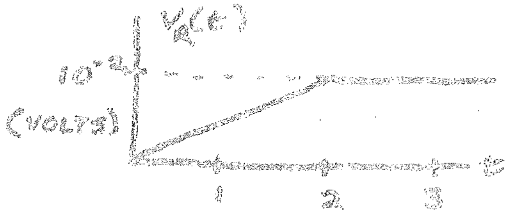
SOLUTIONS



$$i(t) = \begin{cases} 0.05t & ; 0 < t < 2 \\ 0.1 & ; t > 2 \end{cases}$$

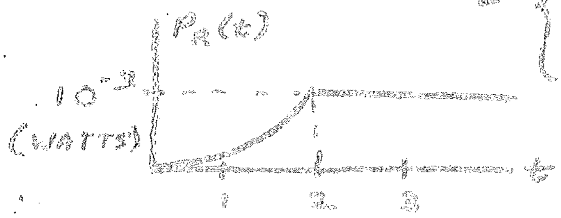
1 (a) FOR RESISTOR

$$V_R(t) = Ri(t) = 0.1\, i(t) = \begin{cases} 5\times10^{-3}\, t & ; 0 < t < 2 \\ 10^{-2} & ; t > 2 \end{cases}$$

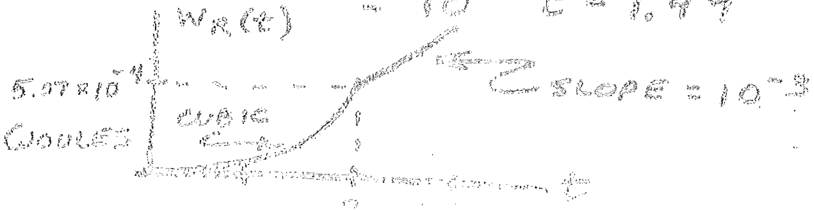


$$P_R(t) = i(t)\, V_R(t) = \begin{cases} (0.05t)(5\times10^{-3}t) & ; 0 < t < 2 \\ 10^{-3} & ; t > 2 \end{cases}$$

$$= \begin{cases} 2.5\times10^{-4}\, t^2 & ; 0 < t < 2 \\ 10^{-3} & ; t > 2 \end{cases}$$

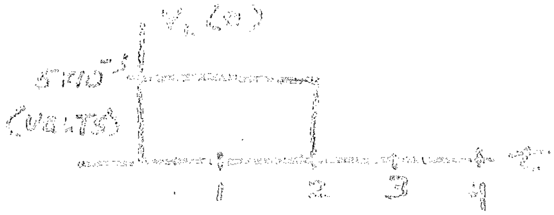


$$W_R(t) = W_R(t_0) + \int_{t_0}^{t} P(t)\,dt$$
$$= 0 + \int_0^t 2.5\times10^{4}\, t^2\, dt \quad ; 0 < t < 2$$
$$= 2.5\times10^{4}\, \frac{1}{3} t^3$$
$$= 8.33\times10^{-5}\, t^3 \quad ; 0 < t < 2$$
$$W_R(2) = 8(8.33\times10^{-5}) = 50.67\times10^{-5} = 5.07\times10^{-4}$$
$$W_R(t) = W_R(2) + \int_2^t 10^{-3}\,dt = 5.07\times10^{-4} + 10^{-3}(t-2)$$
$$= 10^{-3}t - 1.49 \quad ; t > 2$$



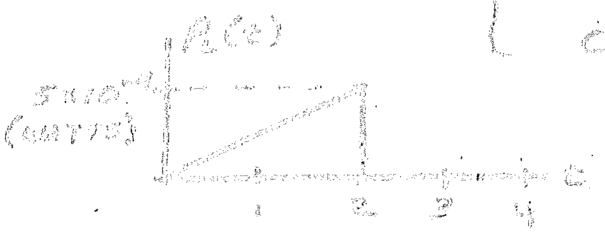
1(b) FOR INDUCTOR,

$$v_L(t) = L\frac{di}{dt} = 0.1\frac{di}{dt} = \begin{cases} 10^{-2} \times 5 & ; 0<t<2 \\ 0 & ; t>0 \end{cases}$$



$$P_L(t) = i(t)\,v_L(t) = \begin{cases} (5\times10^{-3})(5\times10^{-2}t) & ; 0<t<2 \\ 0 & ; t>2 \end{cases}$$

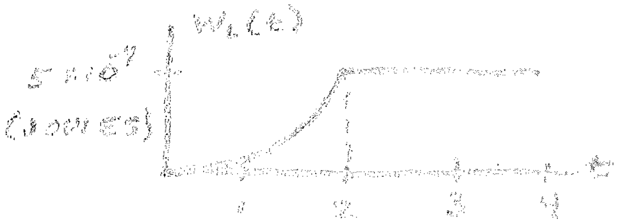
$$= \begin{cases} 2.5\times10^{-4}\,t & ; 0\le t<2 \\ 0 & ; t>2 \end{cases}$$



$$w_L(t) = w(t_0) + \int_{t_0}^{t} P(\tau)\,d\tau$$
$$= w(0) + \int_0^t (2.5\times10^{-4}\tau)\,d\tau \quad ; 0\le t\le 2$$
$$= 0 + 1.25\times10^{-4}\,t^2 \quad ; 0\le t\le 2$$

$$w_L(2) = 5\times10^{-4}$$

$$w_L(t) = w_L(2) + \int_2^t (0)\,d\tau \quad ; t>0$$
$$= 5\times10^{-4}$$



(c) FOR CAPACITOR

$$V_c(t) = V_c(t_0) + \frac{1}{C}\int_{t_0}^{t} i(\tau)\,d\tau$$

$$= V_c(t_0) + 10\int_{t_0}^{t} i(t)\,dt$$

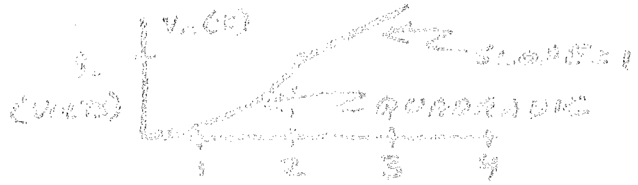
$$= V_c(0) + 10\int_{0}^{t} 5\times10^{-2}\,t\,dt \quad ; 0<t<2$$

$$= 0 + 0.25\,t^2 \quad ; 0<t<2$$

$V_c(2) = 1$ volt

$$V_c(t) = V_c(2) + 10\int_{2}^{t} (0.1)\,dt \quad ; t>2$$

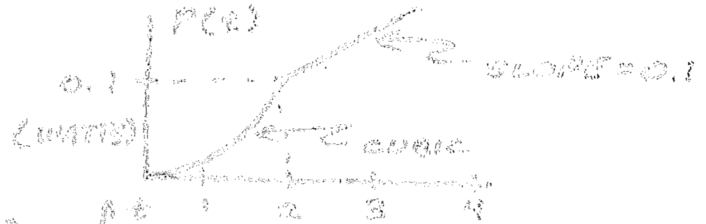
$$= 1 + (t-2) = t-1 \quad ; t>2$$



$$P_c(t) = V_c(t)\,i(t) = \begin{cases} (0.25\,t^2)(0.05\,t) & ; 0<t<2 \\ 0.1\,(t-1) & ; t>0 \end{cases}$$

$$= \begin{cases} 1.25\times10^{-2}\,t^3 & ; 0<t<2 \\ 0.1\,t - 0.1 & ; t>2 \end{cases}$$

$P_c(2) = 0.1$



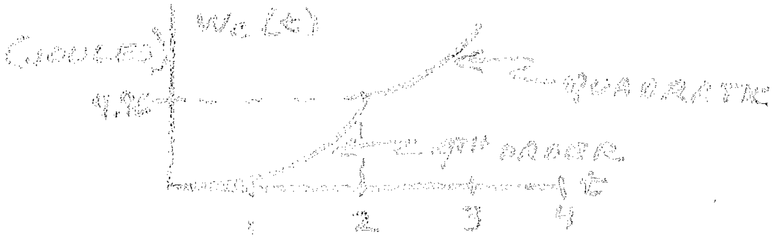
$$W_c(t) = W_c(t_0) + \int_{t_0}^{t} P(\tau)\,d\tau$$

$$= 0 + 1.25\times10^{-2}\int_{0}^{t} t^3\,dt \quad ; 0<t<2$$

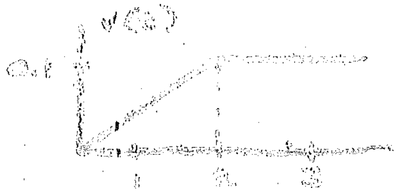
$$= 0.31\,t^4 \quad ; 0<t<1 \Rightarrow W_c(2) = 4.96$$

$$W_c(t) = 4.96 + \int_{2}^{t} (0.1\,t - 0.1)\,dt \quad t>0$$

$$= 0.05\,t^2 - 0.1\,t + 4.96$$



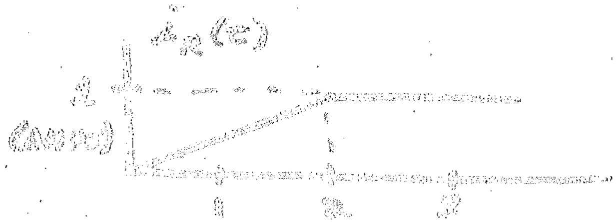
(2)



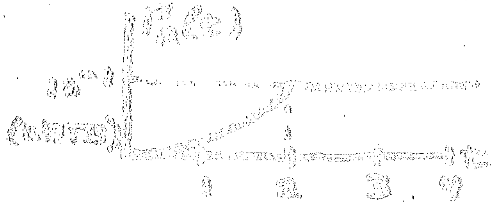
$$v(t) = \begin{cases} 0.05\,t & ; 0 \le t \le 2 \\ 0.1 & ; t > 2 \end{cases}$$

2(a) RESISTOR

$$i_R(t) = \frac{1}{R}\, v(t) = 10\, v(t) = \begin{cases} 0.5\,t & ; 0 \le t \le 2 \\ 1.0 & ; t > 2 \end{cases}$$



$$p_R(t) = v(t)\, i_R(t) = \begin{cases} 2.5 \times 10^{-2}\, t^2 & ; 0 \le t \le 2 \\ 0.1 & ; t > 2 \end{cases}$$



$$w_R(t) = w_R(t_0) + \int_{t_0}^{t} p(\tau)\, d\tau$$

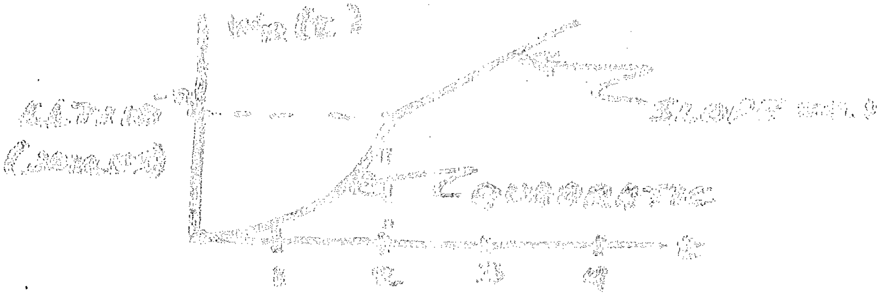
$$= 0 + 2.5 \times 10^{-2} \int_0^t \tau^2\, d\tau \quad ; 0 \le t \le 2$$

$$= 8.33 \times 10^{-3}\, t^3 \quad ; 0 \le t \le 2$$

$$w_R(2) = 6.67 \times 10^{-2}$$

$$w_R(t) = 6.67 \times 10^{-2} + \int_2^t (0.1)\, d\tau$$

$$= 0.067 + 0.1t - 0.2 = 0.1t - 1.33$$

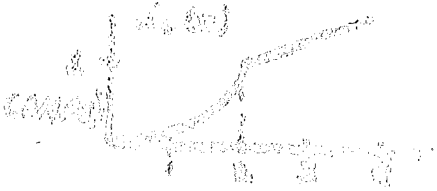


2(b) FOR INDUCTOR

$$i_L(t) = i(t_0) + \frac{1}{L}\int_{t_0}^{t} v(\tau)\,d\tau$$

THIS IS THE SAME MATH AS WE WENT THROUGH IN PROBLEM #1 PART C. OUR ANSWERS ARE:

$$i_L(t) = \begin{cases} 0.5\,t^2 & ; 0 < t < 2 \\ t - 1 & ; t > 2 \end{cases}$$



$P_L(t)$ = THE SAME AS $P_C(t)$ IN PROB 1 C

$W_L(t)$ = " " " $W_C(t)$ " " "

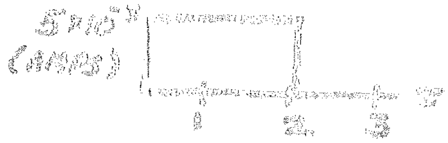
2(C) FOR CAPACITOR

$$i_C(t) = C\frac{dv}{dt}$$

THIS IS THE SAME MATH AS IN PROB. 1 b.

$$\Rightarrow i_C(t) = \begin{cases} 5\times10^{-3} & ; 0 < t < 2 \\ 0 & ; t > 0 \end{cases}$$

$i_C(t)$



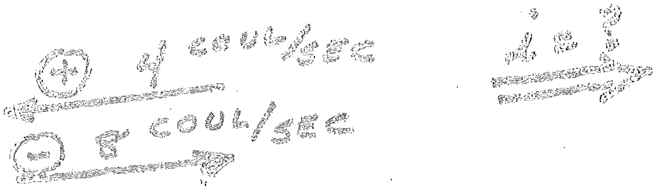
$P_C(t)$ = THE SAME AS $P_L(t)$ IN PROB. 1 b

$W_C(t)$ = " " " $W_L(t)$ " " "

(3) BY NOTING THE SIMILARITIES (OR "DUALITY") OF THE PROBLEMS, WE'VE SAVED SOME WORK.

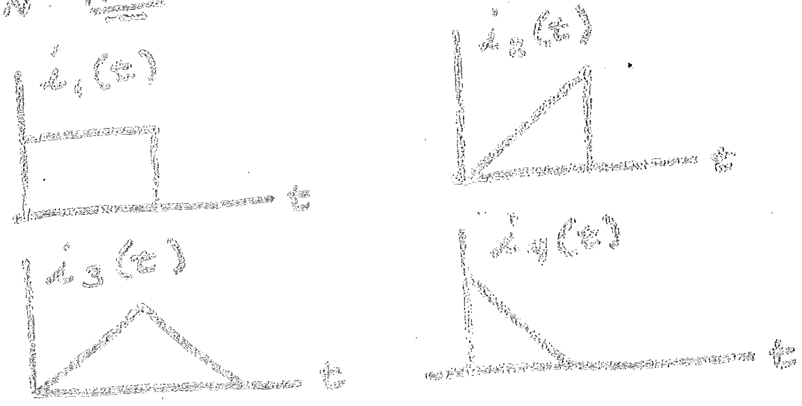
E 231 - SEC A (BOB M[illegible])
EST 1, 9/27/26 (55 minutes)

. (15)(a) A TOTAL OF 4 $\frac{\text{COULOMBS}}{\text{SEC}}$ DUE TO POSITIVE IONS ARE FLOWING FROM RIGHT TO LEFT. EIGHT COULOMBS PER SECOND DUE TO (NEGATIVELY CHARGED) ELECTRONS ARE FLOWING FROM LEFT TO RIGHT. WHAT IS THE TOTAL CURRENT (IN AMPS) FLOWING FROM LEFT TO RIGHT

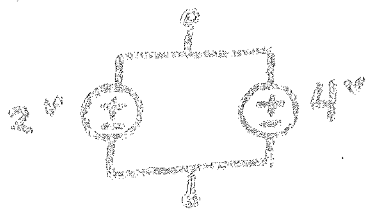


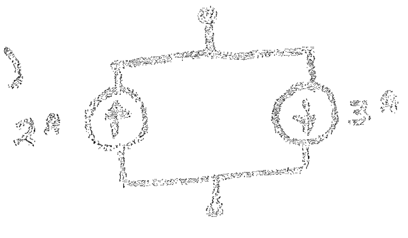
(a) 4 AMPS
(b) −4 AMPS
(c) 12 AMPS
(d) −12 AMP

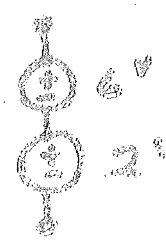
(b) WHICH OF THE FOLLOWING CURRENTS CAN NOT GO THRU AN (IDEAL) INDUCTOR

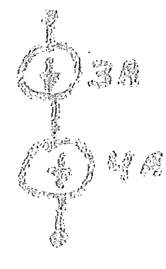


(c) WHICH OF THE FOLLOWING CIRCUITS WILL "BLOW UP" (OR AT LEAST BLOW A FUSE)

(a)


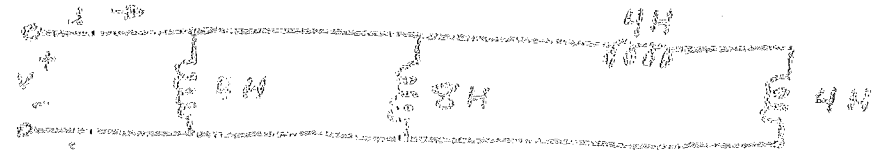
(b)


(c)


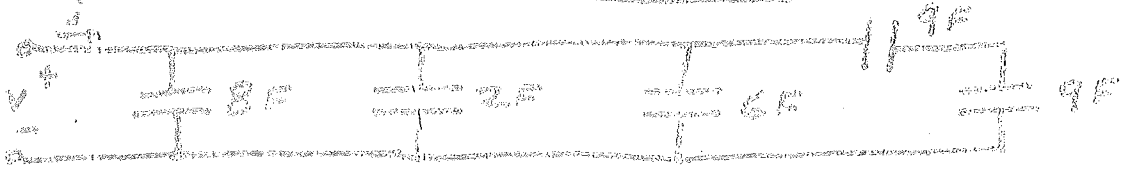
(d)


2. (15) REDUCE THE FOLLOWING TO A SINGLE PASSIVE ELEMENT:

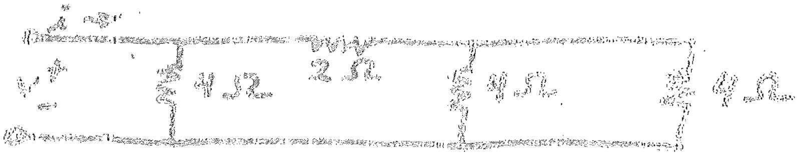
(a)



(b)

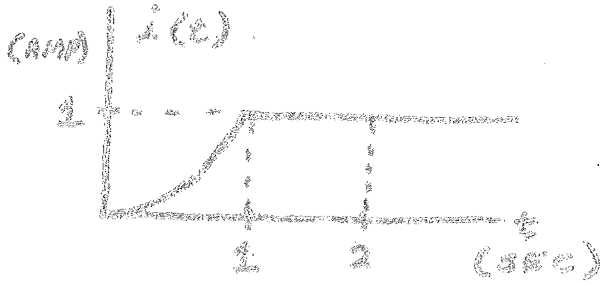


(c)

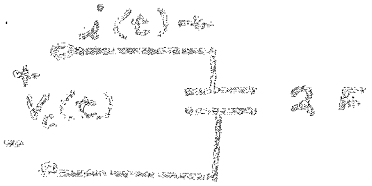


3. (15) GIVEN THE CURRENT

$$i(t) = \begin{cases} t^2 \text{ AMP} ; & 0 \le t \le 1 \text{ SEC} \\ 1 \text{ AMP} ; & t \ge 1 \text{ SEC} \end{cases}$$



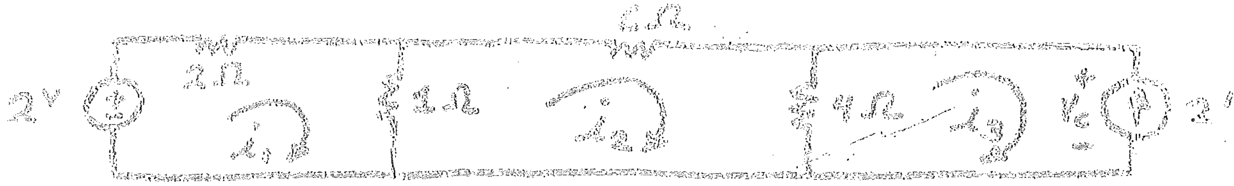
(a) FIND THE VOLTAGE ACROSS A 2 FARAD CAPACITOR AT TIME $t = 2$ SEC (ASSUME THE CAPACITOR IS INITIALLY UNCHARGED ⇒ $V(t=0) = 0$)



(b) WHAT IS THE CORRESPONDING POWER AT TIME $t = 2$ SEC?

(c) WHAT IS $V_c(t = 2 \text{ SEC})$ IF $V_c(t=0) = 1$ VOLT? (ie, REWORK (a) FOR $V_c(t=0) = 1$ VOLT)

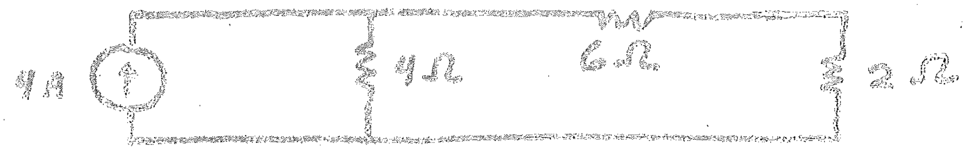
4. (15) FOR THE CIRCUIT:



(a) WHAT IS $i_3$? (HINT: JUST LOOK AT THE CIRCUIT)

(b) WRITE THE LOOP (MESH) EQUATIONS FOR THE CIRCUIT. ASSUME A VOLTAGE $V_c$ ACROSS THE CURRENT SOURCE. DO NOT SOLVE

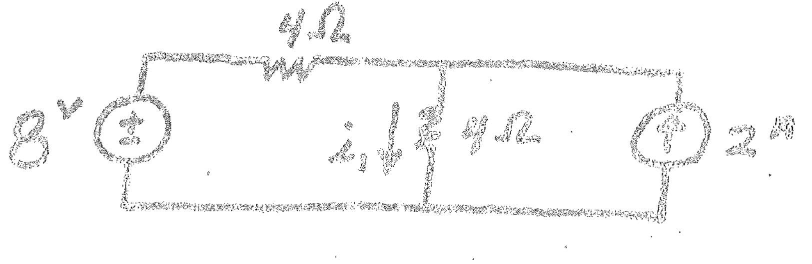
5. (15) FOR THE CIRCUIT



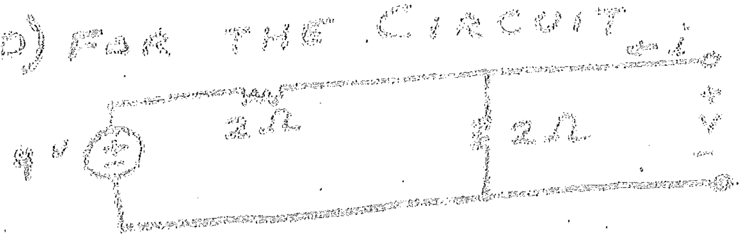
(a) SPECIFY ALL NODES

(b) WRITE THE CORRESPONDING NODE-VOLTAGE EQUATIONS. DO NOT SOLVE

6. (20) BY SUPERPOSITION, DETERMINE $i_1$ IN THE CIRCUIT BELOW. USE CURRENT AND VOLTAGE DIVIDER PRINCIPLES:



7. (20) FOR THE CIRCUIT



(a) FIND THE OPEN CIRCUIT VOLTAGE, $V_{oc}$.

(b) FIND THE SHORT CIRCUIT CURRENT, $I_{sc}$.

(c) DRAW THE CIRCUIT'S v-i CURVE

(d) SKETCH THEVININ'S & NORTON'S EQUIVALENT CIRCUITS.

THE END

"Wisdom is the principal thing; therefore, get wisdom; and with all thy getting get understanding" PROV. 4:7

## SOLUTIONS

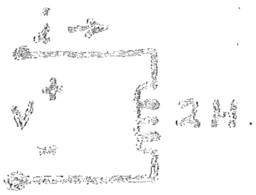
TEST 1

1. (a) $-12$ AMPS

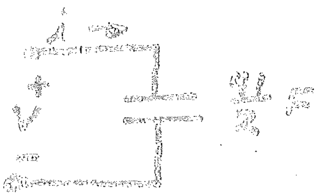
(b) $i_1(t)$, $i_1(t)$, AND $i_4(t)$ ARE NOT ALLOWED SINCE THEY CHANGE INSTANTANEOUSLY

(c) CIRCUITS a AND d WILL "BLOW UP"

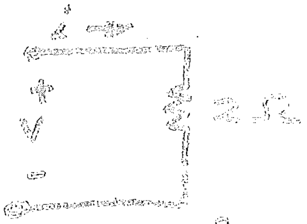
2. (a)



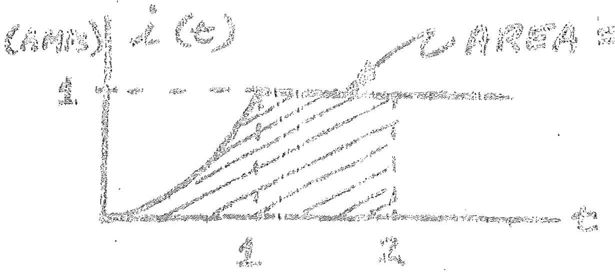
(b)



(c)



3. (a) $v(t) = \frac{1}{C}\int_{-\infty}^{t} i(t)dt = \frac{1}{2}\int_{0}^{2} i(t)dt + \cancel{V(t_0)}^{0} = V(2)$



AREA $= \frac{4}{3}$ AMP-SEC $= \int_0^2 i(t)dt$

$\therefore V(2) = \frac{1}{2}\left(\frac{4}{3}\right) = \frac{2}{3}$ VOLT

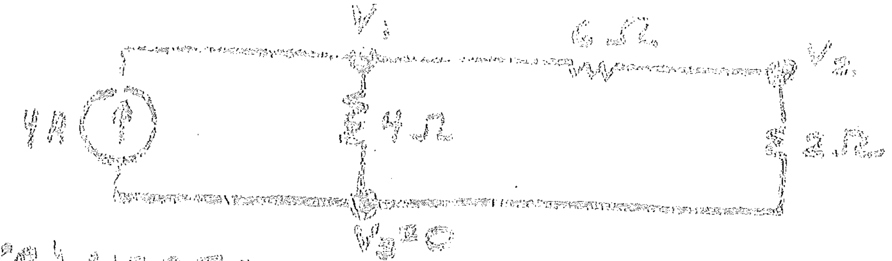
(b) $P(2) = V(2)\,i(2) = \left(\frac{2}{3}\text{ VOLT}\right)\left(1\text{ AMP}\right) = \frac{2}{3}$ WATT

(c) $V(2) = \frac{1}{2}\int_0^2 i(t)dt + 1$ VOLT $= 5/3$ VOLT

4. (a) $i_3 = -2$ AMPS

(b)
$$\left.\begin{array}{l} -2 + 3i_1 - i_2 = 0 \\ 11i_2 - i_1 - 4i_3 = 0 \\ 4i_3 - 4i_2 + V_c = 0 \end{array}\right\}$$

5.

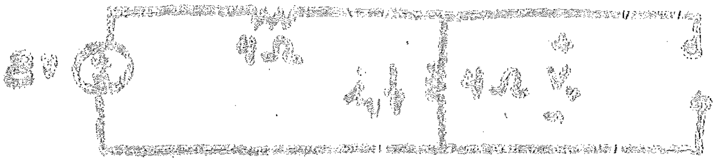


(a) NODES SPECIFIED BY "B"'s

(b) $$\begin{cases} \frac{V_3 - V_1}{4} + \frac{V_2 - V_1}{6} + 4 = 0 \\ \frac{V_1 - V_2}{6} + \frac{V_3 - V_2}{2} = 0 \end{cases}$$

NOTE: $V_3 = 0$

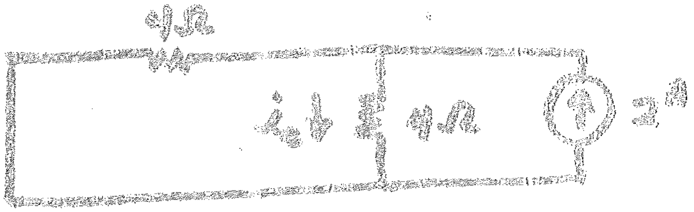
6. FIND, FIRST, THE EFFECT OF THE V SOURCE



BY VOLTAGE DIVIDER:

$$V_v = \frac{4}{4+4} 8 = 4 \text{ VOLTS} \Rightarrow i_v = \frac{V_v}{4} = 1 \text{ AMP}$$

SECOND, FIND EFFECT OF CURRENT SOURCE



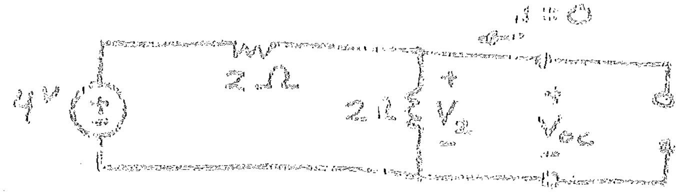
BY CURRENT DIVIDER:

$$i_c = \frac{1/4}{1/4 + 1/4} 2 = 1 \text{ AMP}$$

AND

$$i_1 = i_v + i_c = 2 \text{ AMPS}$$

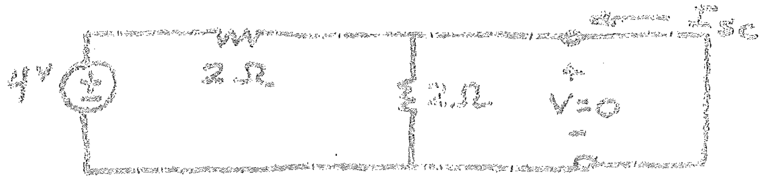
7. (a)



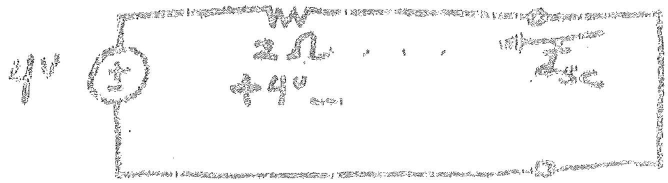
BY VOLTAGE DIVIDER

$$V_{oc} = V_2 = \frac{2}{2+2} 4 = 2 \text{ VOLTS}$$

(b)

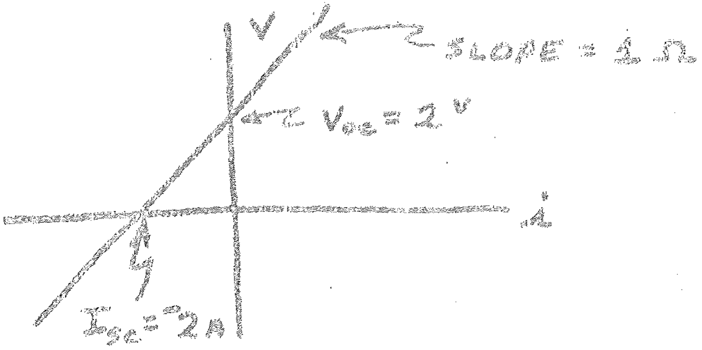


WE HAVE "SHORTED" A 2Ω RESISTOR. AN EQUIVALENT CIRCUIT IS THUS



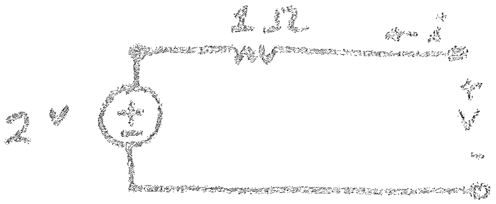
OBVIOUSLY, $I_{sc} = \frac{-4 \text{ VOLTS}}{2 \text{ OHMS}} = {}^{-}2$ AMPS

(c)

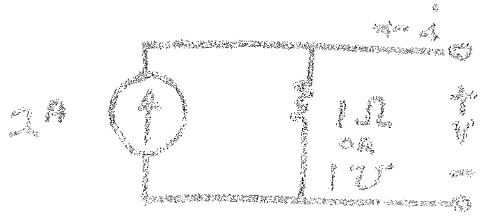


(d) $R_T = R_N = \dfrac{-V_{oc}}{I_{sc}} = 1\,\Omega$

THEVININ:



NORTON:



EE 233

TEST #2 NOV. 5, 1976 Bob Marks

WORK ALL PROBLEMS. SPECIFY YOUR UNITS.

1. (15) (a) SHOW THAT $e^{j\pi} = j$

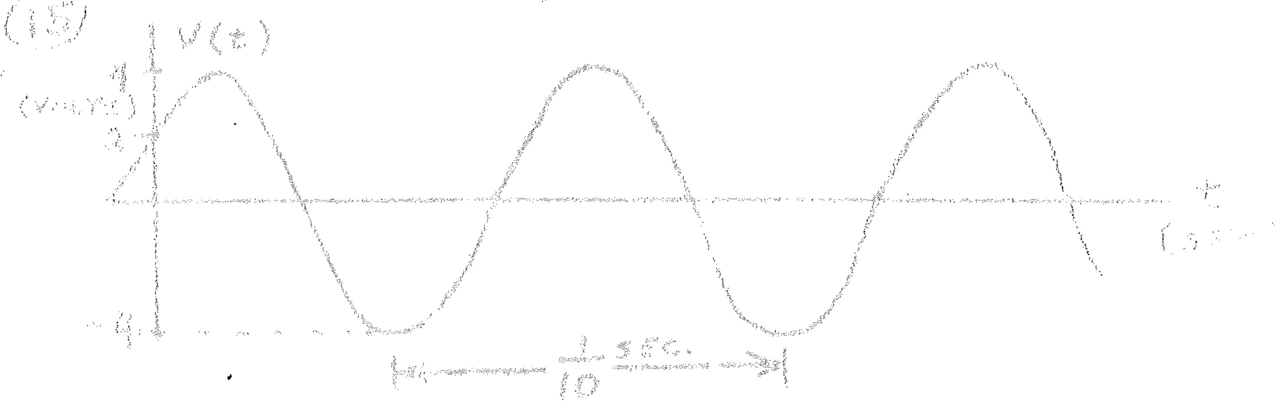
(b) GIVEN THE COMPLEX NUMBER

$W = 1 + j$

→ WRITE $W$ IN POLAR FORM

→ WRITE $\frac{1}{W}$ IN RECTANGULAR FORM.

2. (15)



THE EQUATION FOR THE ABOVE WAVEFORM

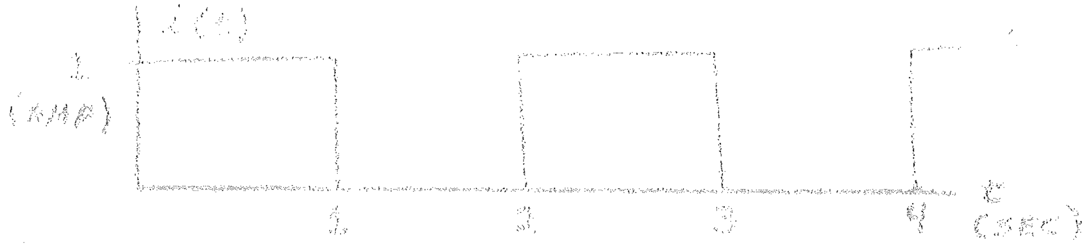
$v(t) = V_0 \cos(2\pi f t + \phi)$

(a) WHAT ARE $V_0$, $f$, AND $\phi$? (HINTS: $\phi < 0$ AND $\cos\frac{\pi}{3} = \cos 60° = \frac{1}{2}$)

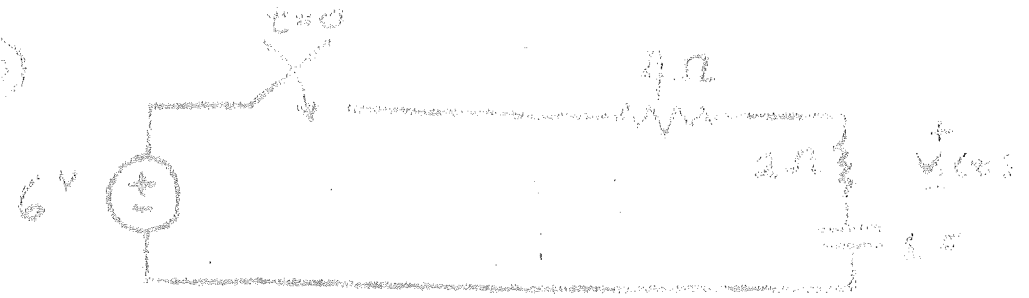
(b) WHAT IS $\omega$ = ANGULAR FREQUENCY AND $T$ = PERIOD

(c) USING $\cos 2\pi f t$ AS A REFERENCE, SKETCH THE PHASER DIAGRAM CORRESPONDING TO

3. ⑳ FIND $I_{AVE}$ AND $I_{RMS}$ ($= I_{EFF}$) FOR TH
PERIODIC CURRENT WAVEFORM:

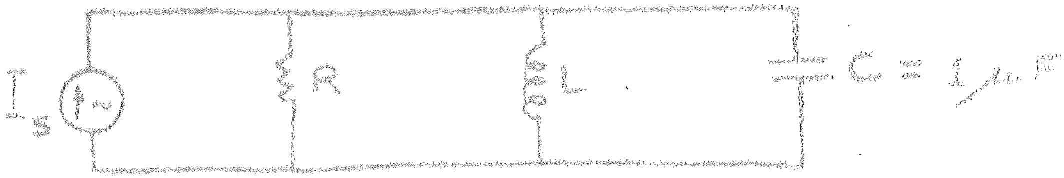


4. ⑳



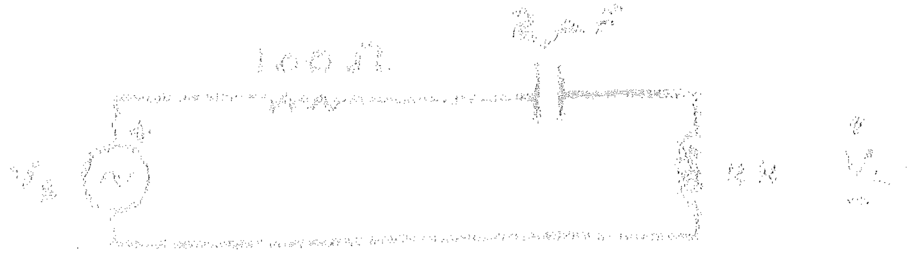
IN THE ABOVE CIRCUIT, FIND AND SKETCH V(t) = VOLTAGE ACROSS THE 2Ω RESISTOR. ASSUME THAT THE VOLTAGE ACROSS THE CAPACITOR, BEFORE THE SWITCH IS THROWN, IS ZERO. (HINT: USE THE "4 NUGGETS").

5. ⑳



THE CURRENT SOURCE SHOWN IS SINUSOIDAL [illegible] ANGULAR FREQUENCY $\omega = 100 \frac{RADIANS}{SEC}$. GIVEN THAT C = 1 μF, FIND THE VALUE OF L SUCH THAT [illegible] OF THE CURRENT FROM THE CURRENT SOURCE WILL PASS THROUGH THE RESISTER, R.

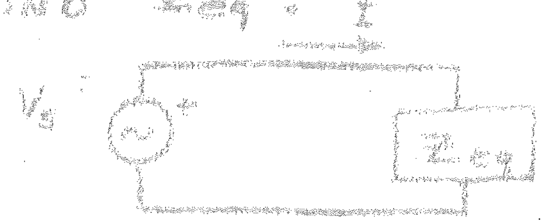
1. ⑳



~~[illegible]~~ $\omega = 100 \frac{\text{RADIANS}}{\text{SEC}}$

a. ASSUMING $V_s$ = 10 VOLTS RMS, FIND THE VOLTAGE (IN PHASOR FORM) OF ACROSS THE 4 HENRY INDUCTOR. SIMPLIFY YOUR ANSWER TO RECTANGULAR FORM (HINT: USE A VOLTAGE DIVIDER).

b. REDUCE THE CIRCUIT TO AN EQUIVALENT IMPEDENCE. THAT IS, FIND $Z_{eq}$:



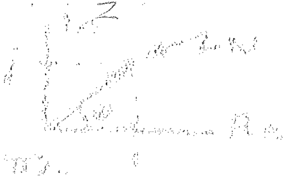
STATE YOUR ANSWER IN <u>POLAR</u> FORM.

TEST # 2 SOLUTIONS

1. a. $e^{j\frac{\pi}{2}} = \cos\frac{\pi}{2} + j\sin\frac{\pi}{2}$

$\cos\frac{\pi}{2} = 0, \sin\frac{\pi}{2} = 1 \Rightarrow e^{j\frac{\pi}{2}} = j$

b. $w = 1 + j$



$\theta = \tan^{-1} 1 = \pi/4$

$r = \sqrt{2} \Rightarrow \underline{w = \sqrt{2}\, e^{j\frac{\pi}{4}}}$

$\frac{1}{w} = \frac{1}{\sqrt{2}\, e^{j\pi/4}} = \frac{1}{\sqrt{2}} e^{-j\pi/4}$,

$= \frac{1}{\sqrt{2}}\cos\frac{\pi}{4} - j\frac{1}{\sqrt{2}}\sin\frac{\pi}{4}$

$= \frac{1}{\sqrt{2}}\cdot\frac{1}{\sqrt{2}} - j\frac{1}{\sqrt{2}}\cdot\frac{1}{\sqrt{2}} = \underline{\frac{1}{2} - j\frac{1}{2}}$

2. a. FROM THE SKETCH:

$V_0 = 4$ VOLTS $\quad f = 1/\frac{1}{10} = 10 \frac{\text{CYCLES}}{\text{SEC}}$

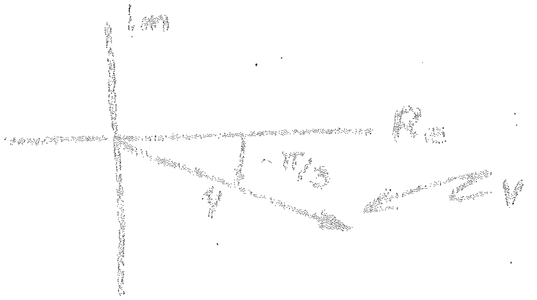
$V(0) = V_0 \cos\phi = 4\cos\phi = 2$

$\Rightarrow \cos\phi = 1/2 \quad \therefore \phi = -\pi/3$ RADIANS

b. $T = \frac{1}{10}$ SECOND

$\omega = 2\pi f = 20\pi \frac{\text{RADIANS}}{\text{SEC}}$

c.



3. FROM SKETCH: $T = 2$ SECONDS

$$I_{AVE} \triangleq \frac{1}{T}\int_T i(t)\,dt$$
$$= \frac{1}{2}\left[\int_0^1 (1)\,dt + \int_1^2 (0)\,dt\right]$$
$$= \frac{1}{2}\left[1 + 0\right] = \frac{1}{2}\text{ AMP.}$$
$$I_{RMS} \triangleq \sqrt{\frac{1}{T}\int_T i^2(t)\,dt}$$
$$\therefore I_{RMS}^2 = \frac{1}{2}\left[\int_0^1 (1)^2\,dt + \int_1^2 (0)^2\,dt\right]$$
$$= \frac{1}{2} \Rightarrow I_{RMS} = \frac{1}{\sqrt{2}}\text{ AMP}$$

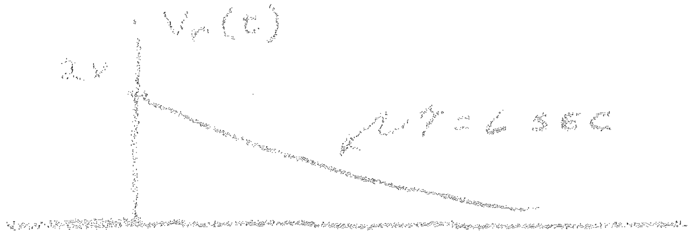
4. USE THE FOUR NUGGETS:

(1) $V_r(0^-) = 0$ (NO CURRENT IS FLOWING BEFORE THE SWITCH CLOSES)

(2) $V_r(0^+) = 2$ VOLTS (USE A VOLTAGE DIVIDER RECOGNIZING THAT, AT $t = 0^+$, THE CAPACITOR ACTS AS A SHORT)

(3) $V_r(\infty) = 0$ (AT $t = \infty$, CAPACITOR ACTS LIKE A OPEN CIRCUIT)

(4) $\tau = R_{eq} C = (2+4)1 = 6$ SEC



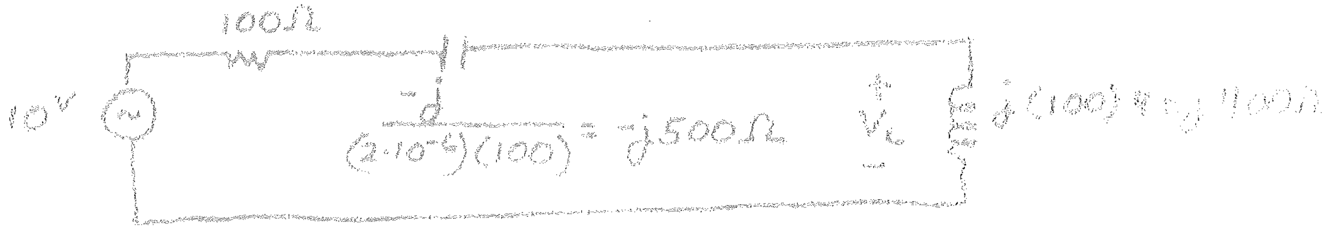
$$\therefore V_r(t) = \begin{cases} 0 & ; t < 0 \\ 2e^{-t/6} & ; t > 0 \end{cases}$$

5. ALL CURRENT WILL PASS THRU RESISTER WHEN L & C ARE IN RESONANCE AT WHICH POINT THEY LOOK LIKE AN OPEN CIRCUIT. THUS, OUR DESIRED INDUCTANCE IS FROM THE RELATION:

$$f = \frac{1}{2\pi\sqrt{LC}} \Rightarrow 2\pi f = \omega = \frac{1}{\sqrt{LC}}$$

$$\Rightarrow LC = \frac{1}{\omega^2} \Rightarrow L = \frac{1}{C\omega^2}$$

$$L = \frac{1}{(1\times10^{-4})(100)^2} = \frac{1}{10^{-2}} = 100\ H$$

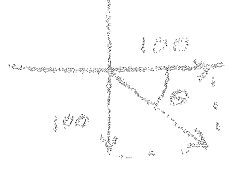


a. BY VOLTAGE DIVIDER

$$V_L = \frac{j400}{100-j500+j400}10 = \frac{j400}{100-j100}10$$

$$= \frac{j40}{1-j}\cdot\frac{1+j}{1+j} = \frac{-40+j40}{2} = -20+j20 \text{ VOLTS}$$

b. $Z_{eq} = 100-j500+j400 = 100-j100\ \Omega$



$$\theta = -45^\circ = -\pi/4$$

$$r = \sqrt{2}\,100$$

$$\Rightarrow Z_{eq} = \sqrt{2}\,100\,e^{-j\frac{\pi}{4}}$$

[illegible] SOLUTIONS [illegible]

[illegible]

[illegible]

[illegible]

GIVEN EULER'S EQUATION:

$$e^{j\theta} = \cos\theta + j\sin\theta$$

SHOW THAT:

(i) $\cos\theta = \frac{1}{2}\left[e^{j\theta} + e^{-j\theta}\right]$

(ii) $\sin\theta = \frac{1}{j2}\left[e^{j\theta} - e^{-j\theta}\right]$

SOL

$$e^{j\theta} = \cos\theta + j\sin\theta$$

$$\Rightarrow e^{j(-\theta)} = e^{-j\theta} = \cos(-\theta) + j\sin(-\theta)$$

OR $e^{-j\theta} = \cos\theta - j\sin\theta$

$$\Rightarrow e^{j\theta} = \cos\theta + j\sin\theta \quad (a)$$

$$e^{-j\theta} = \cos\theta - j\sin\theta \quad (b)$$

ADDING (a) + (b) GIVES

$$e^{j\theta} + e^{-j\theta} = 2\cos\theta$$

$$\Rightarrow \cos\theta = \frac{1}{2}\left[e^{j\theta} + e^{-j\theta}\right]$$

SUBTRACTING (a) + (b) GIVES

$$e^{j\theta} - e^{-j\theta} = j2\sin\theta$$

$$\Rightarrow \sin\theta = \frac{1}{j2}\sin\theta$$

[illegible] COMPLEX NUMBERS

$W = a + jb = re^{j\theta}$

SHOW

(a) $|W| = |W^*|$

METHOD 1: $|w| = |a+jb| = \sqrt{a^2+b^2}$

$|w^*| = |a-jb| = \sqrt{a^2+(-b)^2}$

METHOD 2: $|w| = |re^{j\theta}| = r|e^{j\theta}| = r$

$|w^*| = |re^{-j\theta}| = r|e^{-j\theta}| = r$

(b) $|w|^2 = w w^*$

METHOD 1: $|w|^2 = |a+jb|^2 = (\sqrt{a^2+b^2})^2 = a^2+b^2$

$w w^* = (a+jb)(a-jb) = a^2+b^2$

METHOD 2: $|w|^2 = |re^{j\theta}|^2 = r^2|e^{j\theta}|^2 = r^2$

$w w^* = (re^{j\theta})(re^{-j\theta}) = r^2 e^{j(\theta-\theta)} = r^2$

(c) $\arg w = -\arg w^*$

METHOD 1: $\arg w = \arg a+jb = \operatorname{atan} b/a$

$\arg w^* = \arg a-jb = \operatorname{atan} (-b)/a$

$= -\operatorname{atan} b/a$

METHOD 2: $\arg w = \arg re^{j\theta} = \theta$

$\arg w^* = \arg re^{-j\theta} = \arg re^{j(-\theta)}$

$= -\theta$

EXTRA CREDIT FOR PROBLEM (LOTSA TIME)

GIVEN THAT $\beta$ AND $\gamma$ ARE CONSTANTS, AND THAT

$$g_\pm(x) = \frac{\beta e^x \pm \sqrt{-\beta^2 e^{2x} + (2\beta^2+\gamma^2)e^x - \beta^2}}{e^x - 1}$$

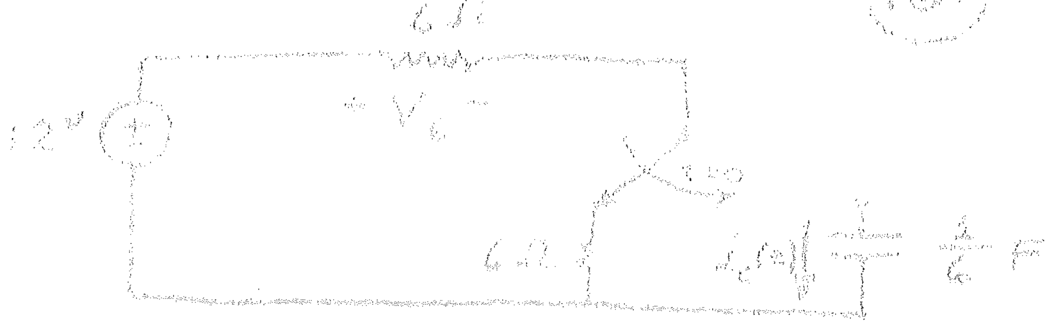
FIND

$$f(x) = \frac{\beta^2}{\pi}\left[\frac{1}{\beta^2+g_-^2(x)}\left(\frac{d g_-(x)}{dx}\right) - \frac{1}{\beta^2+g_+^2(x)}\left(\frac{d g_+(x)}{dx}\right)\right]$$

WHERE $g_+(x)$ AND $g_-(x)$ REFER TO $g_\pm(x)$ USING THE "+" AND THE "−" SIGNS RESPECTIVELY

HOMEWORK

(1.)



(a) USE THE "4 NUGGETS" TO FIND $V_6(t)$

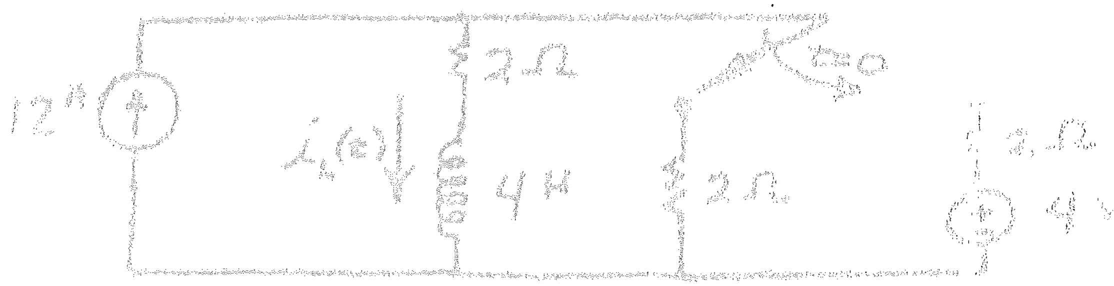
(b)(i) USE THE "4 NUGGETS" TO FIND $i_c(t)$

(ii) USING KIRCHHOFF'S VOLTAGE LAW, SHOW THAT, FOR $t > 0$, $i_c(t)$ MUST SATISFY THE DIFFER. EQ:

$$\frac{d\,i_c(t)}{dt} = -i_c(t)$$

(iii) VERIFY THAT YOUR ANSWER IN (i) SATISFIES THIS DIFFER. EQ.

(2.)



USING THE "4 NUGGETS", FIND $i_L(t)$ [HINT: TO FIND $i_L(\infty)$, USE THE SUPERPOSITION THEOREM WITH VOLTAGE AND CURRENT DIVIDERS]

HOMEWORK

(1.)

(a) USE THE "4 NUGGETS" TO FIND $V_6(t)$

(b)(i) USE THE "4 NUGGETS" TO FIND $i_c(t)$

(ii) USING KIRCHHOFF'S VOLTAGE LAW, SHOW THAT, FOR $t > 0$, $i_c(t)$ MUST SATISFY THE DIFFER. EQ:

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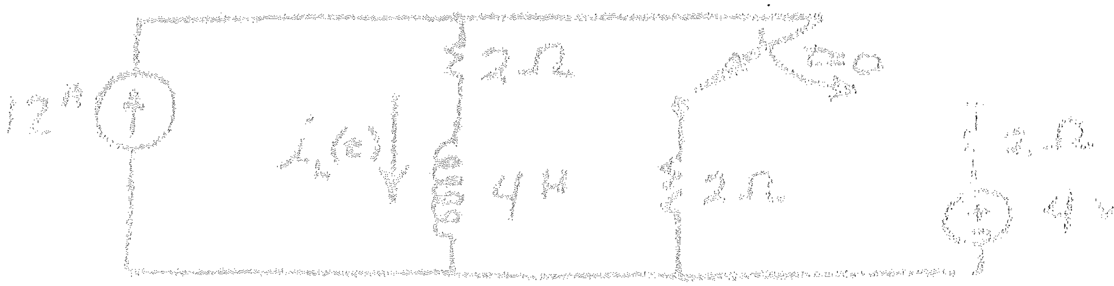
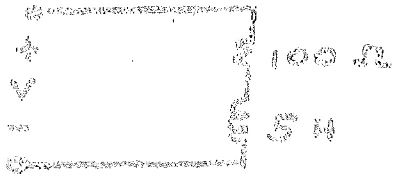
(2.)



USING THE "4 NUGGETS", FIND $i_L(t)$
[HINT: TO FIND $i_L(\infty)$, USE THE SUPERPOSITION THEOREM WITH VOLTAGE AND CURRENT DIVIDERS]

HOMEWORK SOLUTION

PROBLEM:



THE IMPEDANCE OF THIS CIRCUIT IS, AT $\omega = 100$, $Z = 100 + j50$. FIND THE ADMITTANCE (Y), CONDUCTANCE (G), AND THE SUSCEPTANCE (B).

SOLUTION:

$$Y \triangleq \frac{1}{Z} = \frac{1}{100+j50} = \frac{1}{50}\cdot\frac{1}{(2+j)}$$

USE "COMPLEX CONJUGATE" TRICK:

$$Y = \frac{1}{50}\cdot\frac{1}{(2+j)}\cdot\frac{(2-j)}{(2-j)}$$

$$= \frac{1}{50}\,\frac{2-j}{4-j2+j2+1} = \frac{2-j}{50(5)} = \frac{2-j}{250}$$

$$\Rightarrow Y = \left(\frac{1}{125} - \frac{j}{250}\right)\mho \qquad \text{(MHOS)}$$

NOW, IN GENERAL

$$Y = G + jB$$

THUS, FROM THE EXPRESSION FOR Y:

$$G = \frac{1}{125}\,\mho = 0.008$$

AND $B = -\frac{1}{250}\,\mho = -0.004$

## HOMEWORK SOLUTION

1. PROB: FIND $f_{RMS}$ AND $f_{AVE}$ WHEN, FOR $a$ AND $\phi$ CONSTANT, $f(t) = a \cos(2\pi f t + \phi)$

SOLUTION:

(a)
$$f_{AVE} \triangleq \frac{1}{T} \int_T f(t)\,dt$$
$$= \frac{a}{T} \int_0^T \cos(2\pi f t + \phi)\,dt$$
$$= \frac{a}{T} \int_0^T \cos\left[\frac{2\pi t}{T} + \phi\right] dt \qquad (T = 1/f)$$
$$= \frac{a}{T}\left(\frac{T}{2\pi}\right) \sin\left\{\frac{2\pi t}{T} + \phi\right\}\Big|_0^T$$
$$= \frac{a}{2\pi}\left[\sin(2\pi + \phi) - \sin\phi\right]$$

BUT $\sin(2\pi + \phi) = \sin\phi$

$$\Rightarrow f_{AVE} = 0$$

(b)
$$f_{RMS} \triangleq \sqrt{\frac{1}{T} \int_T f^2(t)\,dt} = f_{EFF}$$

$$\therefore f_{RMS}^2 = \frac{a^2}{T} \int_0^T \cos^2\left(\frac{2\pi t}{T} + \phi\right) dt$$
$$= \frac{a^2}{2T} \int_0^T \left[1 + \cos\left\{\frac{4\pi t}{T} + 2\phi\right\}\right] dt$$
$$= \frac{a^2}{2T}\left[t + \left(\frac{T}{4\pi}\right) \sin\left\{\frac{4\pi t}{T} + 2\phi\right\}\right]_0^T$$
$$= \frac{a^2}{2T}\Big[(T - 0)$$
$$+ \left(\frac{T}{4\pi}\right)\left\{\sin(4\pi + 2\phi) - \sin 2\phi\right\}\Big]$$

BUT $\sin(4\pi + 2\phi) = \sin 2\phi$

$$\Rightarrow f_{RMS}^2 = \frac{a^2}{2}$$

OR

$$f_{RMS} = \frac{a}{\sqrt{2}}$$

NOT THAT THE RMS VALUE OF ANY NUSOID IS INDEPENDENT OF ITS FREQUENCY ($f$) AND PHASE ($\phi$).

2. PROB: SHOW THAT $f(t) = a$ = CONSTANT IS "PERIODIC." FIND $f_{RMS}$ AND $f_{AVE}$.

SOLUTION:

(a) OBVIOUSLY, FOR ANY $T$, $f(t) = f(t+T) = a$. THUS, BY DEFINITION, $f(t) = a$ IS "PERIODIC"

(b) $$f_{AVE} = \frac{1}{T}\int_0^T f(t)dt$$
$$= \frac{1}{T}\int_0^T a\,dt = \frac{1}{T}(aT) = a$$

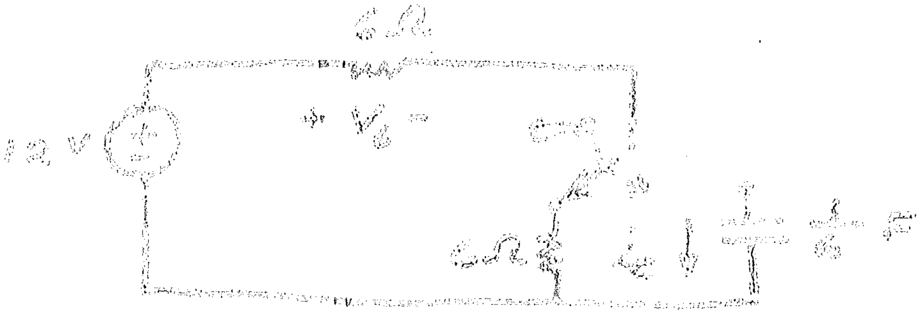
(c) $$f_{RMS}^2 = \frac{1}{T}\int_0^T a^2 dt$$
$$= \frac{1}{T}(a^2 T) = a^2$$

OR

$$f_{RMS} = a = f_{AVE}$$

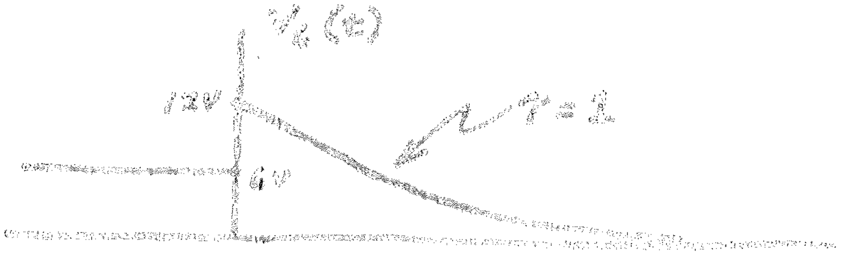
HOMEWORK SOLUTION

(2)



(a) FIND $V_6(t)$

1. $V_6(0^-) = 6$ V (FROM VOLTAGE DIVIDER)
2. $V_6(0^+) = 12$ V (SINCE VOLTAGE ACROSS CAPACITOR REMAINS 0 FOR $t = 0^-$)
3. $V_6(\infty) = 0$ (@ $t \to \infty$, CAPACITOR ACTS AS AN OPEN CIRCUIT)
4. $\tau = RC = (6\Omega)(\frac{1}{6}F) = 1$ SEC



THUS:

$$V_6(t) = \begin{cases} 6 & ; t < 0 \\ 12e^{-t} & ; t > 0 \end{cases}$$

(b) FIND $i_c(t)$

(1) $i_c(0^-) = 0$ (SINCE CAPACITOR IS OUT OF CIRCUIT FOR $t < 0$)

(2) $i_c(0^+) = 2^{AMPS}$ (CAPACITOR VOLTAGE = 0 FOR $t = 0^+ \Rightarrow 12^V$ ARE ACROSS $6\Omega$ RESISTOR $\Rightarrow \frac{12^V}{6\Omega} = 2$ AMPS ARE THRU RESISTOR & CAPACITOR)

(3) $i_c(\infty) = 0$ (@ $t = \infty$, CAPACITOR ACTS AS AN OPEN CIRCUIT)

(4) $\tau = 1$ SEC

THUS:

$$i_c(t) = \begin{cases} 0 & ; t < 0 \\ 2e^{-t} & ; t > 0 \end{cases}$$

(ii) SUMMING VOLTAGES AROUND LOOP FOR $t > 0$:

$$-12 + 6\, i_c(t) + \left[ 6 \int_{t_0}^{t} i_c(t)\,dt + V_c(t_0) \right] = 0$$

DIFFERENTIATE:

$$6 \frac{d\, i_c(t)}{dt} + 6\, i_c(t) = 0$$

OR

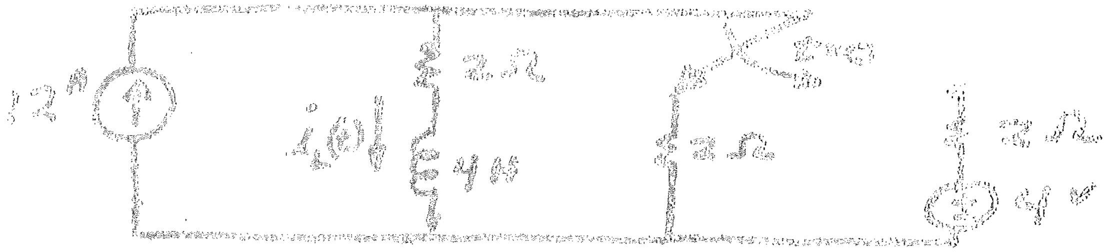
$$\frac{d\, i_c}{dt} = -i_c(t)$$

(iii) OUR SOLUTION IN (i) WAS

$$i_L(t) = 2e^{-t} \quad ; t > 0$$

THUS $$\frac{di_L}{dt} = -2e^{-t} = -i_L(t)$$

(2)

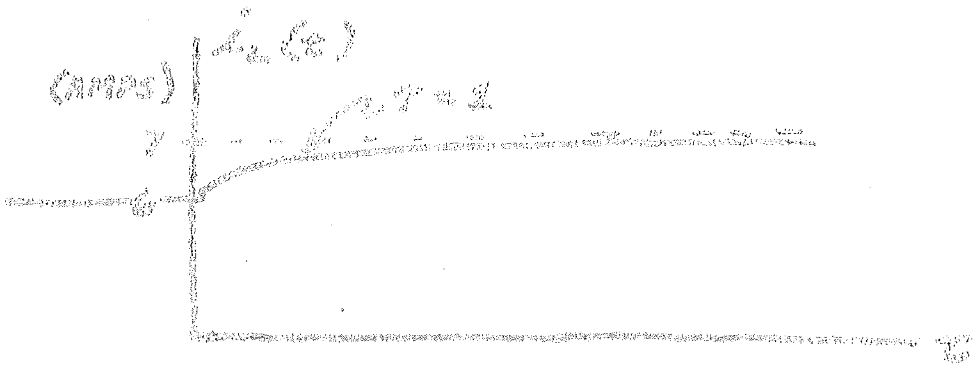


(1) $i_L(0^-)$ = 6 AMPS (INDUCTOR ACTS LIKE A SHORT, AND WE ARE LEFT WITH A CURRENT DIVIDER.)

(2) $i_L(0^+)$ = 6 AMPS (ENERGY CONTINUITY)

(3) $i_L(\infty)$ = 7 AMPS (@ ∞, L ACTS AS SHORT. USE SUPERPOSITION ON REMAINING CIRCUIT. SHORTING 4V SUPPLY, AND LOOKING AT CURRENT SUPPLY, WE GET, USING A CURRENT DIVIDER, $i_c(\infty)$ = 6 AMPS DUE TO CURRENT SUPPLY. NEXT, OPEN CURRENT SUPPLY AND LOOK AT EFFECT OF 4V SUPPLY. BY VOLTAGE DIVIDER, WE HAVE 2 VOLTS ACROSS OUR RESISTOR ⇒ $i_V(\infty) = 2/2 = 1$ AMP. USING SUPERPOSITION, $i_L(\infty) = i_c(\infty) + i_V(\infty)$ = 7 AMPS

(4) $\tau = \frac{L}{R_{eq}} = \frac{4H}{2\Omega + 2\Omega} = 1 \text{ sec}$



$$i_L(t) = \begin{cases} 6 & ; t < 0 \\ 6 + 1(1 - e^{-t/\tau}) & ; t > 0 \end{cases}$$

$$= \begin{cases} 6 & ; t < 0 \\ 7 - e^{-t} & ; t > 0 \end{cases}$$

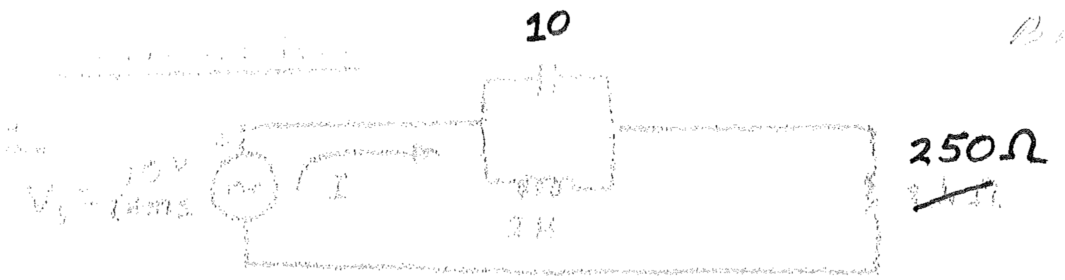
"WORK MAKES LIFE SWEET"

OLD GERMAN PROVERB.

"EH?"

OLD GERMAN

BCF



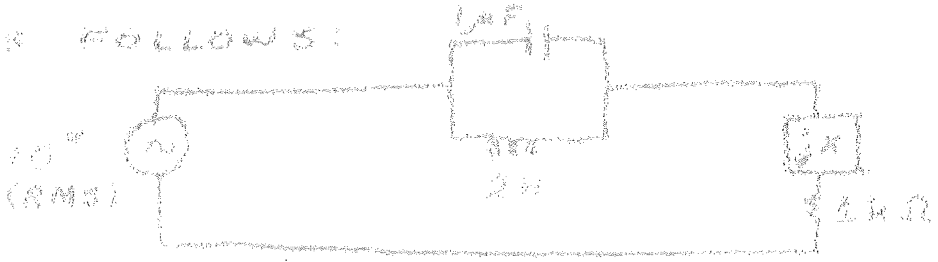
(a) GIVEN THAT $\omega = 100 \frac{\text{RADIANS}}{\text{SEC}}$, AND USING I AS A REFERENCE, SKETCH A PHASER DIAGRAM OF I AND $V_s$.

(b) FROM THIS SKETCH, FIND THE POWER ANGLE, Θ.

(c) WHAT IS THE AVERAGE ACTIVE POWER ASSOCIATED WITH THE 1kΩ RESISTOR? WHAT PERCENT OF VI IS THUS UTILIZED AS ACTIVE (USEFUL) POWER?

(d) IS THE CIRCUIT INDUCTIVE OR CAPACITIVE?

2. WE WISH TO COMPENSATE THE ABOVE CIRCUIT AS FOLLOWS:



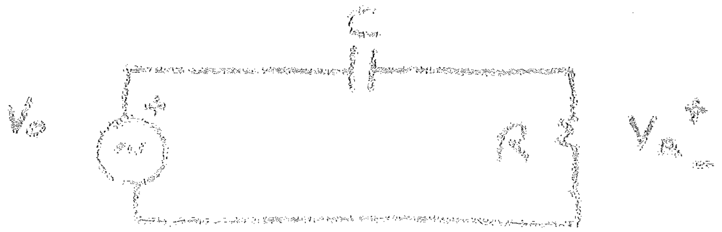
a) FIND jX SUCH THAT THE RATIO OF ACTIVE POWER TO VI IS MAXIMUM (HINT: SET ALL SERIES REACTANCE TO ZERO)

(b) IS X CAPACITIVE OR INDUCTIVE? THAT IS DO WE NEED A CAPACITOR FOR COMPENSATION OR DO WE NEED AN INDUCTOR?

(c) AT $\omega = 100$, WHAT IS THE REQUIRED VALUE OF THE CAPACITOR OR INDUCTOR?

(d) AFTER COMPENSATION, WHAT IS THE TOTAL ACTIVE POWER ASSOCIATED WITH THE 1kΩ RESISTOR?

3.

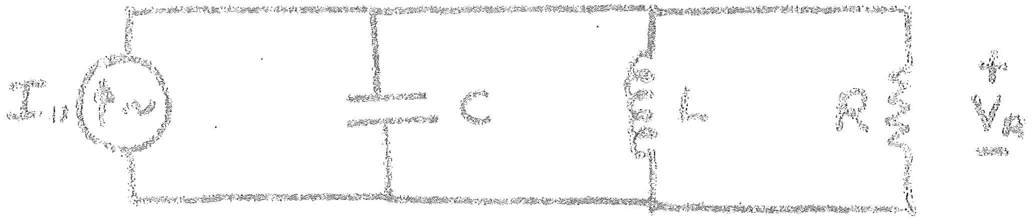


(CLASS PROBLEM)

SHOW THAT

$$|V_R|/|V_0| = \frac{1}{\sqrt{1+(1/\omega RC)^2}}$$

4.



(a) FIND $|V_R|$ AS A FUNCTION OF $I_0, \omega, C, R,$ AND $L$ (USE CURRENT DIVIDER)

(b) WHAT IS $|V_R(\omega=0)|$ ?

WHAT IS $|V_R(\omega=\infty)|$ ?

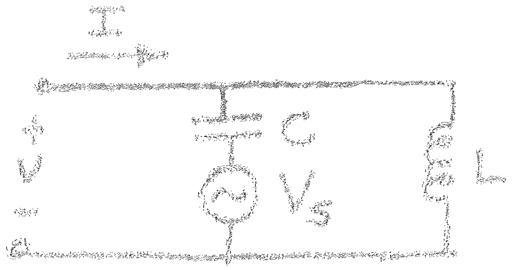
FOR WHAT VALUE OF $\omega$ IS $|V_R(\omega)|$ MAXIMUM? WHAT IS $|V_R(\omega)|$ AT THIS FREQUENCY?

(c) MAKE A GENERAL SKETCH OF $\left|\frac{V_R}{I_0 R}\right|$ VS $\omega$ USING THE RESULTS OF (b).

(d) IF WE WERE TO INCREASE THE VALUE OF L, WHAT WOULD HAPPEN TO THE PEAK OF THE CURVE IN PART C?

5. THE FREQUENCY RESPONSE IN PROBLEM (3) WAS SHOWN IN CLASS TO BE A ~~LOW~~ HI PASS FILTER. IF JOHNNY CASH (LOW VOICE) AND TINY TIM (HI VOICE) SANG A DUET INTO A MICROPHONE (CORRESPONDING TO $V_o$) AND YOU LISTENED THROUGH HEADPHONES (CORRESPONDING TO R AND $V_R$), WHICH OF THE TWO SINGERS WOULD YOU HEAR BEST? WHY?

6.



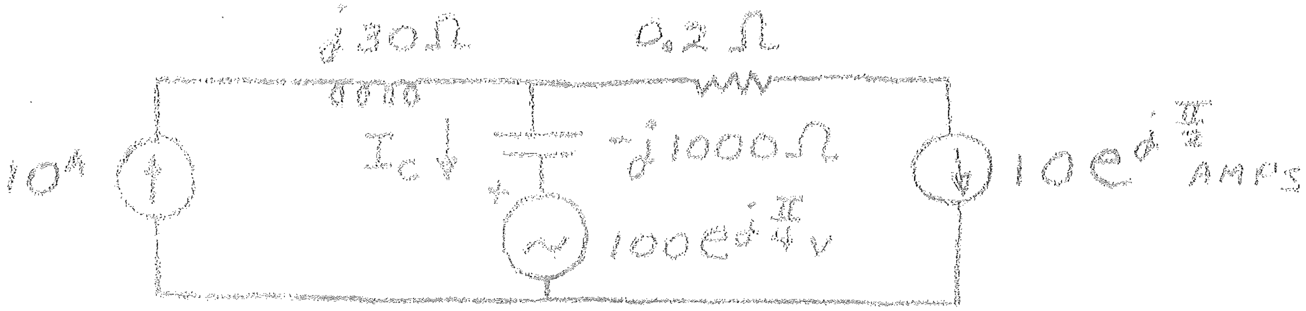
(a) SHOW THAT: $I_{sc} = -j\omega C V_s$

$V_{oc} = \dfrac{\omega L V_s}{\omega L - 1/\omega C}$ AND $Z_{eq} = \dfrac{-j\omega L}{\omega^2 LC - 1}$

(b) SKETCH THE THEVININ AND NORTON EQUIVALENT CIRCUITS

(c) WHAT DOES THE NORTON CIRCUIT CORRESPOND TO WHEN L AND C ARE AT RESONANCE?

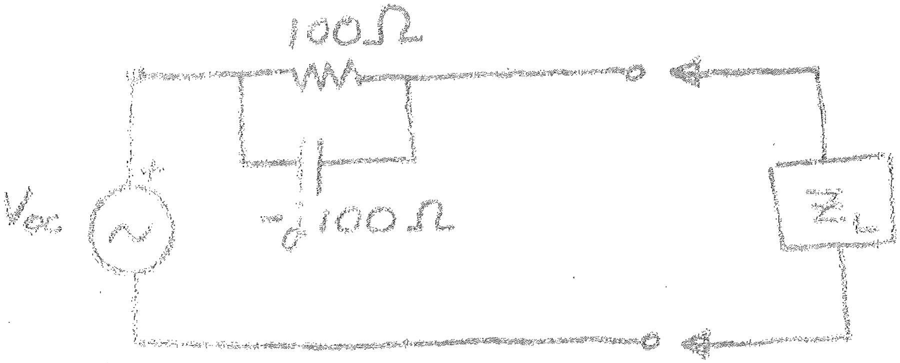
7.



(a) USING SUPERPOSITION, FIND $I_C$

(b) WHICH LUMPED CIRCUIT ELEMENTS HERE DO NOT HAVE AN EFFECT ON THE VALUE OF $I_C$?

8.



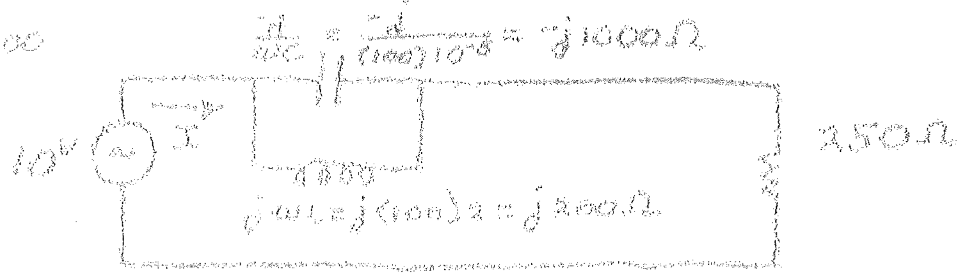
(a) FIND $Z_L$ SUCH THAT MAXIMUM POWER IS TRANSFERED TO THE LOAD.

(b) ASSUMING THAT $\omega = 25 \frac{RAD}{SEC}$, DETERMINE A TWO ELEMENT SERIES COMBINATION WHICH WILL GIVE THE DESIRED $Z_L$. SPECIFY EACH ELEMENT'S VALUE IN OHMS, FARADS, OR HENRIES AS APPROPRIATE.

9. Pg. 203, #5

## HOMEWORK SOLUTIONS

1. $\omega = 100$



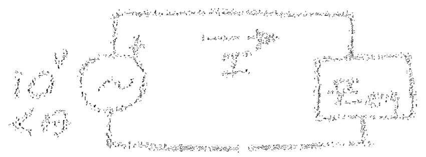
2. COMBINING L & C:

$$\frac{1}{Z_{eq}} = \frac{1}{j200} + \frac{1}{-j1000} = \frac{1}{j200}\left[1 - \frac{1}{5}\right]$$

$$= \frac{1}{j200}\left(+\frac{4}{5}\right) = +\frac{1}{j250} \Rightarrow Z_{eq} = +j250\Omega$$

COMBINING THIS AND RESISTOR GIVES **ETC**

$$Z_{eq} = 250 + j250$$



NOW $V = IZ$

$$10\angle\theta = [I\angle 0][250 + j250]$$

$$10e^{j\theta} = 250 I(1 + j)$$

$$= \sqrt{2}\,250 I e^{+j\pi/4}$$

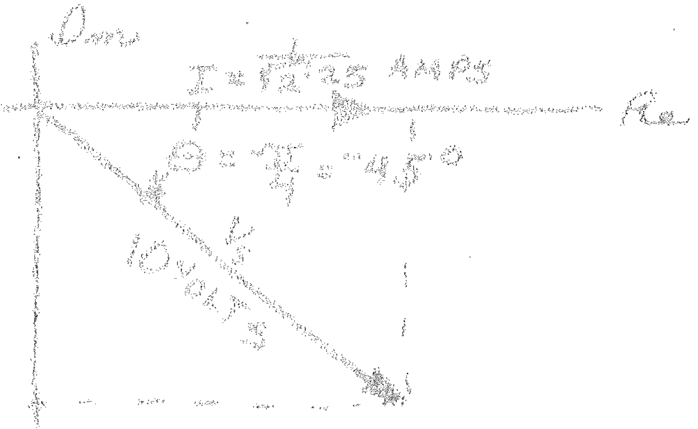
EQUATING THE MAGNITUDES:

$$10 = \sqrt{2}\,250 I \Rightarrow I = \frac{1}{\sqrt{2}\,25} \text{ AMPS}$$

EQUATING arg( ):

$$\theta = +\pi/4$$

$$\Rightarrow V = 10e^{+j\pi/4}, \quad I = \frac{1}{\sqrt{2}\,25} = 0.0283$$



b. OBVIOUSLY, $\theta = +\frac{\pi}{4} = +45^\circ$

c. $I = 1/\sqrt{2}\,25$ AMPS (RMS)

$P_R$ = AVERAGE POWER IN RESISTOR

$= I^2 R = \frac{\text{AMP}}{2\cdot 25\cdot 25} \times 250\Omega = \frac{1}{5}$ WATT

$|VI| = P_R / \cos\theta = \sqrt{2}\, P_R = \sqrt{2}/5$ VOLT-AMPS

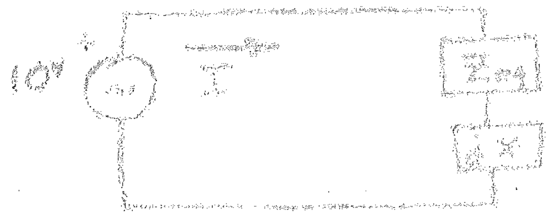
THUS $P_R/|VI| = \frac{1}{\sqrt{2}} \cong 70\%$

d. THE CIRCUIT IS CAPACITIVE SINCE THE SUM TOTAL OF THE REACTANCE IS NEGATIVE.

2. IN PROB. 1, WE SHOWED THAT

$Z_{eq} = 250 - j250 \ \Omega$

THUS OUR CIRCUIT IS



a. TO MAXIMIZE RATIO OF USEFUL POWER TO $|VI|$, WE SET ALL REACTANCE TO ZERO:

$0 = j\,\text{Im}[Z_{eq}] + jX = -j250 + jX$

THUS $X = 250\ \Omega$

b. SINCE $X > 0$, IT IS INDUCTIVE

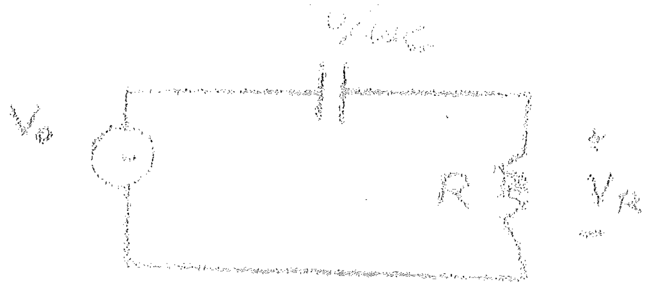
$X = \omega L \Rightarrow 250 = (100)L \Rightarrow L = 2.5$ HENRIES

c. AFTER COMPENSATION, WE ARE @ RESONANCE AND $V_s = RI \Rightarrow$ THUS

$P_{ACTIVE} = V_s^2/R = 100/250 = 0.4$ WATTS

(NOTE THIS IS LARGER THAN OUR POWER IN PROBLEM 1C).

3.



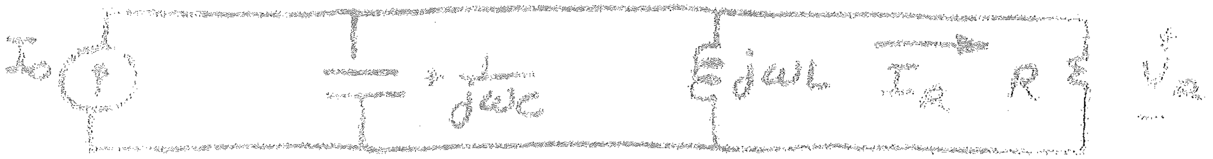
BY VOLTAGE DIVIDER:

$$V_R = \frac{R}{R - j/\omega C} V_o = \frac{V_o}{1 - j/\omega RC}$$

$$\Rightarrow V_R/V_o = 1 \Big/ 1 - j/\omega RC$$

$$\Rightarrow |V_R/V_o| = 1 \Big/ \sqrt{1 + (1/\omega RC)^2}$$

4.



(a) BY CURRENT DIVIDER

$$I_R = \frac{1/R}{1/R - j/\omega L + j\omega C} I_o$$

$$= \frac{I_o}{1 + j(\omega RC - R/\omega L)}$$

$$V_R = I_R R = \frac{I_o R}{1 + j(\omega RC - R/\omega L)}$$

THUS

$$|V_R| = \frac{|I_o| R}{\sqrt{1 + (\omega RC - \frac{R}{L\omega})^2}}$$

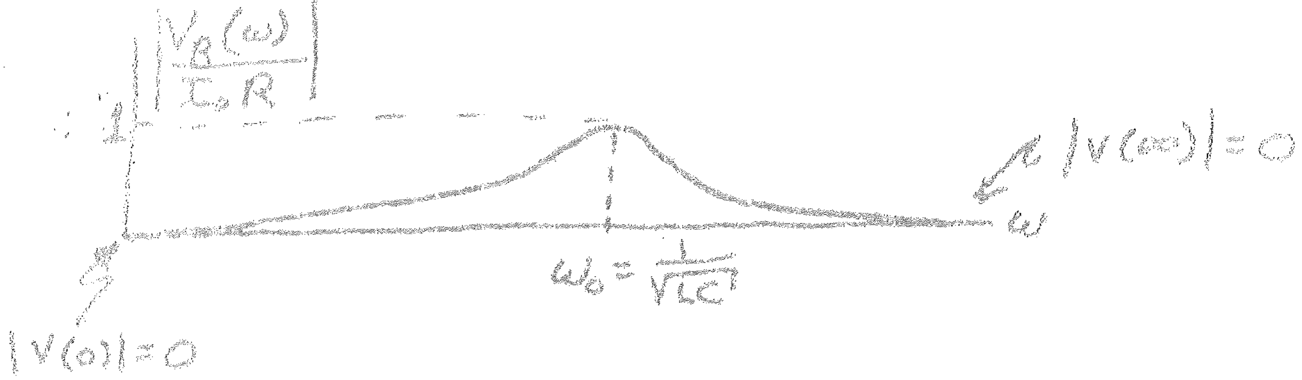
(b) $|V_1(\infty)| = |V_R(0)| = 0$

$|V_R(\omega)|$ WILL BE MAXIMUM WHEN L & C ARE AT RESONANCE:

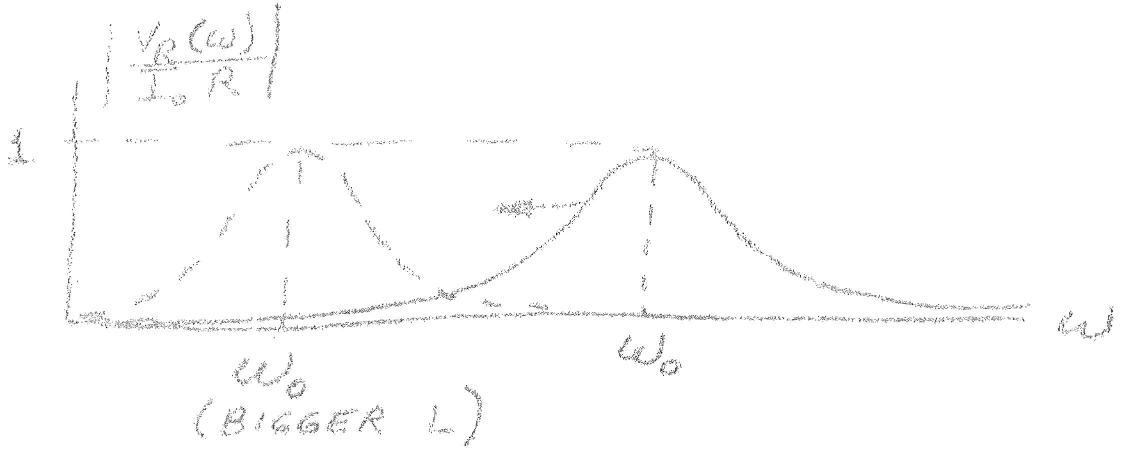
$$\omega_0 = 1/\sqrt{LC}$$

AT $\omega = \omega_0$; $|V_R(\omega)| = |I_0| R$

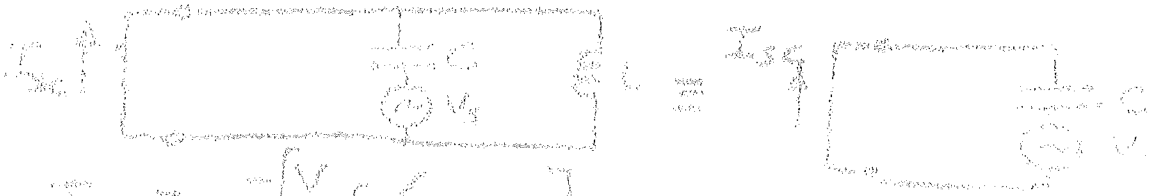
(c) $$\left|\frac{V_R}{I_0 R}\right| = \frac{1}{\sqrt{1 + \left(\omega RC - \frac{B}{\omega L}\right)^2}}$$



(d) INCREASING L DECREASES $\omega_0 = \frac{1}{\sqrt{LC}}$ THUS, THE PEAK OF THE CURVE WILL SHIFT TO THE LEFT

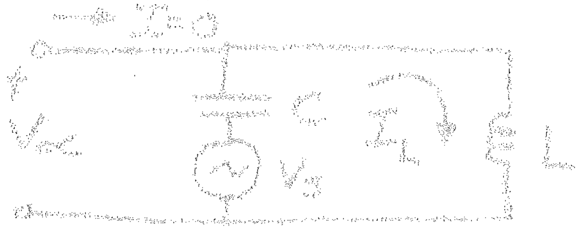


6, (a) FIND $I_{sc}$



$$I_{sc} = -\left[V_s / \tfrac{1}{j\omega C}\right] = -j\omega C\, V_s \Leftarrow \text{OHM'S LAW}$$

FIND $V_{oc}$



$$V_s = \left(\frac{-j}{\omega C} + j\omega L\right) I_L \Leftarrow \text{KIRCH. LOOP LAW}$$

$$\Rightarrow I_L = \frac{V_s}{-j/\omega C + j\omega L} = \frac{V_s}{j\left(\omega L - \frac{1}{\omega C}\right)}$$

SINCE L IS IN PAR. WITH $V_{oc}$:

$$V_{oc} = (j\omega L) I_L \Leftarrow \text{OHMS LAW}$$

$$= \frac{(j\omega L)V_s}{j\left(\omega L - \frac{1}{\omega C}\right)} = \frac{\omega L\, V_s}{\omega L - 1/\omega C}$$

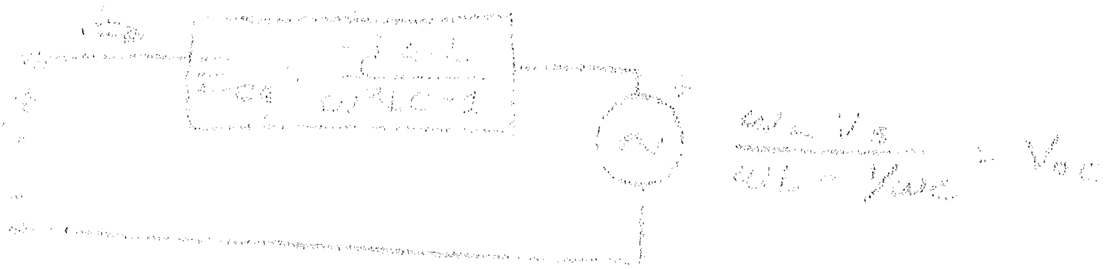
NOW

$$Z_{eq} = V_{oc}/I_{sc} = \frac{\frac{\cancel{\omega} L \cancel{V_s}}{\omega L - 1/\omega C}}{-j\cancel{\omega} C \cancel{V_s}}$$

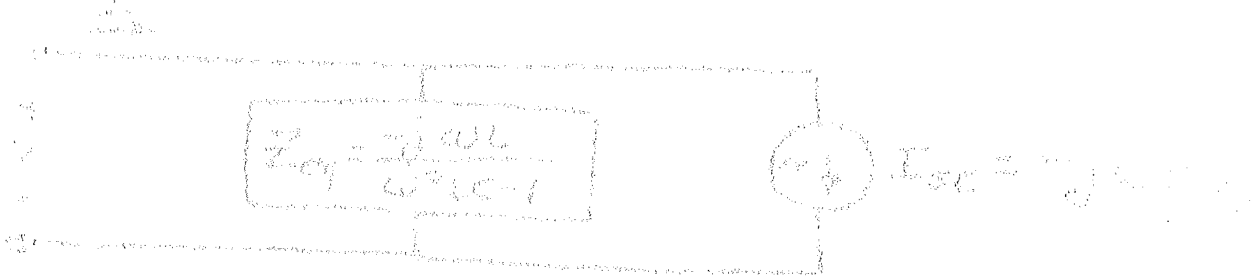
$$= \frac{-j L}{C\left(\omega L - \frac{1}{\omega C}\right)}$$

$$= \frac{-j L}{\omega LC - 1/\omega} = \frac{-j\omega L}{\omega^2 LC - 1}$$

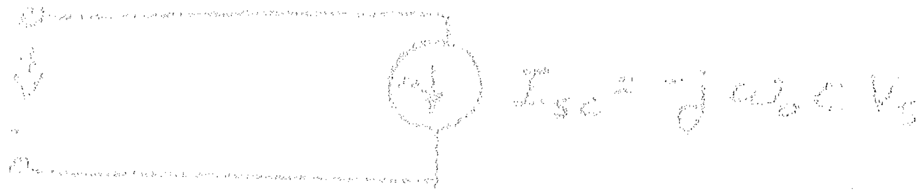
(b) THEVENIN:



NORTON:

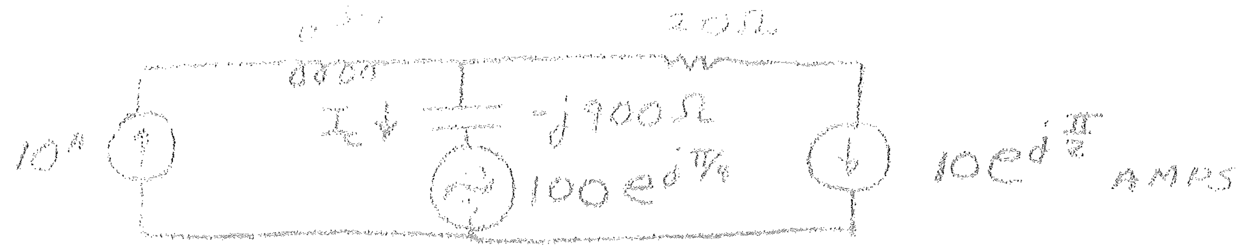


(c) AT RESONANCE, $\omega^2 = 1/LC = \omega_0^2$ AND $Z_{eq} = \infty$ = OPEN CIRCUIT. THE NORTON EQUIVALENT BECOMES:



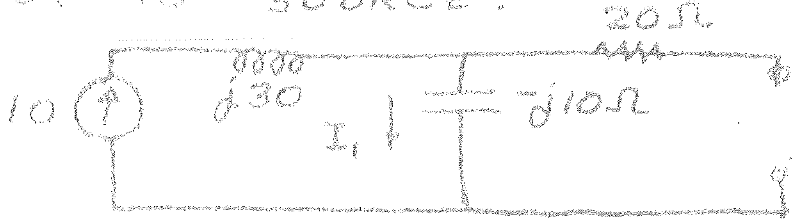
THIS, OF COURSE, IS AN IDEAL CURRENT SOURCE.

7.



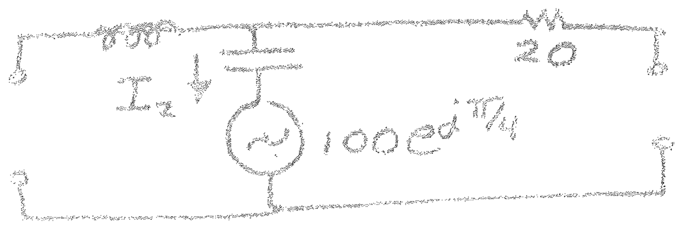
(a) FIND $I_c$

FOR $10^A$ SOURCE:



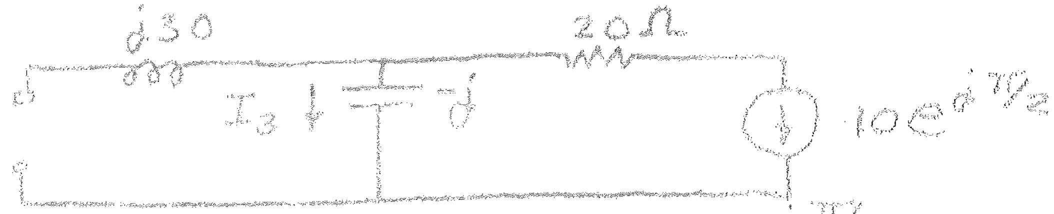
OBVIOUSLY, $I_1 = 10$ AMPS

FOR $100e^{j\pi/4}$ VOLT SUPPLY:



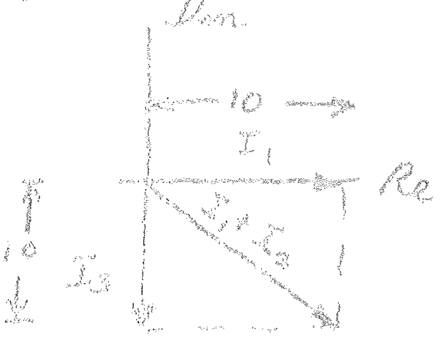
OBVIOUSLY, $I_2 = 0$

FOR $20e^{j\pi/2}$ CURRENT SUPPLY:



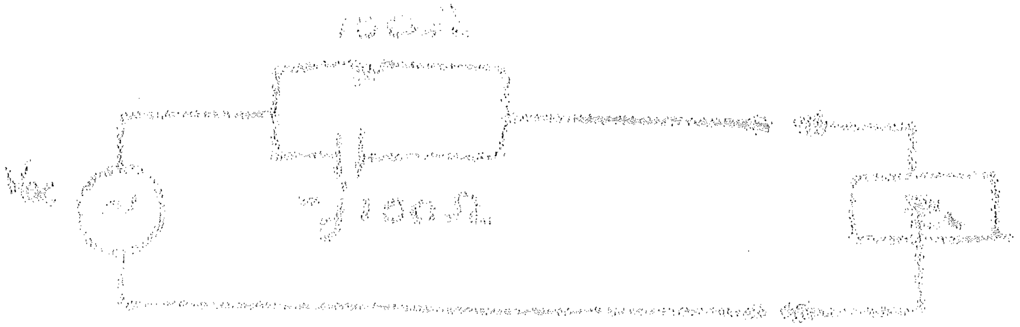
OBVIOUSLY, $I_3 = -10e^{j\pi/2}$

$I_c = I_1 + I_2 + I_3 = \sqrt{2}\,10e^{-j\pi/4}$ AMPS.



b. ONLY THE CURRENT SOURCES HAVE AN EFFECT ON $I_c$ ⇒ $I_c$ IS INDEPENDENT OF VOLTAGE SOURCE, R, L, AND C.

8.



(a) $\frac{1}{Z_{eq}} = \frac{1}{100} - \frac{1}{j100} = \frac{1}{100}\left(1 - \frac{1}{j}\right) = \frac{j+1}{j100}$

$\Rightarrow Z_{eq} = \frac{100}{j+1} \cdot \frac{(j+1)}{(j+1)} = \frac{100(1-j)}{2} = 50 - j50\,\Omega$

MAXIMUM POWER WILL BE XMITTED WHEN

$Z_L = Z_{eq}^{*} = 50 + j50\,\Omega$

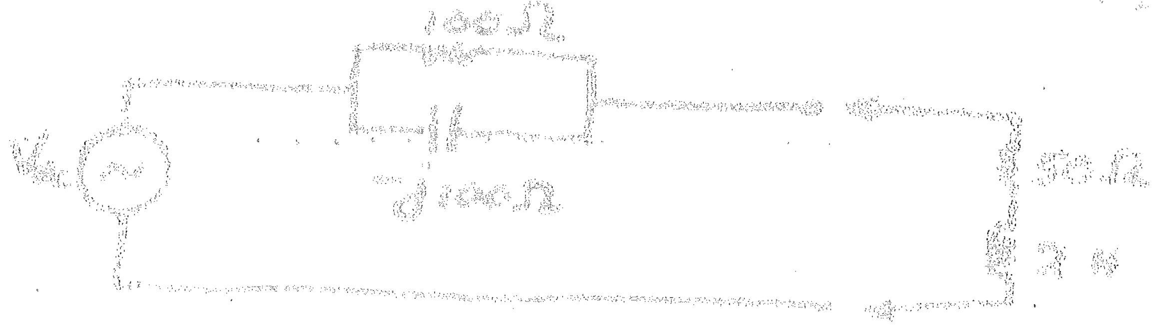
(b) $Z_L = 50 + j50\ \Omega$

$R_L = 50\,\Omega \quad X_L = 50\,\Omega$

$X_L > 0 \Rightarrow$ WE MUST USE AN INDUCTOR:

$X_L = 50 = \omega L = 25L \Rightarrow L = 2\,H$

THUS, OUR RESULTING CIRCUIT IS:



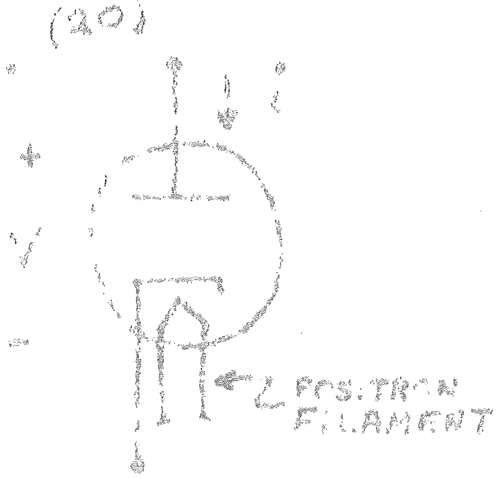
"COMMON SENSE IS PREJUDICE LEARNED BEFORE THE AGE 18"

ALBERT EINSTEIN

EE

TEST #3    DEC. 10, 1976    BOB MARKS

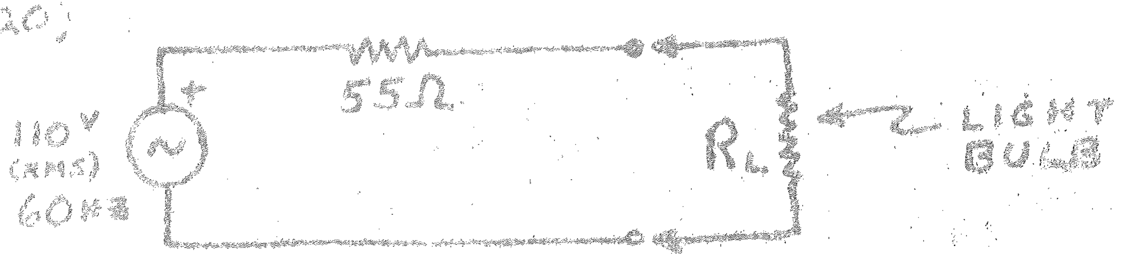
1. (20)



SUPPOSE AN ELECTRONICS FIRM HAS INVENTED A "POSITRON FILAMENT" THAT BOILS OFF POSITRONS INSTEAD OF ELECTRONS. (A POSITRON HAS AN EQUAL BUT OPPOSITE CHARGE OF AN ELECTRON).

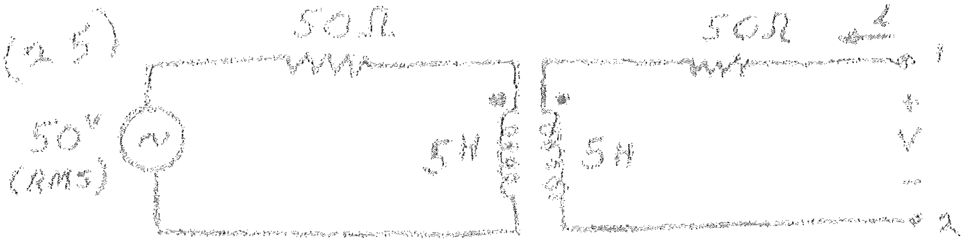
EXPLAINING YOUR REASONING, SKETCH THE V-$i$ CURVE OF A TUBE-TYPE DIODE WHICH USES THIS POSITRON FILAMENT. USE $i$ AS YOUR VERTICAL AXIS AND ASSUME THAT THE DIODE IS A SHORT CIRCUIT WHEN IT CONDUCTS.

2. (20)



A LIGHT BULB, DENOTED BY $R_L$, IS PLUGGED INTO A 110 VOLT (RMS) 60HZ OUTLET. WHAT AVERAGE POWER IS DISSIPATED BY THE BULB WHEN THE MOST EFFICIENT USE IS MADE OF THE SOURCE? HOW WOULD THIS POWER BE EFFECTED IF WE RAISED THE FREQUENCY TO 120HZ?

3. (25)

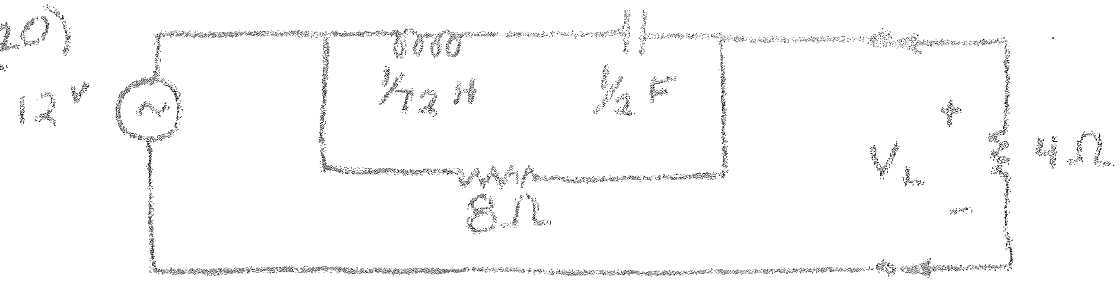


AN IDEAL TRANSFORMER (K=1) IS USED IN THE ABOVE CIRCUIT WITH $\omega=10$

(a) DETERMINE AND SKETCH THE THEVENIN AND NORTON EQUIVALENT CIRCUITS.

(b) IF WE WISHED TO CONNECT AN IMPEDANCE $Z_L$ BETWEEN TERMINALS 1 AND 2 SUCH THAT MAXIMUM POWER IS TRANSFORMED, WHAT VALUE OF $Z_L$ WOULD WE USE? IS $Z_L$ CAPACITIVE OR INDUCTIVE? WHY?

4. (20)



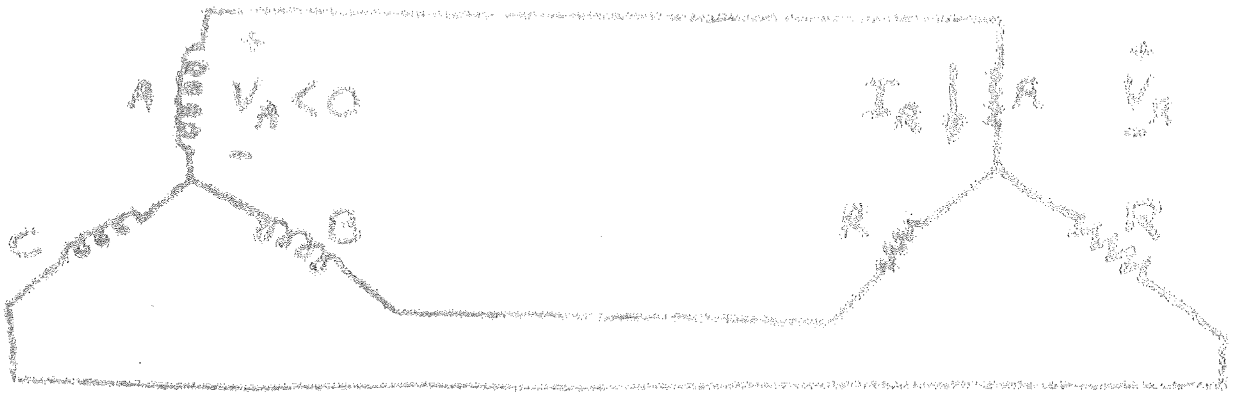
(a). DETERMINE $V_L(\omega)$ FOR $\omega=0$ AND $\omega=\infty$

(b). AT WHAT FREQUENCY IS $|V_L(\omega)|$ MAXIMUM? WHY? WHAT IS THE VALUE OF $V_L(\omega)$ AT THIS FREQUENCY?

(c). USING THE RESULTS OF (a) AND (b), MAKE A ROUGH SKETCH OF $|V_L(\omega)|$.

(25)

5. FOR THE FOLLOWING 3-PHASE CIRCUIT, USE THE VOLTAGE ACROSS COIL A, $V_A$, AS A REFERENCE, AND FIND $I_R$ AND $V_R$ AS A FUNCTION OF THE VOLTAGE $V_A$ AND THE RESISTANCE R.



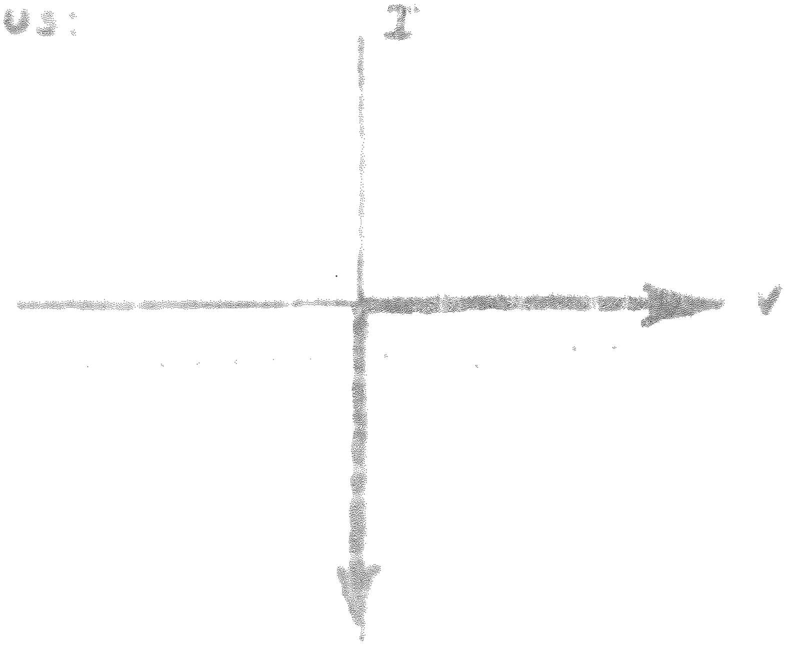
# TEST # 3 SOLUTIONS by MARKS

1.

WHEN WE MAKE $V > 0$, THE PLATE WILL BE AT A HIGHER VOLTAGE THAN THE CATHODE. THE NEGATIVE CATHODE WILL ATTRACT THE POSITRONS AND THE POSITIVE PLATE WILL REPEL THEM. THUS, NO POSITRON FLOW AND WE HAVE AN OPEN CIRCUIT:

$$I = 0 \quad \text{FOR} \quad V > 0$$

AS SOON AS WE TRY TO MAKE $V < 0$, POSITRONS WILL START TO FLOW AND WE WILL HAVE A CURRENT FLOWING FROM THE CATHODE TO THE PLATE (ie, POSITIVE CHARGE FLOW). THUS, FOR $I < 0$, $V = 0$. THE V-I CURVE IS THUS:



2. MAXIMUM POWER IS TRANSFERED WHEN $Z_L = Z_{eq}^*$. THUS, WE HAVE $Z_L = (55\Omega)^* = R_L = 55\Omega$. WITH THIS LOAD, WE MAY USE A VOLTAGE DIVIDER TO FIND THE VOLTAGE ACROSS $R_L$:

$$V_L = \frac{R_L}{R_L + 55} 110^V = \frac{1}{2} 110V = 55V \text{ (RMS)}$$

THE AVERAGE POWER IS

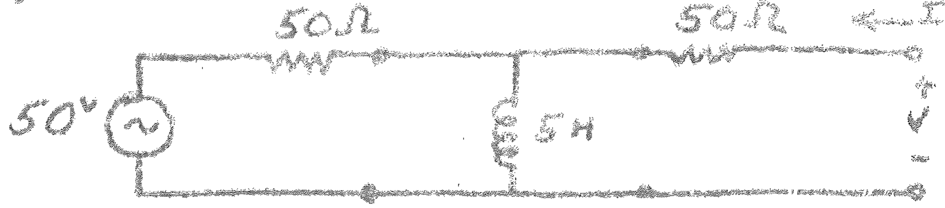
$$P_{AVE} = V_L^2 / R_L = (55 V_{RMS})^2 / 55\Omega = 55 \text{ WATTS}$$

FREQUENCY HAS NO EFFECT ON THIS POWER.

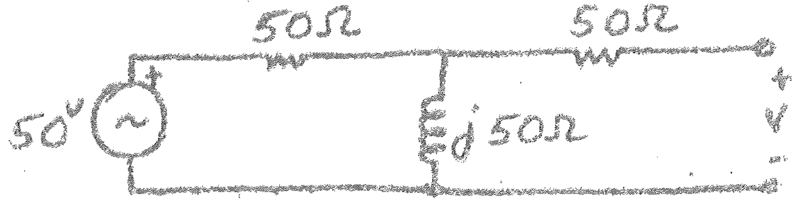
3(a) FIRST, COMPUTE M:

$$M = k\sqrt{L_1 L_2} = 1\sqrt{5 \cdot 5} = 5H$$

NOW, USE THE T EQUIVALENT CIRCUIT:



USE ω = 10 AND WRITE IMPEDANCE:



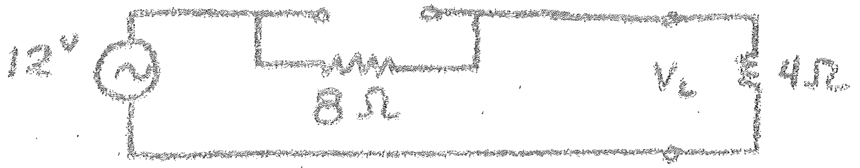
USE VOLTAGE DIVIDER TO FIND $V_{OC}$:

$$V_{OC} = \frac{j50}{50 + j50} \ast 50 = \frac{j50}{1+j} \cdot \frac{1-j}{1-j} = 25(1+j)$$

VOLTS (RMS)

(3b) MAXIMUM POWER IS TRASFERRED WHEN $Z_L = Z_{eq}^* = (75 + j25)^* = 75 - j25\ \Omega$; $Z_L$ IS CAPACITIVE SINCE IT HAS A NEGATIVE REACTANCE.

4. (a) AT $\omega = 0$, THE CAPACITOR ACTS LIKE AN OPEN CIRCUIT:



USING A VOLTAGE DIVIDER:

$$V_L = \frac{4}{4+8}\ 12 = 4 \text{ VOLTS}$$

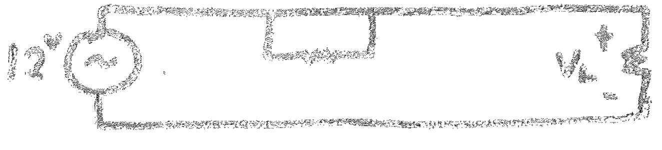
AT $\omega = \infty$, THE INDUCTOR ACTS LIKE AN OPEN CIRCUIT. THUS

$$V_L(\infty) = V_L(0) = 4 \text{ VOLTS}$$

(b) $V_L(\omega)$ WILL BE MAXIMUM WHEN L AND C ARE AT RESONANCE:

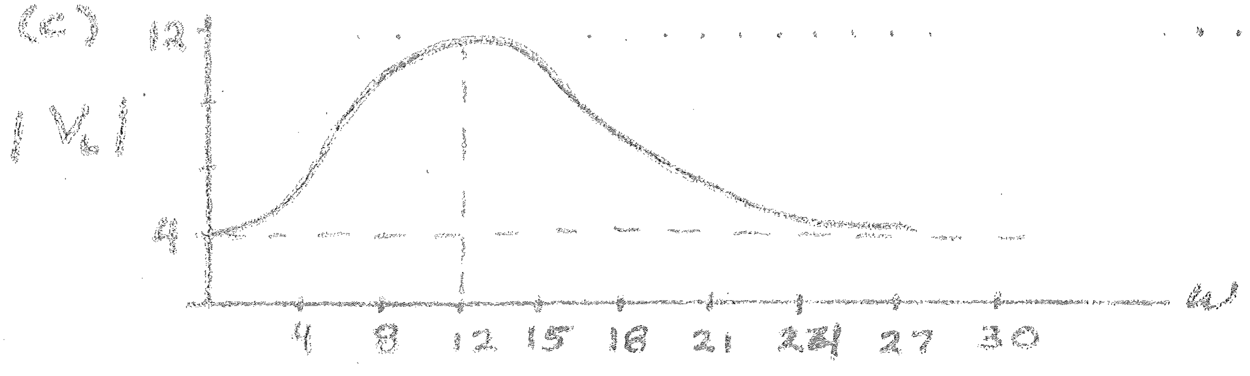
$$\omega_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{\frac{1}{72} \cdot \frac{1}{2}}} = \sqrt{144} = 12 \frac{\text{RAD}}{\text{SEC}}$$

AT THIS FREQUENCY, L AND C ACT LIKE A SHORT CIRCUIT:



$\Rightarrow V_L(\omega_o) = 12\ V$

(c)



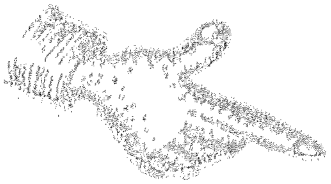
(NAME)

EE 233
"ELECTRICAL SYSTEM'S ANALYSIS"
SECTION 002
**BOB MARKS**

# FINAL EXAM

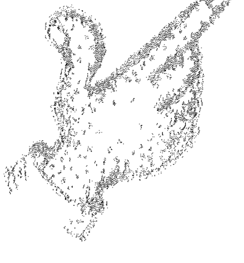
| | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| → | |
| FINAL SCORE | |
| | |
| % | |

- TIME: $2\frac{1}{2}$ HOURS
- 270 POINTS TOTAL.
- WORK PROBLEMS IN THIS BOOKLET. FOR ADDITIONAL PAPER, SEE INSTRUCTOR.



"...THE WISDOM OF THIS WORLD
IS FOOLISHNESS WITH GOD."
1 COR. 3:19

"COMMIT THE WORKS UNTO THE LORD,
AND THY THOUGHTS SHALL BE
ESTABLISHED"
PROV. 16:3



#1. (60)

TRUE / FALSE

STATE YOUR ANSWER WITH A "T" FOR TRUE AND AN "F" FOR FALSE. ANSWERS RESEMBLING "$\overset{T}{F}$" WILL NOT BE GRADED. DO NOT ANSWER QUESTIONS YOU ARE COMPLETELY UNSURE OF.

TOTAL SCORE = TOTAL RIGHT − ½ TOTAL WRONG

1. CURRENT MAY BE DEFINED AS THE RATE OF CHANGE OF VOLTAGE WITH RESPECT TO TIME. ________

2. POWER IS THE RATE AT WHICH ENERGY IS TRANSFERRED WITH RESPECT TO TIME. . . ________

3. FOR A UNIFORM CURRENT DENSITY, THE RESISTANCE OF A CYLINDRICAL CONDUCTOR IS PROPORTIONAL TO ITS CROSS SECTIONAL AREA. . . . . . . . ________

4. CONDUCTANCE, ADMITTANCE, AND SUSCEPTANCE ARE ALL MEASUREABLE IN UNITS OF "SIEMENS". ________

5. CAPACITOR'S, INDUCTORS, AND RESISTORS ARE ALL CAPABLE OF STORING ENERGY. . . . . . . . . . ________

6. CAPACITORS STORE ENERGY IN AN ELECTRIC FIELD. . . . . . . . . . . . . . . . . . . . . . ________

7. VOLTAGE CANNOT CHANGE INSTANTANEOUSLY ACROSS AN INDUCTOR. . . . . . . . . . . . ________

8. OHM'S LAW MAY BE WRITTEN: $I = GV$ . . . ________

9. THE V-i CHARACTERISTIC OF AN INDUCTOR IS: $i = L\, dV/dt$ . . . . . . ________

FOR OFFICIAL USE ONLY

| | |
|---|---|
| YOUR LAB GRADE: | |
| YOUR COURSE GRADE FOR EE233 IS: | |

10. A CURRENT SOURCE WITH $I=0$ IS THE SAME THING AS AN OPEN CIRCUIT. . . . ________.

11. ALL MESHES ARE LOOPS AND VISA VERSA________.

12. IF TWO OR MORE LUMPED CIRCUIT ELEMENTS HAVE IDENTICAL VOLTAGES ACROSS THEM, THEY ARE SAID TO BE CONNECTED IN PARALLEL. . ________.

13. IF $C_1$ AND $C_2$ ARE CONNECTED IN SERIES, THE EQUIVALENT CAPACITANCE IS $C_{eq}=C_1+C_2$. . ________.

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21. IF $W$ IS A COMPLEX NUMBER, THEN $\arg W$ IS ALSO A COMPLEX NUMBER ________.

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23. IN A DEL CONNECTED THREE PHASE SYSTEM, $V_{LINE} = \sqrt{3}\, V_{COIL}$ . . . . . . ____________

24. THE DIFFUSION LENGTH IN A SEMICONDUCTOR DIODE DECREASES WHEN THE DIODE CONDUCTS . . . . . . . . . . . ____________

25. "REVERSE" BIASED SEMICONDUCTOR DIODES CONDUCT . . . . . . . . . . . ____________

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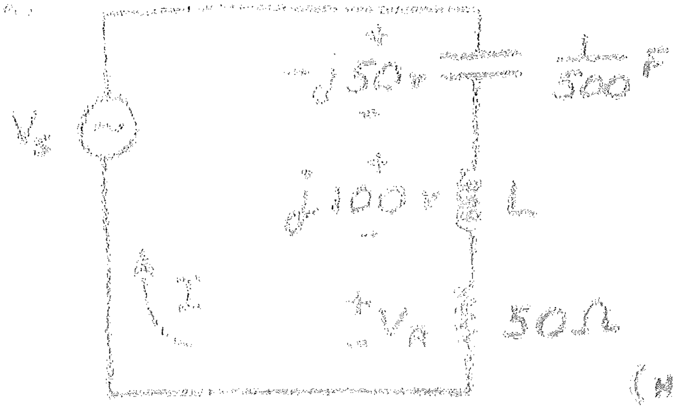
30. SILICON SEMICONDUCTORS MAY BE DOPED WITH ARSENIC AND SHOULD THUS NOT BE SWALLOWED. . . . . . . . . . . . ____________



**GIVEN THAT $\omega = 10$**

FIND

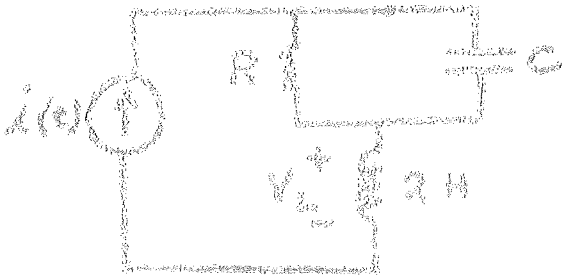
① $V_S$ (IN POLAR FORM)

② L (IN HENRIES)

(HINT: FIRST DETERMINE $I$)

(30)

#3.



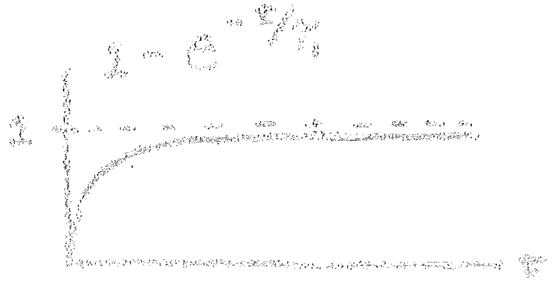
GIVEN THAT

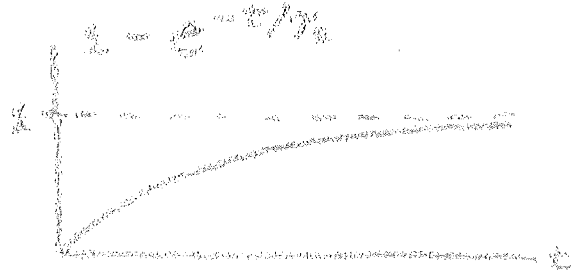
$$i(t) = \begin{cases} -t(1-t) \text{ amps} ; & 0<t<1 \\ 0 ; & \text{OTHERWISE} \end{cases}$$

WHERE t IS IN SECONDS, FIND AND SKETCH $V_L(t)$ FOR ALL t.

(30)

#4.

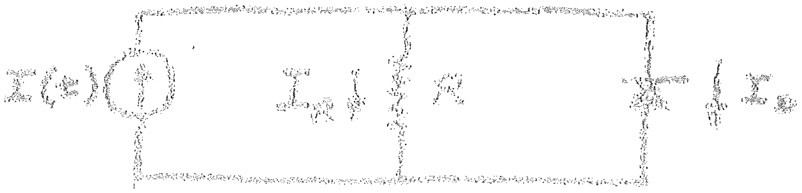




WHICH IS LARGER: $\tau_1$ OR $\tau_2$?
EXPLAIN YOUR REASONING.

(30)

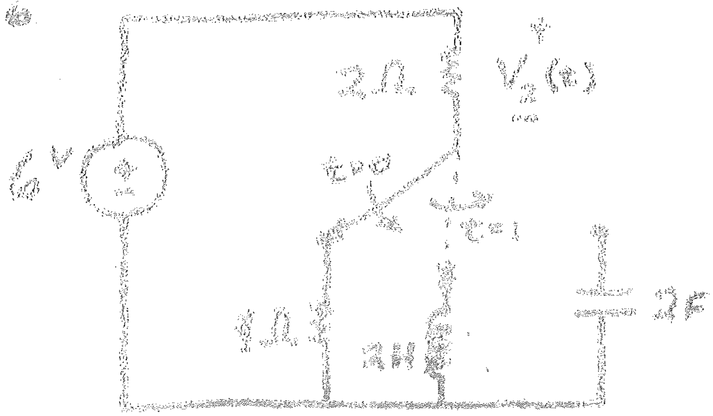
#5.



GIVEN THAT $I(t) = I_0 \sin 2\pi t$, SKETCH $I_R(t)$ AND $I_D(t)$. EXPLAIN YOUR REASONING.

(30)

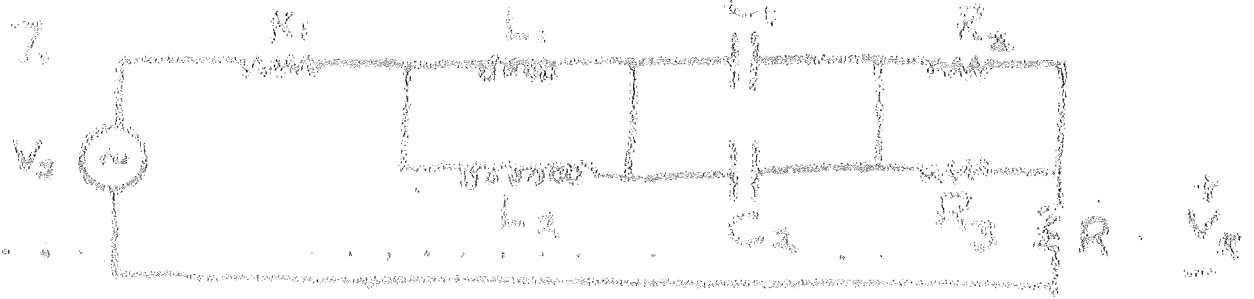
#6



THE SWITCH IS THROWN FROM THE 4Ω RESISTOR TO THE 2H INDUCTOR AT t=0 AND THEN TO THE 2F CAPACITOR ONE SECOND LATER. SKETCH $V_2(t)$ NOTING ALL TRANSIENT AND LIMITING VALUES FOR ALL TIME t. SPECIFY ALL TIME CONSTANTS IN YOUR SKETCH.

(30)

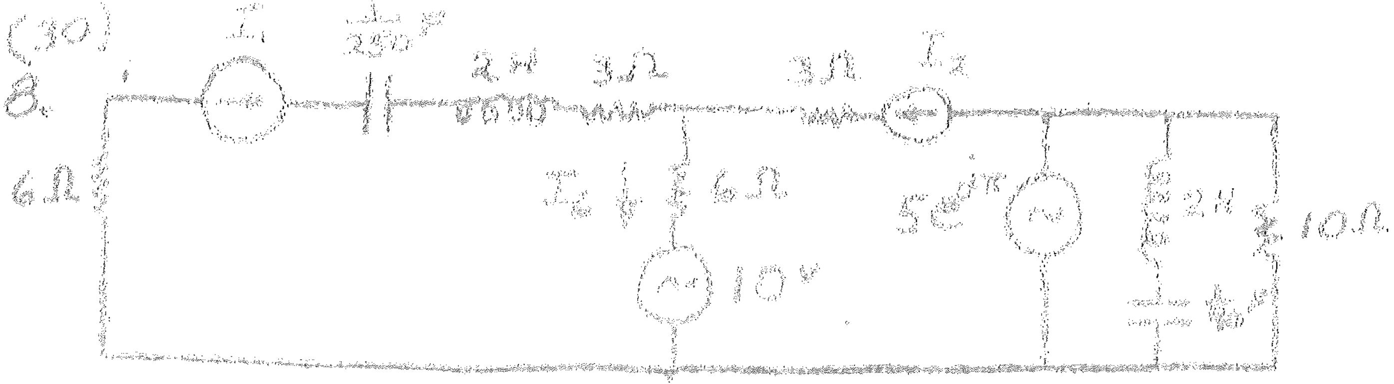
#7.



ASSUMING $R_1 = R_2 = R_3 = R$, $L_1 = L_2$, AND $C_1 = C_2$, SKETCH $|V_R(\omega)|$. SPECIFY $|V_R(\infty)|$, $|V_R(0)|$, AND THE FREQUENCY (OR FREQUENCIES) WHICH MAXIMIZE (OR MINIMIZE) $|V_R(\omega)|$

ALSO → WHAT TYPE OF FILTER IS THIS? ←

#8. (30)



FIND THE RELATION BETWEEN $I_1$ AND $I_2$ SUCH THAT $I_6 = \frac{1}{250}$ AMP. USE SUPERPOSITION AND SHOW WORK. $\omega = 10$.

EE 333
SEC 002
BOB
MARKS

#1. (60)

TRUE / FALSE

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[illegible]
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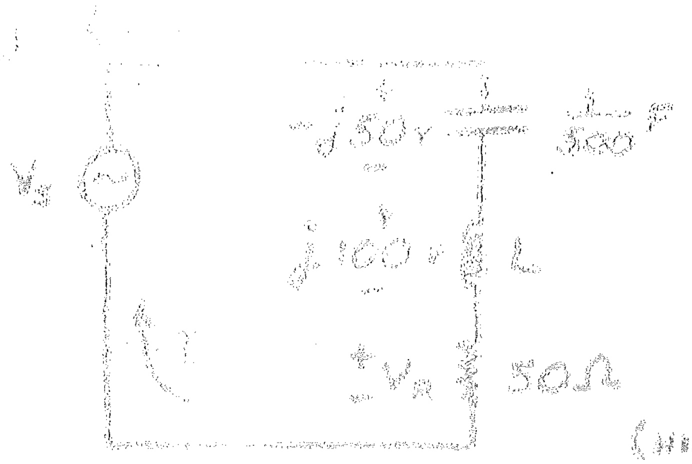
#1



GIVEN THAT $\omega = 10$

FIND

① $V_s$ (IN POLAR FORM)

② L (IN HENRIES)

(HINT: FIRST DETERMINE I)

NOW, THE CAPACITOR'S VOLTAGE IS

$$V_C = \frac{-j}{\omega C} I$$

$$\Rightarrow -j50 = \frac{-j}{(10)\left(\frac{1}{500}\right)} I$$

THUS

$$I = (50)(10)\left(\frac{1}{500}\right) = 1 \text{ AMP}$$

① $\Rightarrow V_R = (50\Omega)(1 \text{ AMP}) = 50$ VOLTS

SUMMING THE VOLTAGES AROUND THE LOOP:

$$V_s = (-j50) + (j100) + (50)$$

$$= 50 + j50 = \sqrt{2}\,50\,e^{j\pi/4}$$

② NOW THE VOLTAGE ACROSS INDUCTOR IS

$$V_L = (j\omega L) I$$

OR,

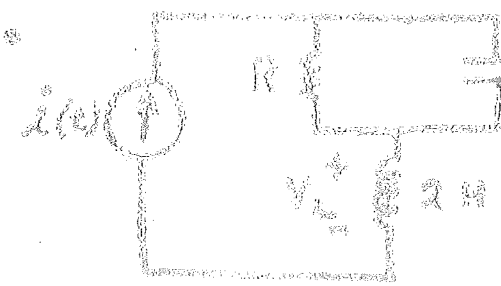
$$100 = j(10)L(1)$$

WHICH GIVES

$$L = 10\ H$$

(30)

#3.



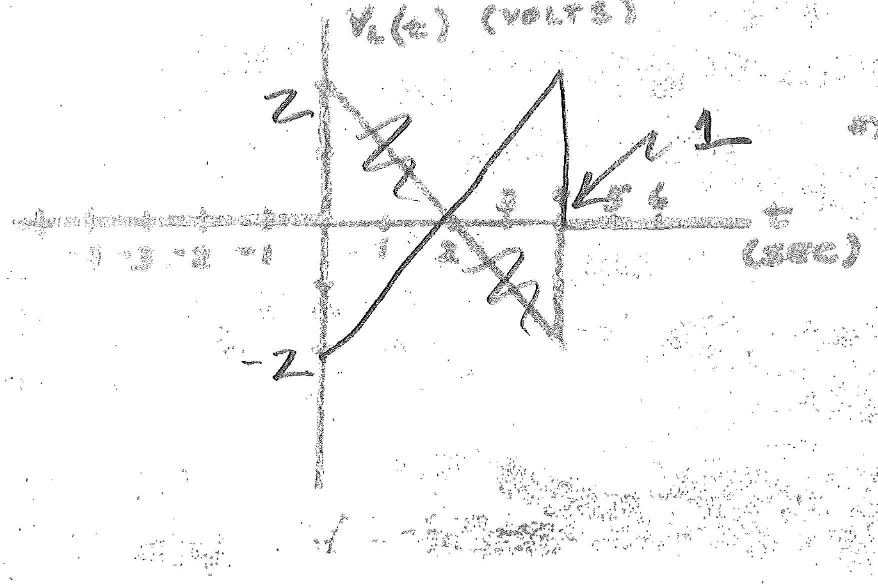
GIVEN THAT $i(t) = \begin{cases} -t(1-t) \text{ AMPS} ; & 0<t<1 \\ 0 & ; \text{OTHERWISE} \end{cases}$ WHERE t IS IN SECONDS, FIND AND SKETCH $V_L(t)$ FOR ALL t.

FIRST, WE NOTE THAT THE R AND THE C HAVE NO EFFECT ON THE CURRENT THRU THE INDUCTOR. THAT IS, THE INDUCTOR AND CURRENT SOURCE ARE IN SERIES. FOR AN INDUCTOR:

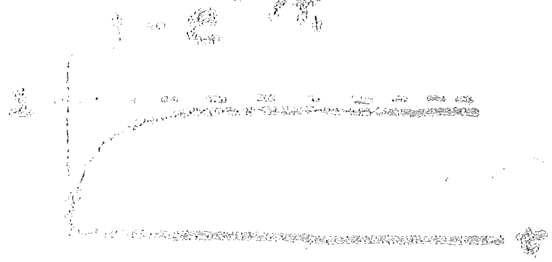
$$V_L = L \frac{di}{dt}$$

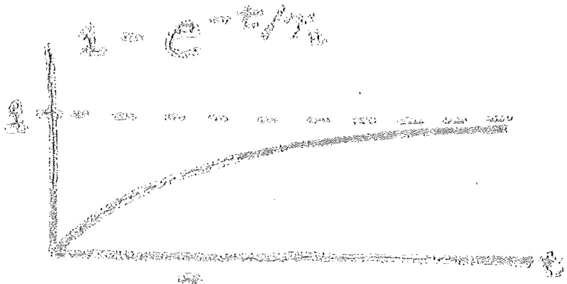
THUS

$$\begin{aligned} V_L(t) &= (2H) \frac{d}{dt}[-t(1-t)] \\ &= 2H \frac{d}{dt}[t^2 - t] \\ &= 2[2t-1] \\ &= 4t-2 \text{ (VOLTS)}; \quad 0<t<1 \end{aligned}$$

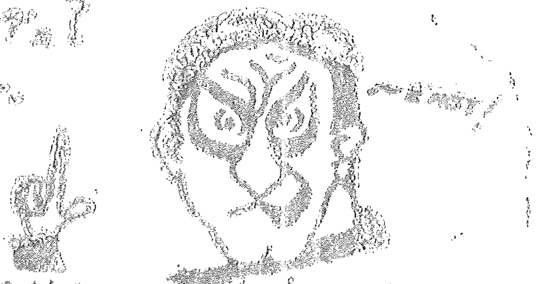


#4, p.





WHICH IS LARGER : $\tau_1$ OR $\tau_2$?
EXPLAIN YOUR REASONING.

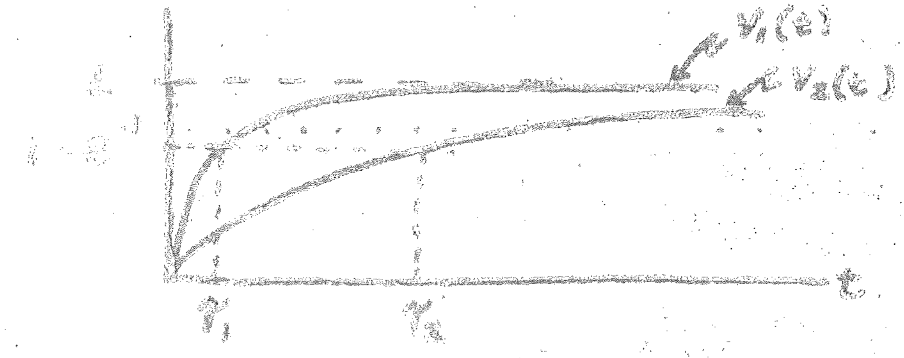


THERE ARE A NUMBER OF WAYS IN WHICH THIS PROBLEM CAN BE WORKED. I WOULD DO THE FOLLOWING. LET

$$V_1(t) = 1 - e^{-t/\tau_1}$$
$$V_2(t) = 1 - e^{-t/\tau_2}$$

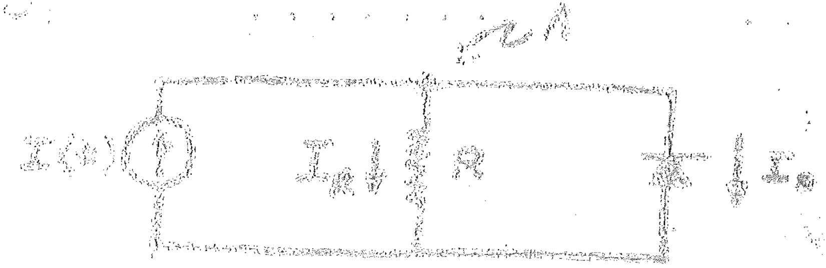
NOTE THAT $V_1(\tau_1) = V_2(\tau_2) = 1 - e^{-1} \approx 0.6$

LOOKING AT THE GRAPHS:

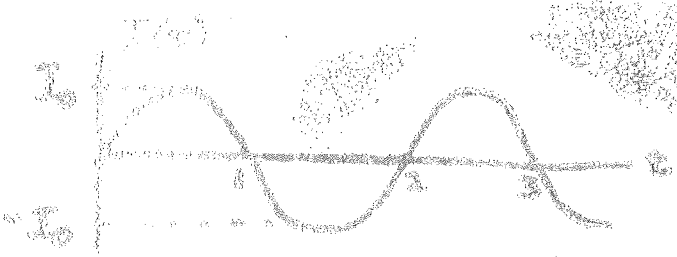


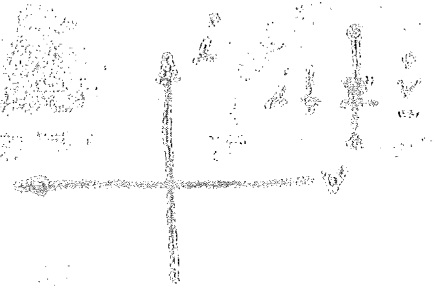
OBVIOUSLY, $\tau_2 > \tau_1$

#5.

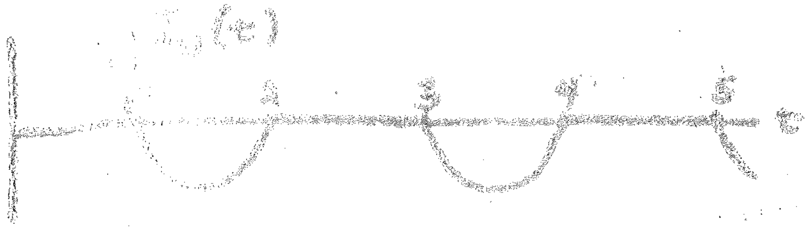


GIVEN THAT $I(t) = I_0 \sin 2\pi t$, SKETCH $I_R(t)$ AND $I_D(t)$. EXPLAIN YOUR REASONING.

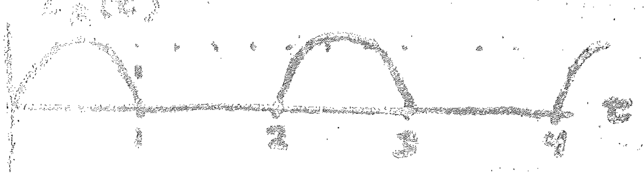




FOR $I(t)<0$, THE DIODE WILL CONDUCT, AND ALL OF THE CURRENT WILL GO THRU THE DIODE (WHICH IS A SHORT)

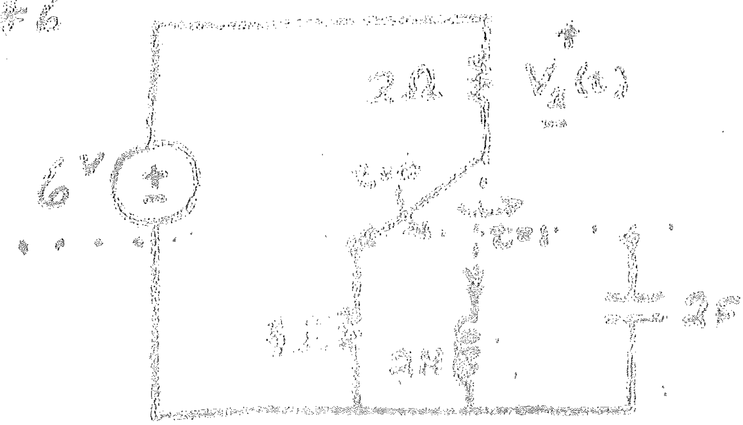


FOR $I(t)>0$, THE DIODE IS AN OPEN CIRCUIT AND ALL OF $I(t)$ MUST GO THRU THE RESISTOR



NOTE THAT $I_R(t)+I_D(t)=I(t)$, CONFIRMING KIRK'S NODE LAW AT A

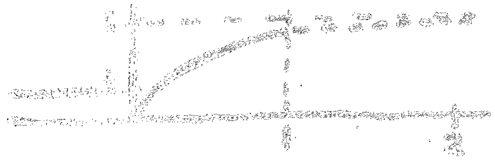
#6



THE SWITCH IS THROWN FROM THE 4Ω RESISTOR TO THE 2H INDUCTOR AT $t=0$ AND THEN TO THE 2F CAPACITOR ONE SECOND LATER. SKETCH $V_2(t)$ NOTING ALL TRANSIENT AND LIMITING VALUES FOR ALL TIME $t$. SPECIFY ALL TIME CONSTANTS IN YOUR SKETCH.

BEFORE SWITCH IS THROWN, WE USE A VOLTAGE DIVIDER $\Rightarrow V_2(t) = \frac{2}{2+4} 6 = 2$ VOLTS. ; $t<0$

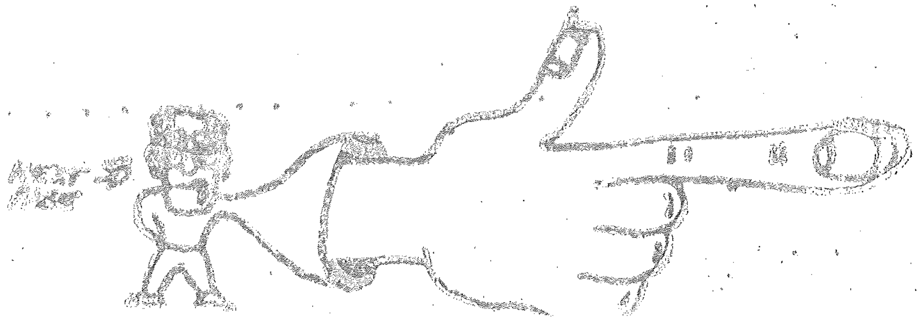
AT THE INDUCTOR, WE CAN'T ALLOW CURRENT $\Rightarrow V_2(0+) = 0$. IF WE WERE TO LEAVE THE SWITCH ON L, WE WOULD GET $V_2(\infty) = 6$. THAT IS, AT $t=\infty$, L WOULD ACT LIKE A SHORT. OBVIOUSLY, $\tau_1 = L/R = 1$ SECOND. OUR CURVE WOULD LOOK LIKE



THE EQUATION FOR $0<t<1$ IS

$$V_2(t) = 6(1-e^{-t})$$

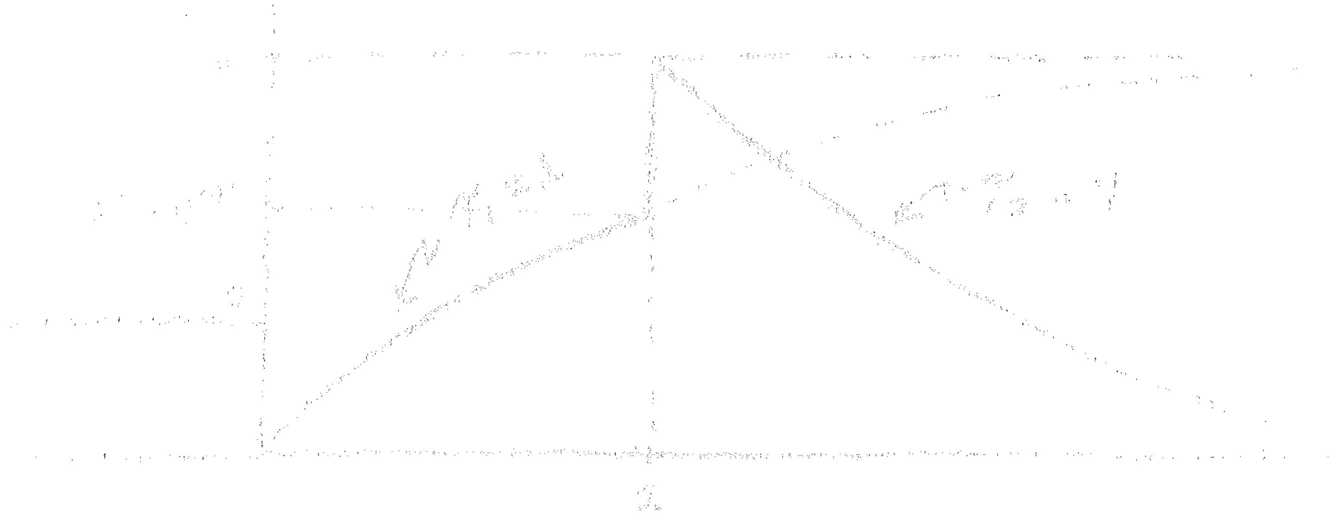
NOTE THAT $V_2(1-) = 6(1-e^{-1})$



WHEN WE THROW THE SWITCH, THE [illegible] VOLTAGE [illegible] ACROSS THE [illegible] FOR, SINCE VOLTAGE CAN'T CHANGE INSTANTANEOUSLY ACROSS THE CAPACITOR, THUS

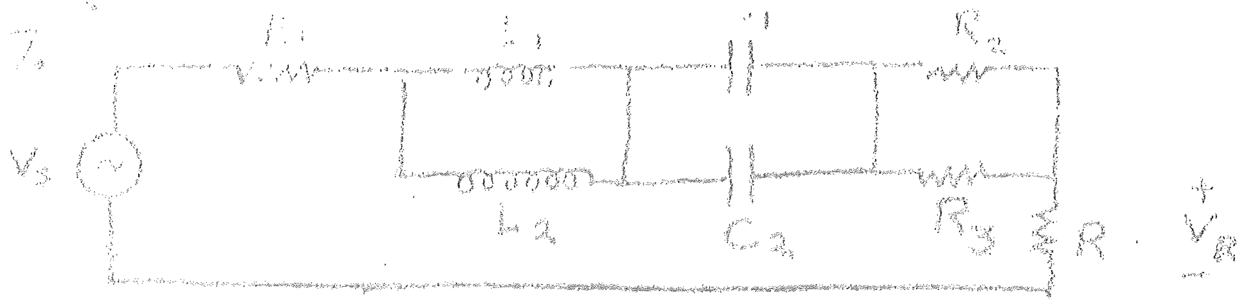
$V_C(1^+) = 6$ VOLTS

[illegible] AT ∞, THE CAPACITOR LOOKS LIKE AN OPEN CIRCUIT, THUS, $V_C(\infty) = 0$. ALSO, $\tau_2 = RC = (2\Omega)(2F) = 4$ s. THE FINAL CURVE THEN LOOKS LIKE



[illegible] SHOULD BE WRAPPING AND [illegible] NOT "PERFECT" LONG [illegible]

#7.

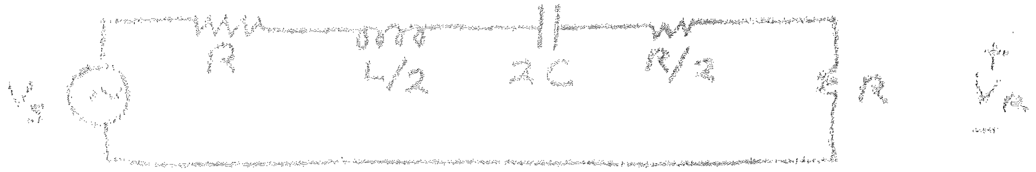


ASSUMING $R_1 = R_2 = R_3 = R$, $L_1 = L_2$, AND $C_1 = C_2$, SKETCH $|V_R(\omega)|$. SPECIFY $|V_R(\infty)|$, $|V_R(0)|$, AND THE FREQUENCY (OR FREQUENCIES) WHICH MAXIMIZE (OR MINIMIZE) $|V_R(\omega)|$

ALSO ⟹ WHAT TYPE OF FILTER IS THIS ? ⟸

LET $L = L_1 = L_2$, $R = R_1 = R_2 = R_3$, $C = C_1 = C_2$.

FIRST OFF SIMPLIFY THE CIRCUIT

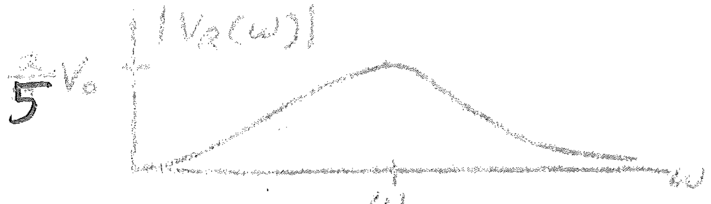


AT $\omega = \infty$, THE INDUCTOR LOOKS LIKE AN OPEN CIRCUIT $\Rightarrow |V(\infty)| = 0$

AT $\omega = 0$, THE CAPACITOR LOOKS OPEN

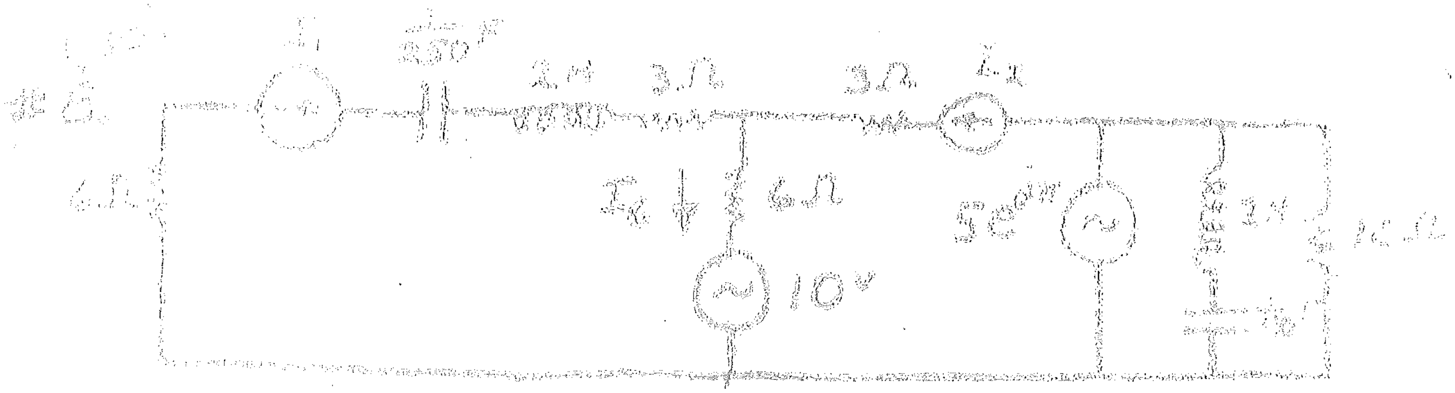
$$\Rightarrow |V(0)| = 0$$

AT $\omega_0 = 1/\sqrt{(\frac{L}{2})(2C)} = 1/\sqrt{LC}$, THE INDUCTOR AND CAPACITOR ARE AT RESONANCE (SHORT CIRCUIT). USING A VOLTAGE DIVIDER: $|V_R(\omega_0)| = \frac{R}{\frac{5}{2}R} V_s = \frac{2}{5} V_s$. HERE, $|V_R(\omega)|$ IS MAXIMIZED



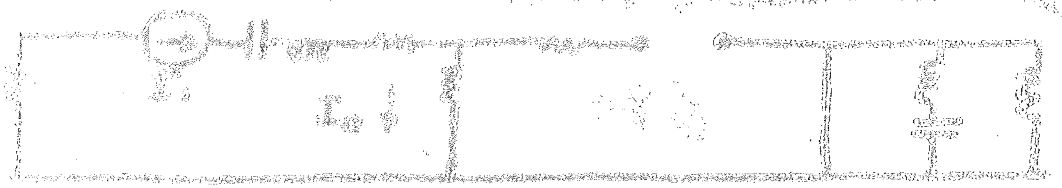
⟵ BANDPASS FILTER

#6.



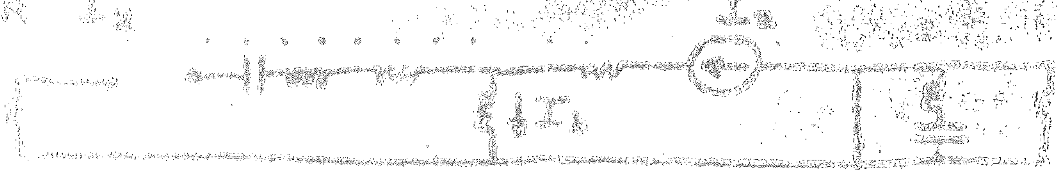
FIND THE RELATION BETWEEN $I_1$ AND $I_2$ SUCH THAT $I_6 = \frac{1}{250}$ AMP. USE SUPERPOSITION AND SHOW WORK. $\omega = 10$.

(a) FOR $I_1$



OBVIOUSLY, $I_6 = I_1$

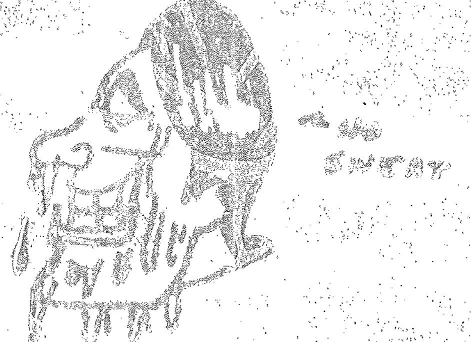
(b) FOR $I_2$



OBVIOUSLY, $I_6 = I_2$

(c) SHORTING A VOLTAGE SUPPLY WILL HAVE NO EFFECT SINCE OPENING $I_1$ AND $I_2$ LEAVES NO CURRENT PATH. THUS

$$I_6 = I_1 + I_2 = \frac{1}{250} \text{ AMP}$$



B

space here

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4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b) ABOUT AVERAGE] (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE [✓ (a) EXCELLENT] (b) PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

* well presented and clearer than in the book

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a) HELPFUL] (b) KIND OF HELPFUL (c) NOT HELPFUL [✓ (d) A PAIN] (SOMETIMES)

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS SUPERPOSITION THEOREM

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS to understand electricity a lot more (really didn't care about it before)

also to spell KIRCHHOFF

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b) BE SOMEWHAT HELPFUL] (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING. CH. E.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD (b) FAIR (c) POOR (d) NONEXISTANT [✓ (e) ALL OF THE ABOVE]

USE BACK FOR COMMENTS →

✓ CHECK HERE IF YOU USED BACK

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- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

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7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS three Phase circuits

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A-

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9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS the general vague idea of how electricity is used

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I feel that Bobby did a good job in teaching this class. The lectures were presented with the material made easy to understand. I would recommend Mr. Marks to my fellow constituents.

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USE BACK FOR COMMENTS

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I enjoyed the way the instructor presented the material. It helps if he is interested and involved in what he's teaching.

I would have enjoyed this course a lot had I been interested in EE to begin with. It was a good course and worth the time even though it was required.

The tests were O.K., Fair as a whole, and usually ~~Not~~ of ~~too long~~ ~~reasonab~~ ~~reso~~ reasonable length.

Merry Christmas!

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SEE BACK FOR COMMENTS

( ✓ ) CHECK HERE [illegible]

The Lectures were very good and well organized. The one complaint I have, is that the tests do not reflect the Lectures & what I learned somehow. Hmwrk problems that call for a proof, followed by a test with practical problems is a poor practice I think. I wish that I could have been able to use the book more, but, somehow it didn't follow the lectures as well as it should.

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6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a) HELPFUL] (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS Thevinin's & Norton's theorms + three phase

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS the general vague idea of how electricity is used

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL (b) BE SOMEWHAT HELPFUL [✓ (c) WILL BE OF NO HELP AT ALL] (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b) FAIR] (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS

☑ CHECK HERE IF YOU USED BACK

One thing I enjoy is hearing about common applications of some particular theories and how they are put to use.

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS B.

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS B.

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b) ABOUT AVERAGE] (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE [✓ (a) EXCELLENT] (b) PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a) HELPFUL,] (b) KIND OF HELPFUL (c) AIN'T HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS Thevenin & Norton's Equ.

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) B

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS linear circuit analysis

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE [✓ (a) WILL BE VERY HELPFUL] (b) BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b) FAIR] (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS B.

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS B.

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c)] CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b)] ABOUT AVERAGE (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b)] PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a)] HELPFUL (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS THEV-NORTONS EQ CIRCUITS

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS POWER

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b)] BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b)] FAIR (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS ⟶

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS B

2. THE GRADE I FEEL I <u>SHOULD</u> RECEIVE IN THIS COURSE IS B

3. I TOOK THIS COURSE (a) FOR GAINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE (b) ABOUT AVERAGE [✓ (c) HARD] (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b) PRETTY GOOD] (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS (a) HELPFUL [✓ (b) KIND OF HELPFUL] (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS ____

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) B

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS ____

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b) BE SOMEWHAT HELPFUL] (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b) FAIR] (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →

☐ CHECK HERE IF YOU USED BACK

DEC 10

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS B.

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS I'm NOT SURE

3. I TOOK THIS COURSE (a) FOR GRINS [✓ (b) CAUSE I WANTED TO] [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b) ABOUT AVERAGE] (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b) PRETTY GOOD] (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS (a) HELPFUL [✓ (b) KIND OF HELPFUL] (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS THREE PHASE

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A [illegible]

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS DIODES + (TV) CRT

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE [✓ (a) WILL BE VERY HELPFUL] (b) BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b) FAIR] (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS ⟹

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS A.

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS A.

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c)] CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE (b) ABOUT AVERAGE [✓ (c)] HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b)] PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a)] HELPFUL (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS ______

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS EE courses are not hard if you have a good instructor

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b)] BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WA (a) GOOD (b) FAIR [✓ (c)] POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS A+

2. THE GRADE I FEEL I <u>SHOULD</u> RECEIVE IN THIS COURSE IS A-

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c)] CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b)] ABOUT AVERAGE (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b)] PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a)] HELPFUL (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL DON'T QUITE UNDERSTAND (IF ANY) IS Thev & Nort Equivalents

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A good

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS 3. phase

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b)] BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b)] FAIR (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →

JD ☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS C

2. THE GRADE I FEEL I <u>SHOULD</u> RECEIVE IN THIS COURSE IS C

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE (b) ABOUT AVERAGE [✓ (c) HARD] (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b) PRETTY GOOD] (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS (a) HELPFUL (b) KIND OF HELPFUL [✓ (c) NOT HELPFUL] (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL DON'T QUITE UNDERSTAND (IF ANY) IS polyphase systems

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS complex #'s

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b) BE SOMEWHAT HELPFUL] (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD (b) FAIR [✓ (c) POOR] (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS B.

2. THE GRADE I FEEL I <u>SHOULD</u> RECEIVE IN THIS COURSE IS B.

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b) ABOUT AVERAGE] (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE [✓ (a) EXCELLENT] (b) PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a) HELPFUL] (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS Power $\xrightarrow{on}$ I'm behind

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A.

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS How a TV works

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b) BE SOMEWHAT HELPFUL] (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b) FAIR] (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

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USE BACK FOR COMMENTS →

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS A.

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS A.

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b) ABOUT AVERAGE] (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE [✓ (a) EXCELLENT] (b) PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a) HELPFUL] (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS Three Phase connection

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A.

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS how circuit components work.

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE [✓ (a) WILL BE VERY HELPFUL] (b) BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b) FAIR] (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

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USE BACK FOR COMMENTS ⟹

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS
COURSE IS B

2. THE GRADE I FEEL I <u>SHOULD</u> RECEIVE IN
THIS COURSE IS C

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE
I WANTED TO [✓ (c)] CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER
ENGINEERING COURSE'S I'VE HAD, THIS
ONE WAS (a) A BREEZE [✓ (b)] ABOUT AVERAGE
(c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT
[✓ (b)] PRETTY GOOD (c) AVERAGE (d) A SNOW
JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL,
THE HOMEWORK WAS [✓ (a)] HELPFUL
(b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS
COURSE WHICH I STILL QUITE DON'T
UNDERSTAND (IF ANY) IS —

8. IF YOU WERE TO GIVE THE INSTRUCTOR
A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS
COURSE (IF ANYTHING) IS —

10. AS FAR AS MY CAREER GOES, I FEEL
THAT THIS COURSE (a) WILL BE VERY
HELPFUL [✓ (b)] BE SOMEWHAT HELPFUL
(c) WILL BE OF NO HELP AT ALL
(d) HAS DESTROYED MY CONCEPT IN
ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS
[✓ (a)] GOOD (b) FAIR (c) POOR (d) NONEXISTANT
(e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →
☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS B (MAYBE)

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS B

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c)] CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b)] ABOUT AVERAGE (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b)] PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a)] HELPFUL (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS THEVENINS + NORTONS

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS ____________

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b)] BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS [✓ (a)] GOOD (b) FAIR (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

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USE BACK FOR COMMENTS

☑ CHECK HERE IF YOU USED BACK

EXAMS ARE A LITTLE LONG. (USUALLY ONE PROBLEM TOO LONG).

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS D

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS A

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b)] ABOUT AVERAGE (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE [✓ (a)] EXCELLENT (b) PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a)] HELPFUL (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS THEVININ to NORTON

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) B+

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS HOW LUCKY I AM TO BE IN CHE INSTEAD OF EE.

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b)] BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b)] FAIR (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS C+ → B?

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS B

3. I TOOK THIS COURSE (a) FOR GAINS (b) CAUSE I WANTED TO [✓ (c)] CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b)] ABOUT AVERAGE (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT (b) PRETTY GOOD [✓ (c)] AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS (a) HELPFUL [✓ (b)] KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS THEVININ & NORTON EQUIVALENCE (MORE PROBLEMS)

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS CRT

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL (b) BE SOMEWHAT HELPFUL [✓ (c)] WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b)] FAIR (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS B→A

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS A

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b) ABOUT AVERAGE] (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b) PRETTY GOOD] (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS (a) HELPFUL [✓ (b) KIND OF HELPFUL] (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS Thev-Norton's

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS HOW A TV WORKS

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL (b) BE SOMEWHAT HELPFUL [✓ (c) WILL BE OF NO HELP AT ALL] (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b) FAIR] (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

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USE BACK FOR COMMENTS ⟹

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS
COURSE IS B.

2. THE GRADE I FEEL I SHOULD RECEIVE IN
THIS COURSE IS A.

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE
I WANTED TO [✓ (c)] CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER
ENGINEERING COURSE'S I'VE HAD, THIS
ONE WAS (a) A BREEZE [✓ (b)] ABOUT AVERAGE
(c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT
(b) PRETTY GOOD [✓ (c)] AVERAGE (d) A SNOW
JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL,
THE HOMEWORK WAS [✓ (a)] HELPFUL
(b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS
COURSE WHICH I STILL QUITE DON'T
UNDERSTAND (IF ANY) IS three Phase.

8. IF YOU WERE TO GIVE THE INSTRUCTOR
A GRADE, IT WOULD BE A(N) B.

9. THE NEATEST THING I LEARNED IN THIS
COURSE (IF ANYTHING) IS Ohm's LAW

10. AS FAR AS MY CAREER GOES, I FEEL
THAT THIS COURSE (a) WILL BE VERY
HELPFUL [✓ (b)] BE SOMEWHAT HELPFUL
(c) WILL BE OF NO HELP AT ALL
(d) HAS DESTROYED MY CONCEPT IN
ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS
(a) GOOD [✓ (b)] FAIR (c) POOR (d) NONEXISTANT
(e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS ________.

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS B

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b) ABOUT AVERAGE] (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b) PRETTY GOOD] (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a) HELPFUL] (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS ✓ ________

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS ac circuit syst

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b) BE SOMEWHAT HELPFUL] (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS [✓ (a) GOOD] (b) FAIR (c) POOR (d) NON EXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS ⇒

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS C.

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS C.

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE (b) ABOUT AVERAGE [✓ (c) HARD] (d) IMPOSSIBLE

5. THE LECTURES WERE (a) EXCELLENT [✓ (b) PRETTY GOOD] (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS (a) HELPFUL (b) KIND OF HELPFUL (c) NOT HELPFUL [✓ (d) A PAIN]

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL DON'T QUITE UNDERSTAND (IF ANY) IS All [illegible]

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS the lesson of time [illegible]

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL (b) BE SOMEWHAT HELPFUL [✓ (c) WILL BE OF NO HELP AT ALL] (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD (b) FAIR (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS [illegible]

[illegible]

The lectures were very well organized.
You know [illegible] [illegible], whether [illegible] I
didn't understand it.

The labs were also at the beginning [illegible]
[illegible] and for the lab instructor (Coordinator)
was at times completely lost.

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS C

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS B

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c) CAUSE I HAD TO.]

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b) ABOUT AVERAGE] (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE [✓ (a) EXCELLENT] (b) PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a) HELPFUL] (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

Your solution sheet were most helpful.

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS Circuit analysis

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A (Excellent)

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS about a CRT

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b) WILL BE SOMEWHAT HELPFUL] (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b) FAIR] (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS

☐ CHECK HERE IF YOU USED BACK

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS A.

2. THE GRADE I FEEL I <u>SHOULD</u> RECEIVE IN THIS COURSE IS A.

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c)] CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b)] ABOUT AVERAGE (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE [✓ (a)] EXCELLENT (b) PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a)] HELPFUL (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS open & short circuits

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS ______________.

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL [✓ (b)] BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD (b) FAIR [✓ (c)] POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

- - - - - - - - - - - - - - - - - - - - - - - - - - - -

USE BACK FOR COMMENTS ⟹

☑ CHECK HERE IF YOU USED BACK

I think you did a very good job helping us understand this course. I appreciated the extra time you spent by giving us reviews, it's too bad more people didn't take advantage of them.

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS A

2. THE GRADE I FEEL I SHOULD RECEIVE IN THIS COURSE IS A not ~~[illegible]~~ sure, I never am, because I always feel I could do better.

3. I TOOK THIS COURSE (a) FOR GRINS (b) CAUSE I WANTED TO [✓ (c)] CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b)] ABOUT AVERAGE (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE [✓ (a)] EXCELLENT (b) PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a)] HELPFUL (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A no kidding

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS Application overall T.V., Radio

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE [✓ (a)] WILL BE VERY HELPFUL (b) BE SOMEWHAT HELPFUL (c) WILL BE OF NO HELP AT ALL (d) HAS DESTROYED MY CONCEPT IN ENGINEERING. I am working for S.W. Bell this summer and it should help

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD (b) FAIR [✓ (c)] POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →

☐ CHECK HERE IF YOU USED BACK

While I didn't get anything out of lab, I learned a great deal in here and enjoyed. My major is engineering physics and am hoping to direct my graduate work toward an area in which I could use this then.

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE IS B

2. THE GRADE I FEEL I <u>SHOULD</u> RECEIVE IN THIS COURSE IS B

3. I TOOK THIS COURSE (a) FOR GRINS [✓ (b) CAUSE I WANTED TO] (c) CAUSE I HAD TO.

4. COMPARED WITH THE DIFFICULTY OF OTHER ENGINEERING COURSE'S I'VE HAD, THIS ONE WAS (a) A BREEZE [✓ (b) ABOUT AVERAGE] (c) HARD (d) IMPOSSIBLE

5. THE LECTURES WERE [✓ (a) EXCELLENT] (b) PRETTY GOOD (c) AVERAGE (d) A SNOW JOB (e) VERY RESTFUL.

6. AS FAR AS UNDERSTANDING THE MATERIAL, THE HOMEWORK WAS [✓ (a) HELPFUL] (b) KIND OF HELPFUL (c) NOT HELPFUL (d) A PAIN

7. THE PRIMARY TOPIC COVERED IN THIS COURSE WHICH I STILL QUITE DON'T UNDERSTAND (IF ANY) IS Thevinin & Norton Theroem.

8. IF YOU WERE TO GIVE THE INSTRUCTOR A GRADE, IT WOULD BE A(N) A+

9. THE NEATEST THING I LEARNED IN THIS COURSE (IF ANYTHING) IS Kirckhoffs Law

10. AS FAR AS MY CAREER GOES, I FEEL THAT THIS COURSE (a) WILL BE VERY HELPFUL (b) BE SOMEWHAT HELPFUL [✓ (c) WILL BE OF NO HELP AT ALL] (d) HAS DESTROYED MY CONCEPT IN ENGINEERING.

11. THE LECTURE AND LAB COORDINATION WAS (a) GOOD [✓ (b) FAIR] (c) POOR (d) NONEXISTANT (e) ALL OF THE ABOVE

USE BACK FOR COMMENTS →

☒ CHECK HERE IF YOU USED BACK

Bob, your a damn good teacher!
if you teach next semester I would
like to take the course that follows
this one.

K L

12 Toby W. Oyer ✓
1. Bob Ballard ✓
7~~6~~. Steve Jones ✓
17 ELYAHOUZADEH, YOUSSEF.
10~~9~~ DEE MAKEY ✓
13 Dean Pierce ✓
3. Joe Craig ✓
6 Lynn Howerton ✓
8~~7~~. Mike E Little ✓
2. Clifton M Bloodworth ✓
15~~14~~ Manny Sirago ✓
14 Robert Ross ✓
16 Walter WHEELER ✓
11 ~~10~~ Tim McClaskey ✓
9~~8~~ Raúl Madrid ✓
0 5. Kelly Davis
0 4. Gregg Barton

Marks

E.E. 233 LAB. INSTRUCTORS

THE LAB. SCHEDULE FOR E.E. 233 IS AS FOLLOWS:

EXPT. # 1 MARCH 7-11 EXPT. # 3 APRIL 11-15

EXPT. # 2 MARCH 28-April 1 EXPT. # 4 APRIL 25-29

LET's MEET IN ROOM EE67 ON FRIDAY, MARCH 4, AT 2PM TO COLLECT EQUIPMENT AND DO EXPT. # 1.

Tom Stenis

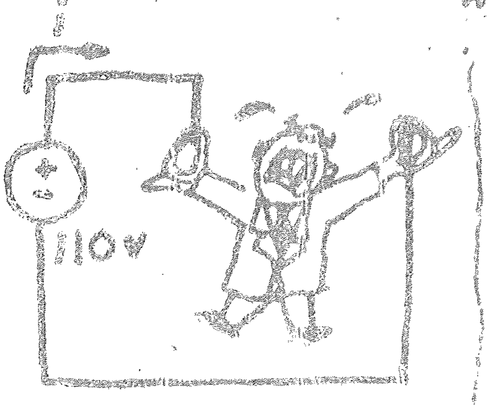
QUIZ # 2

1. A VOLTAGE $v(t) = \frac{2V_0}{S} t$ IS APPLIED ACROSS AN INDUCTOR WHICH AT TIME $t = 0$, HAS ONE AMP FLOWING THROUGH IT. IF THE INDUCTOR HAS A VALUE OF 2 mH ($= 2 \times 10^{-3}$ H), FIND THE CURRENT THROUGH THE INDUCTOR AT TIME $t = 2$ SECONDS. ASSUME $S = 2 \times 10^3$ SEC AND $V_0 = 4$ VOLTS. [HINT: $i_L(t) = i(t_0) + \frac{1}{L} \int_{t_0}^{t} v(t)\,dt$]

2. FOR THE SAME VOLTAGE WAVEFORM, FIND THE CURRENT THROUGH A 2 mF ($= 2 \times 10^{-3}$ F) CAPACITOR AT TIME $t = 2$ SEC. [$i_c(t) = C \frac{dV}{dt}$]

3. 10 mA TO 100 mA ($1 \text{ mA} = 10^{-3}$ AMPS) THRU THE BODY COULD RESULT IN MUSCULAR PARALYSIS AND EXTREME BREATHING DIFFICULTIES. OVER 100 mA COULD RESULT IN DEATH.

SUPPOSE MR. SNURD ACCIDENTLY GRABS THE LEADS OF A 110 VOLT SOURCE (LIKE A WALL SOCKET). ASSUME MR. SNURD IS WET, AND THAT THE RESISTANCE BETWEEN HIS RIGHT AND LEFT HANDS. IS 1000 Ω. IF 100 mA THRU MR. SNURD' HEART WILL KILL HIM, WHAT WILL HIS CONDITION BE? SHOW YOUR WORK.



# QUIZ # 1 - SOLUTIONS

1. $i_L(t) = i(t_0) + \frac{1}{L}\int_{t_0}^{t} V(t)\,dt$

$t_0 = 0$, $i(0) = 1$ AMP $L = 2 \times 10^{-3}$ H,

$V(t) = \frac{2V_0}{S}t$ ; $S = 2\times10^{3}$ SEC, $V = 4$ VOLTS

$\Rightarrow i_L(t) = 1 + \frac{1}{L}\int_0^t \frac{2V_0}{S}t\,dt$

$= 1 + \frac{V_0}{SL}\int_0^t 2t\,dt = 1 + \frac{V_0 t^2}{SL}$

AT $t = 2$ SEC

$$i_L(2) = 1 + \frac{(4V)(2\,\text{SEC})^2}{(2\times10^{3}\,\text{SEC})(2\times10^{-3}\,\text{H})} = 1 + 4 = 5 \text{ AMPS}$$

2. $i_C(t) = C\frac{dV}{dt}$

$= C\frac{d}{dt}\frac{2V_0}{S}t = \frac{2CV_0}{S}$

$$= \frac{2(2\times10^{-3}\,\text{F})(4\,\text{VOLT})}{2\times10^{3}\,\text{SEC}} = 8\times10^{-6}\,\text{A} = 8\,\mu\text{A}$$

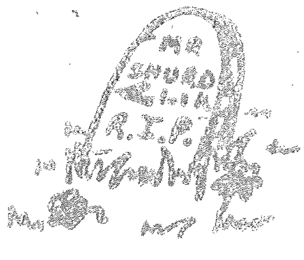
THUS, @ $t = 2$ SEC, $i_C(2) = 8\times10^{-6}\,\text{A} = 8\,\mu\text{A}$

3. OHM'S LAW: $V = iR$

$V = 110$ V $i = 100$ mA $= 0.1$ A

$R = \frac{V}{I} = \frac{110\,\text{V}}{0.1\,\text{A}} = 1100\,\Omega$

$= 1.1\,\text{k}\Omega \Leftarrow$ MINIMUM ALLOWABLE RESISTANCE



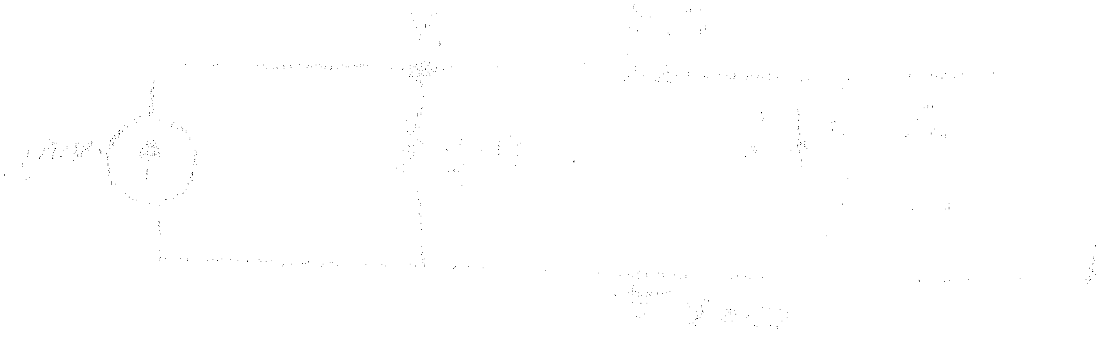
DETERMINE THE VOLTAGE $V_1$ ACROSS THE [illegible]

(2) FOR THE FOLLOWING CIRCUIT

(a) SET UP THE MATRIX EQUATION [illegible]
NODE VOLTAGES SHOWN

(b) SOLVE FOR $V_1$ AND $V_2$

(c) WHAT IS THE CURRENT [illegible]
4Ω RESISTOR ?



QUIZ #2 SOLUTIONS, EE 103 (MARKS) [illegible]

(1)(a) $8 + 9i_1 - i_2 = 0 \Rightarrow -8 = 9i_1 - i_2$

( ) $-15 - i_2 + 10i_2 = 0 \Rightarrow 15 = -i_1 + 10i_2$

MATRIX: $\begin{bmatrix} -8 \\ 15 \end{bmatrix} = \begin{bmatrix} 9 & -1 \\ -1 & 10 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$

(b) $\Delta = \det \begin{bmatrix} 9 & -1 \\ -1 & 10 \end{bmatrix} = 90 - 1 = 89$

$\Delta_1 = \det \begin{bmatrix} -8 & -1 \\ 15 & 10 \end{bmatrix} = -80 - (-15) = -65$

$\Delta_2 = \det \begin{bmatrix} 9 & -8 \\ -1 & 15 \end{bmatrix} = 135 - 8 = 127$

$i_1 = \Delta_1/\Delta = -65/89 = 0.73$ AMPS, $i_2 = \Delta_2/\Delta = \frac{127}{89} = 1.4$[illegible]

(c) $V_1 = (i_1 - i_2)1\Omega = \frac{-65-127}{89} = \frac{-192}{89} = 2.16$ VOLTS

(2)(a) $2 + 4(-V_1) + (V_2 - V_1)8 = 0 \Rightarrow 2 = 12V_1 - 8V_2$

( ) $4(-V_2) + 2(4 - V_2) + 8(V_1 - V_2) = 0 \Rightarrow 8 = -8V_1 + 14V_2$

MATRIX: $\begin{bmatrix} 2 \\ 8 \end{bmatrix} = \begin{bmatrix} 12 & -8 \\ -8 & 14 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$

(b) $\Delta = \det \begin{bmatrix} 12 & -8 \\ -8 & 14 \end{bmatrix} = 168 - 64 = 104$

$\Delta_1 = \det \begin{bmatrix} 2 & -8 \\ 8 & 14 \end{bmatrix} = 28 + 64 = 92$

$\Delta_2 = \det \begin{bmatrix} 12 & 2 \\ -8 & 8 \end{bmatrix} = 96 + 16 = 112$

$V_1 = \Delta_1/\Delta = 92/104 = 0.885$ VOLTS, $V_2 = \frac{\Delta_2}{\Delta} = \frac{112}{104} = 1.0$[illegible]

(c) $i = (V_2 - 4)2 = \left(\frac{112}{104} - 4\right)2$

$= -5.85$ AMPS.

"A REPROOF ENTERETH MORE INTO A WISE MAN THAN A HUNDRED STRIPES INTO A FOOL"

PROV. 17:10

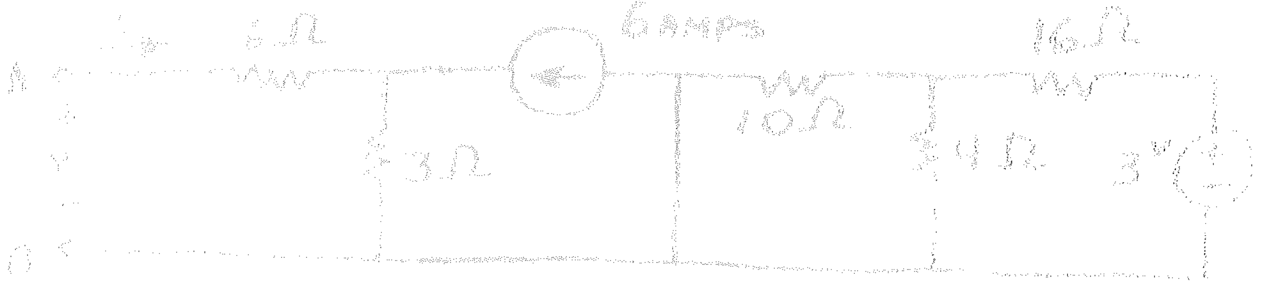
[illegible]

(1) FOR THE FOLLOWING CIRCUIT

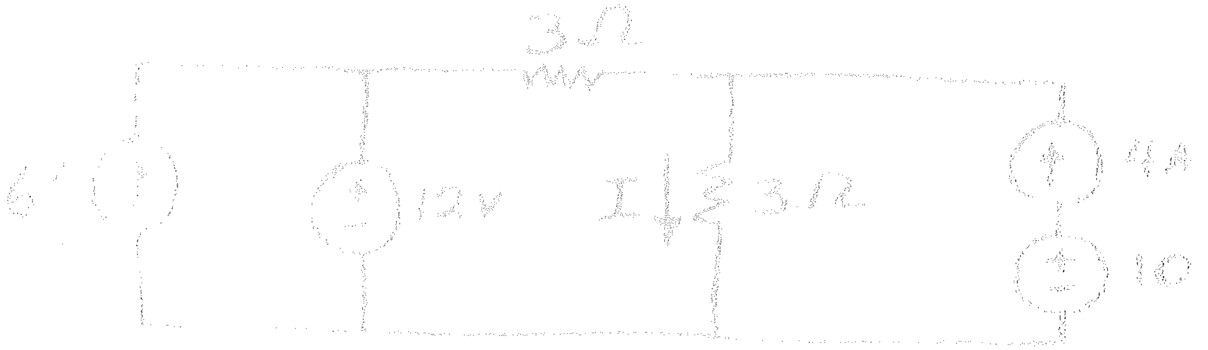
(a) DETERMINE $V_{oc}$ AND $I_{sc}$

(b) SKETCH THE THEV. & NORTON EQUIVALENT

(c) IF WE CONNECTED A 9Ω RESISTOR BETWEEN TERMINALS A AND B, WHAT WOULD BE THE CORRESPONDING VOLTAGE AND CURRENT? (a, v & i)



(2) USING SUPERPOSITION, DETERMINE THE CURRENT I THRU THE 3Ω RESISTOR.



QUIZ #2, SOLUTIONS (MARKS) 2, 4/7

1) (a) UNDER SHORT CIRCUIT CONDITIONS, THE 6 AND 3 OHM RESISTORS FORM A CURRENT DIVIDER WITH THE 6 AMP SOURCE, THUS

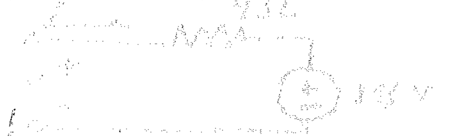
$$I_{sc} = \frac{\frac{1}{6}}{\frac{1}{6}+\frac{1}{3}} 6 = 2 \text{ AMPS}$$

UNDER OPEN CIRCUIT CONDITIONS, ALL OF THE 6 AMPS MUST PASS THRU THE 3 OHM RESISTOR

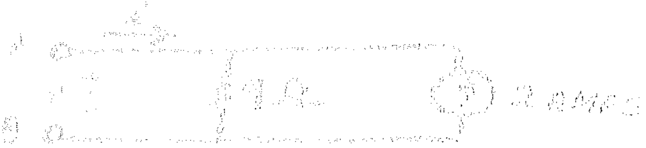
$\Rightarrow V_{oc} = (6 \text{ AMPS})(3 \text{ OHMS}) = 18$ VOLTS

(b) $R = V_{oc}/I_{sc} = 9\ \Omega$

THEVENIN:



NORTON:



(c) USE THEVENIN:

BY VOLTAGE DIVIDER

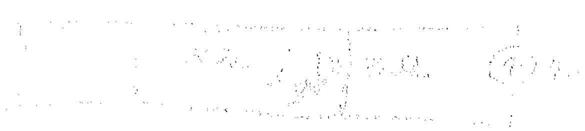
V = 9 VOLTS

I = 9/9 = 1 AMP

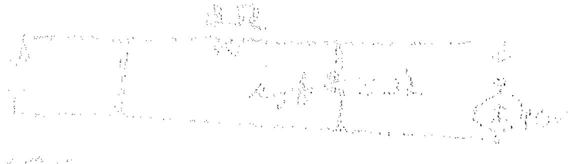
2) (i) FOR 6 AMP SOURCE ⟹ ALL 6 AMPS GOES THRU THE SHORT [illegible]

(ii) FOR 12V SOURCE ⟹ OBVIOUSLY, $i_2 = \frac{6}{2} = 3$ AMPS

(iii) FOR 4 AMP SOURCE ⟹ BY CURRENT DIVIDER $i_3 = 2$ AMPS



(iv) FOR 10 VOLT SUPPLY ⟹ OBVIOUSLY, $i_4 = 0$



$\therefore i_1 + i_2 + i_3 + i_4 = 4$ AMPS

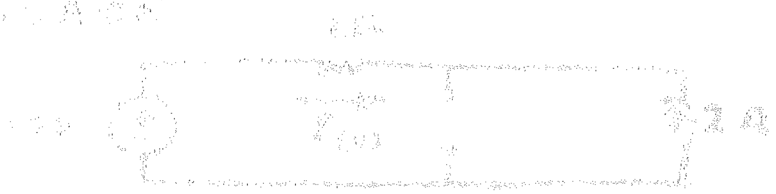
[illegible]

[illegible]

[illegible]

# QUIZ #[illegible] SOLUTIONS (by Manny!)

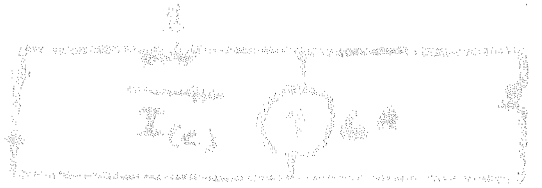
① FIRST, FIND EFFECT FROM 12 VOLT SOURCE:



OBVIOUSLY,

$I_{(1)} = 12/3 = 4$ amps

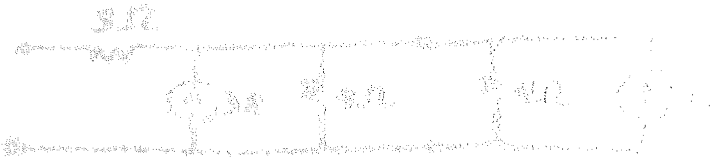
NOW, EFFECT OF AMP SOURCE:



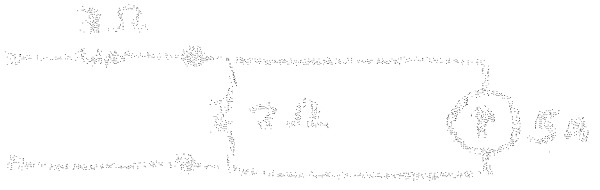
FROM CURRENT DIVIDER, $I_{(2)} = -\frac{2}{3}6 = -4$ amps

THUS, $I = I_{(1)} + I_{(2)} = 0$

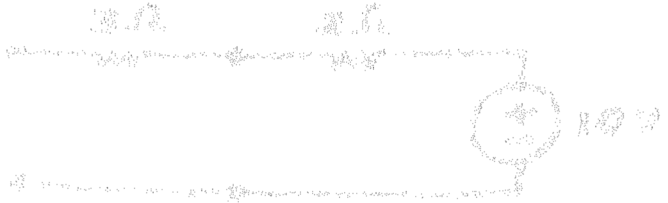
② CHANGE INTO NORTON:



COMBINE PARALLEL ELEMENTS:



CHANGE BACK TO A THEVENIN:



≡

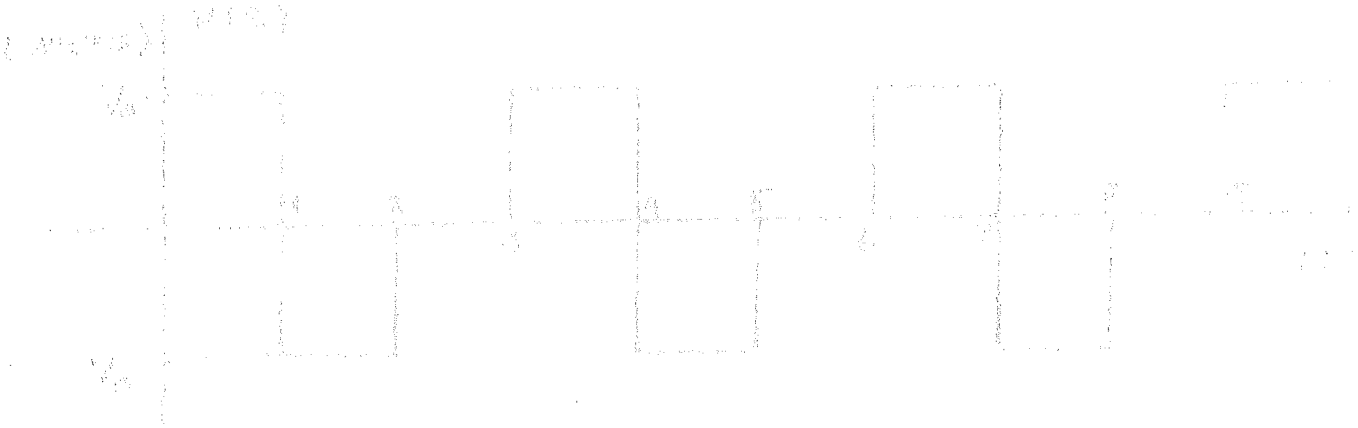
← ANSWER?

QUIZ [illegible] CHE 3 [illegible]

NAME ([illegible])

(10) 1. SHOW THAT $e^{j\pi/2} = j$

(10) 2. COMPUTE $V_{avg}$ AND $V_{rms}$ ([illegible]) OF THE FOLLOWING PERIODIC VOLTAGE [illegible]



(10) 3. SKETCH THE FOLLOWING COMPLEX NUMBERS ON THE COMPLEX PLANE, NOTING MAGNITUDE AND PHASE ANGLE, (φ)

(a) $W = 1 + j$ (b) $W = \sqrt{2}\, e^{j\pi/4}$

[illegible] FOR (a) AND (b)

[illegible]

[illegible]

[illegible]

(... b) EULER: $e^{j\pi/4} = \cos\frac{\pi}{4} + j\sin\frac{\pi}{4}$

$= j$

2. SINCE, IN A PERIOD, THERE IS AN EQUAL AMOUNT OF POSITIVE & NEGATIVE AREA, $V_{avg} = 0$. (EASY)

$V^2(t)$ IS $V_0^2$ FROM 0 TO 2 AND 0 FROM 2 TO 3.

THUS $V_{rms}^2 = \frac{1}{3}\left[2V_0^2\right] \Rightarrow V_{rms} = \sqrt{\frac{2}{3}}\,V_0$ (EASY)

ANOTHER WAY: $T = 3$

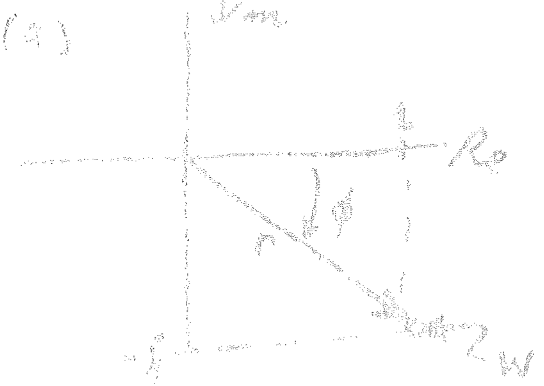
$$V_{avg} = \frac{1}{T}\int_T v(t)\,dt = \frac{1}{3}\left[\int_0^1 V_0\,dt + \int_1^2 (-V_0)\,dt + \int_2^3 (0)\,dt\right]$$

$$= \frac{1}{3}(0) = 0$$

$$V_{rms}^2 = \frac{1}{T}\int_T v^2\,dt = \frac{1}{3}\left[\int_0^2 V_0^2\,dt + \int_2^3 0\,dt\right]$$

$$= \frac{2}{3}V_0^2 \Rightarrow V_{rms} = \sqrt{2/3}\,V_0$$

3. (a)



$r = \sqrt{1^2 + 1^2} = \sqrt{2}$

$\phi = \text{atan}\,{}^{-1}/_1 = -45^\circ = -\pi/4$

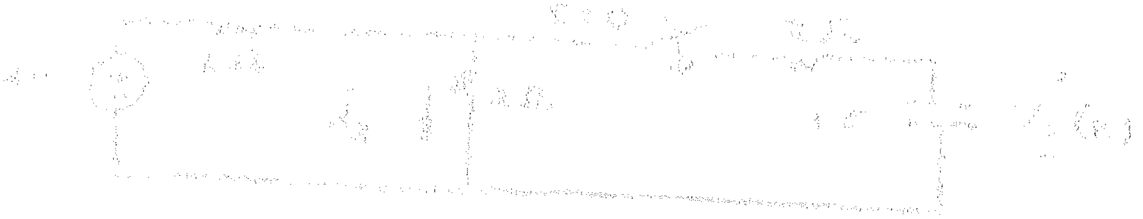
$\Rightarrow W = \sqrt{2}\,e^{-j\pi/4}$

(b) SAME AS (a)

([illegible] #6 (TAKE HOME). EE 221 ([illegible])

SOLUTION!!

USE THE "FOUR ANSWERS" TO FIND $V_C(t)$ AND $i_x(t)$ IN THE FOLLOWING CIRCUIT. SKETCH RESULTS. [EQUATIONS NOT NECESSARY]



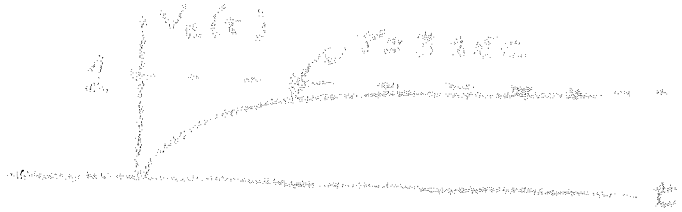
(a) FOR $V_C(t)$:

$V_C(0^-) = 0$

$V_C(0^+) = 0$ ⇒ V CAN'T CHANGE INSTANTLY ACROSS A C

$V_C(\infty) = 1$ VOLT ⇒ @ ∞, C ACTS AS OPEN CIRCUIT

$\tau = R_{eq}C = 3$ ⇒ $(2\Omega \| 2\Omega) + 2\Omega = R_{eq} = 3\Omega$



$V_C(t) = (1 - e^{-t/3})$

(b) FOR $i_x(t)$

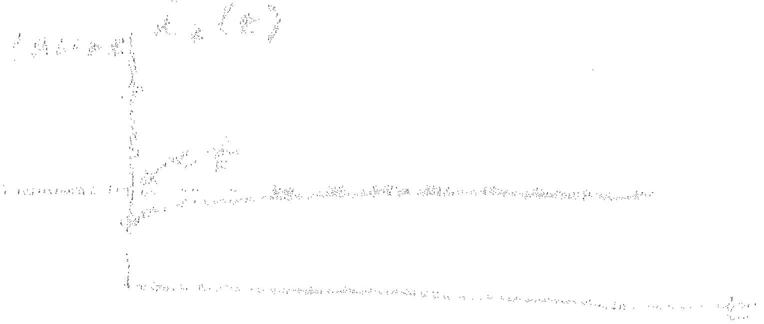
$i_x(0^-) = \frac{1}{2}$ AMP

$i_x(0^+) = \frac{1}{3}$ AMP

$i_x(\infty) = \frac{1}{2}$ AMP

τ = 3 SEC

*WHEN LIKE THIS, YOU [illegible] MUST REMEMBER ONE CHANGE.



$$i_x(t) = \frac{1}{3} + \left(\frac{1}{2} - \frac{1}{3}\right) \times \left(1 - e^{-t/3}\right)$$

$$= \frac{1}{2} - \frac{1}{6} e^{-t/3} \quad ; t > 0$$

1977

Marks

EE 233 Lab. Instructions

Here are some extra problem sets you can use in the lab problem session. The chapter headings do not refer to our textbook, but to the text which I am writing. I would appreciate a copy of any accurate solution to any of these problems.

Tom

1. A point charge $Q_1 = +1.6 \times 10^{-18}$ coulombs, is separated from another point charge $Q_2 = -3.2 \times 10^{-17}$ coulombs, by a distance of $10^{-3}$ meters. The charges are in a vacuum.

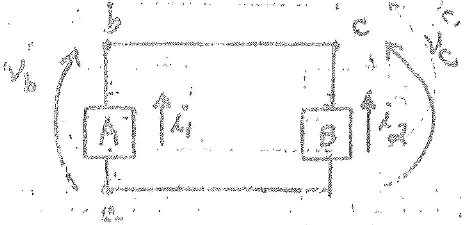
   a) Sketch a diagram of the physical layout.

   b) Find the force on each charge and indicate the direction on the sketch.

2. A $+1.6 \times 10^{-19}$ coulombs charge ($Q_3$) is brought into the vicinity of the charges of problem 1. If $Q_1 + Q_2$ remains fixed in position, find at least one point where $Q_3$ could be located and the net force on it be zero. How many such points are there?

3. In the glass tube of fig. 2, the density of free electron is equal to the density of free ions, and is $1.6 \times 10^{-12}$ coulombs per cubic meter. If the electrons are travelling at $10^4$ m/sec. and the ions at $10^2$ m/sec., calculate the current from plate (a) to (b), assuming plate (a) is positively charged.

4. A copper wire, 0.01 meters in diameter, has a density of free electrons equal to $84 \times 10^{28}$ electrons/$M^3$. If a current in the wire is 2 amperes what is the average velocity of the electrons?

5. 

In the circuit shown, $i_1 = 1$ ampere $= -i_2$. $v_b = v_c = 5t$.

   1) Sketch curves of $i_1$, $v_b$ and power supplied by box A vs. time, from zero to 10 seconds.

   2) Calculate the power supplied by box A at time = 1, 2, and 5 seconds.

   3) Calculate the power absorbed by box B at 1, 2 and 5 seconds.

   4) Calculate theenergy supplied by box A from 0 to 5 seconds.

6. In the circuit of problem 5, $v_b = 10-5t$, $i_1 = -i_2 = 10t$.

   a) Sketch the curve of $p_s$ of box A vs t, from 0 to 5 seconds.

   b) Calculate $p_s$ of box A at t = 0, 1, 2, 3, 4 seconds.

   c) Calculate energy supplied by box A from 0 to 5 seconds.

7. Repeat problem [illegible]

8. For problem 7, find the power absorbed by box R at t = 0, .5, 1 and 2 seconds

9. Omit

~~A glass-ceramic rod, 0.3 meters long, 1 cm in diameter, has equal charges concentrated on each end. This is crude model of an insulator supporting two conductors. Consider the charges as point charges. What is the maximum charge, $Q_1$, before the rod will break in tension. The tensile strength of the glass-ceramic is 20,000 psi.* Assume the forces will produce a uniform stress throughout the material.~~

*P.132 CRC Handbook of Tables for Applied Engineering Science.

10. A consumer of electrical energy requires 100 amperes of steady current over an 8 hour period, from a steady voltage source of 110 volts.

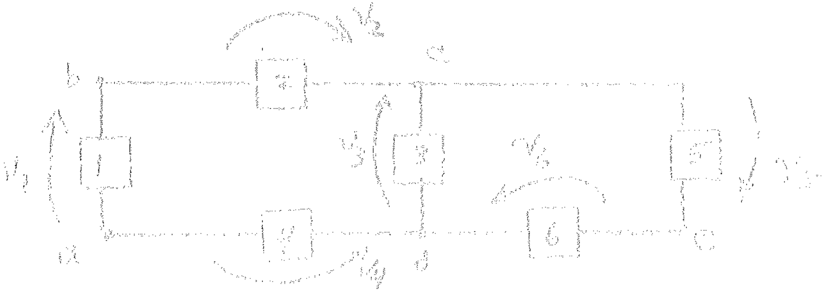
a) What power is the customer using?

b) How much energy in joules and watt-sec. is he using in the 8 hr. period?

c) If he is paying 3 ¢ per kilowatt- hr. for the energy what is the cost for the 8 hrs?

11. How many electrons make up a coulomb? If a gas ion is doubly ionized (losing 2 orbital electrons), how many such ions are there in 1 coulomb of charge?

12.



Using the defined voltages shown in the figure, write KVL around the following loops:

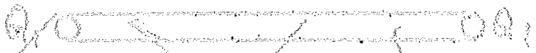
1) A b c d a 2) d c e d 3) a b c e d a

4) d e c d 5) a d c b a

7. Repeat problem 6, for $i = -10 + 10t = -i_2$.

8. For problem 7, find the power absorbed by box 5 at t = 0, .5, 1 and 2 seconds.

9. Omit



~~A glass-ceramic rod, 0.1 meters long, 1 cm in diameter, has equal charges concentrated on each end. This is crude model of an insulator supporting two conductors. Consider the charges as point charges. What is the maximum charge, $Q_1$, before the rod will break in tension. The tensil strength of the glass-ceramic is 20,000 psi.* Assume the forces will produce a uniform stress throughout the material.~~

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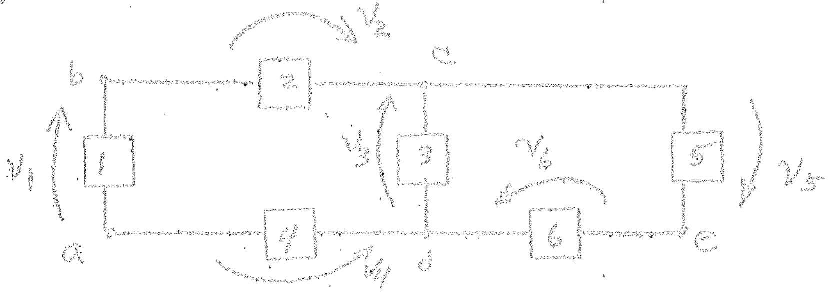


Using the defined voltages shown in the figure, write KVL around the following loops:

1) a b c d a     2) d c e d     3) a b c e d a

4) d e c d     5) a d c b a

1. A [illegible] wire (rubber [illegible]) [illegible] AWG 14 [illegible] to allowable current carrying capacity [illegible] amperes [illegible] in free air [illegible]

Reference:
Bolz, Ray E., and George L. Tuve, "Handbook of Tables for Applied Engineering Science", Ohio: The Chemical Rubber Company, [illegible]

a) What is the resistance of 50 feet of the copper wire?

b) What is RHW insulation?

c) What is the diameter (in mils), of the wire?

d) What is the power absorbed by 50 feet of the wire when carrying the maximum allowable current?

e) What is the voltage across the 50 feet of wire when carrying maximum allowable current?

2. Repeat problem 1 for AWG 00 wire which has [illegible] amperes allowable current.

3. The resistivity of nichrome is 100 x $10^{-8}$ ohm-m (at 20°C), and the temperature coefficient is 4.4 x $10^{-4}$ /°C. A 50 ohm resistor is to be made from nichrome ribbon with [illegible] x $10^{-}$ [illegible] diameter?

a) What length of wire is needed (20°C)?

b) When the voltage across the resistor is [illegible] volts, how much power is it absorbing?

c) If the temperature rises to 60°C, what is the resistance?

4. A cable 20 meters long is used to connect a 480 volt source to a 5 amp load. The cable has two copper conductors, each of size AWG 12.

a) What is the voltage across the load?

b) Repeat part (a) if aluminum is substituted for the copper.

5. A 1000 ohm resistor is rated for 1/2 watt.

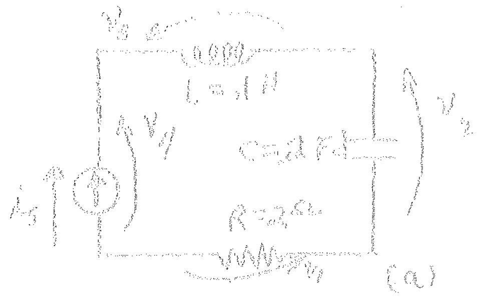
a) What is the maximum $\overset{\text{possible}}{\text{current}}$ through it [illegible] without exceeding its rating? [illegible]

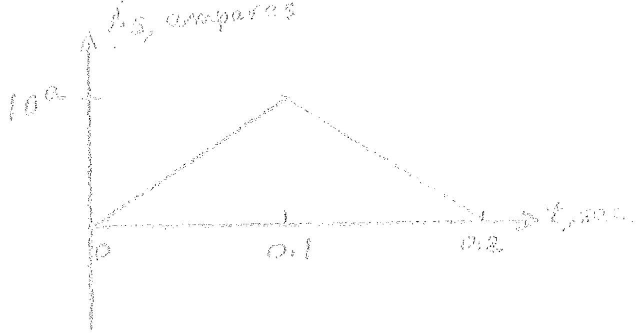
b) What is the maximum possible voltage [illegible] exceeding its rating? [illegible]

6. a) A 10,000 ohm resistor in an electrical circuit will have 100 volts across it. What should be its power-rating?

b) If two 5000 ohm resistors in series are substituted for the 10,000 ohm resistor, what should be the power-rating of each one?

7.





The circuit shown in fig. (a) has a source supplying current as shown in figure (b). There is zero energy stored in L and C at t = 0.

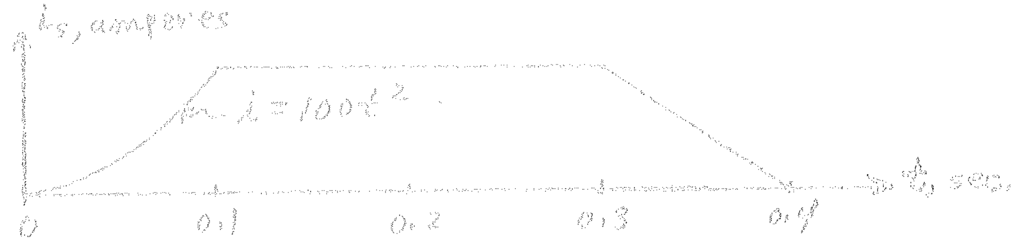
a) Sketch curves of $v_1$, $v_2$, $v_3$, and $v_4$ vs. t, showing values at t = 0, .1 and .2 seconds, .3 and .4 sec. for prob. 8.

b) Sketch curves of energy stored in L and energy stored in C vs t, showing values at t = 0, .1 and .2 seconds, .3 and .4 seconds for prob. 8.

c) What is the instantaneous power absorbed by R at t = 0.05 and 0.15 seconds?

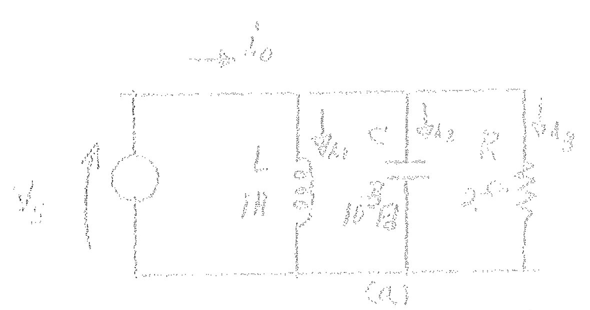
d) Repeat (c) for the inductor, and for the capacitor.

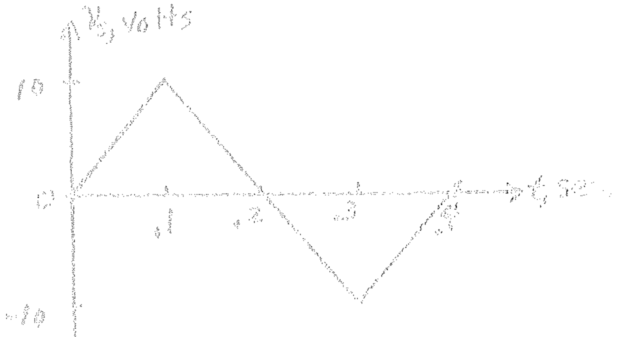
8.



Repeat problem 7 using the current shown.

9.





The source voltage waveform for circuit (a) is given in fig. (b). No energy is stored in L or C at t = 0.

a) Sketch $i_1$, $i_2$ and $i_3$ vs t. Show values at t = .1, .2, .3, .4 and .5 seconds.

b) Sketch a curve of $i_0$ vs t.

c) What energy is stored in L and in C at t = .3 seconds?

d) What instantaneous power is the source supplying at t = 0.2 seconds?

c) How much energy has each of the elements absorbed by time t = 0.5 seconds?

d) Find the energy supplied by the source, by time t = 0.5 seconds.

11.

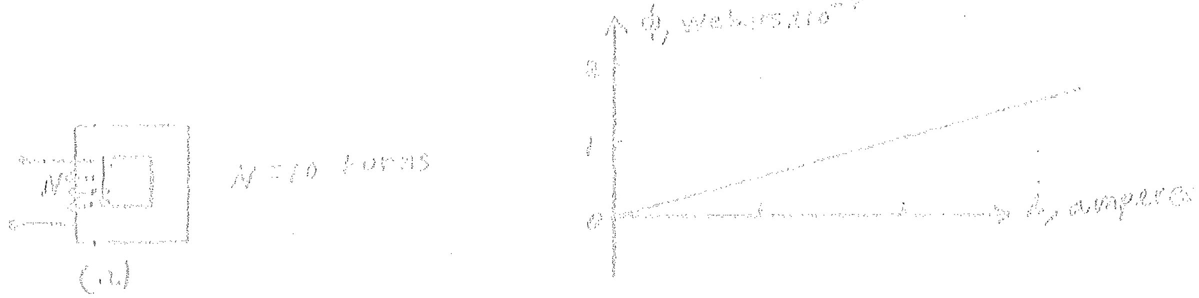


Figure (a) shows a coil with a closed iron core. The $\phi$-i curve for this coil without the iron core is shown in fig. (b).

a) What is the inductance of the coil without the iron core?

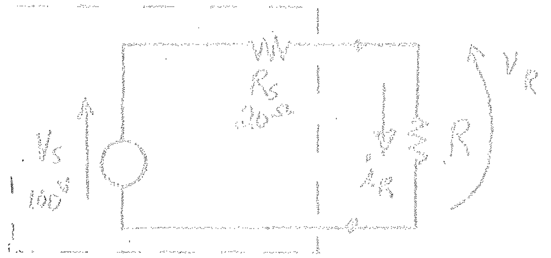
b) If the iron core increases the slope of curve fig. (a) by 2000 times, what is the inductance of the coil ... with the iron core?

c) If the number of turns for coil of part (b) is doubled, find the new value of inductance.

12. A parallel plate condenser with an air dielectric has a value of capacitance of $10^{-6}$ Fd.

a) What is the new value of c if the distance between plates is doubled? How much is c increased by changing the dielectric to polystyrene?

13.



The model for a practical source connected to a load is shown in the figure.

a) Find $v_1$ and $i_R$ for the following values of R (in ohms).

R = 0.5, 10, 20, 100, 200 and infinity.

b) Plot a curve of $v_R$ vs $i_R$.

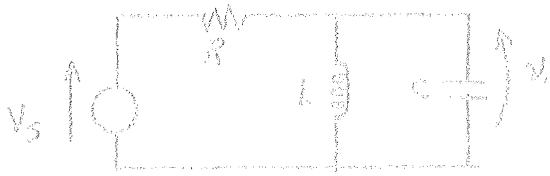
c) On one set of axes, plot a curve of power absorbed by R and power absorbed by $R_s$ vs R.

d) What is the relative values of the two resistors (R, $R_s$) for the case of maximum power absorbed by R?

14.

Plot curves of $v_R$ and $i_R$ vs R, using these values of R (ohms); 0, .5Ω, 1, 2, 10, 100, infinity.

15.



$v_c(0) = -2$ volts

a) Define loop currents.

b) Write the voltage equations in terms of the defined currents and circuit elements.

16.

a) Using the loop method, solve for the currents in each source.

b) Find the power supplied by each source

c) Find the power absorbed by each resistor.

17. a) For the circuit in problem 16, define branch currents and solve for the current in the 20 volt source.

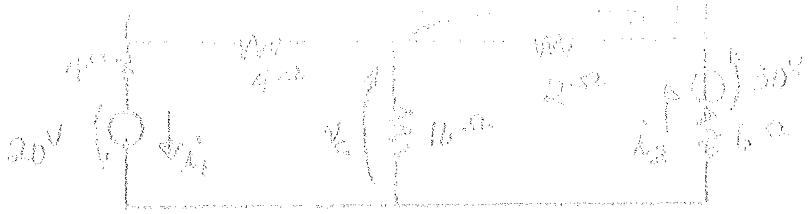
b) Find the power supplied by the 20 volt source.

18. a) For the circuit of problem 16, define the minimum number of unknown voltages, using node 'a' as a reference.

b) Solve for the voltage(s) of part (a).

c) Find $i_R$.

19.



a) Solve for current $i_1$ using the loop method.

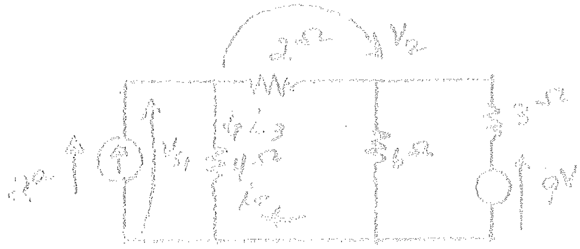
b) Solve for voltage $v_c$ using the node method.

20. For the circuit of problem 19:

a) Solve for current $i_2$ using the loop method.

b) Solve for voltage $v_2$ using the node method.

21.



Find the current in the 4 ohm resistor.
Find $V_2$, power supplied by the 9 volt source.

22. For the circuit of problem 21, find the voltage across the 6 ohm resistor.
Find $i_3$, $V_{s1}$, power supplied by the 2ampere source.

23. For the circuit of problem 21, find the current in the 2 ohm resistor, and $i_5$.

24.

When maximum detail is desirable, and a digital computer is available for a solution, circuit analysis can be done using the following procedure:

1) Define branch voltages $v_1$, $v_2$, $v_3$, $v_4$, $v_5$, $v_6$.

2) Define branch currents $I_1$, $I_2$, $I_3$, $I_4$, $I_5$, $I_6$.

3) Write KVL in terms of voltages defined in step 1.

$V_1 + V_2 - V_4 = 0$

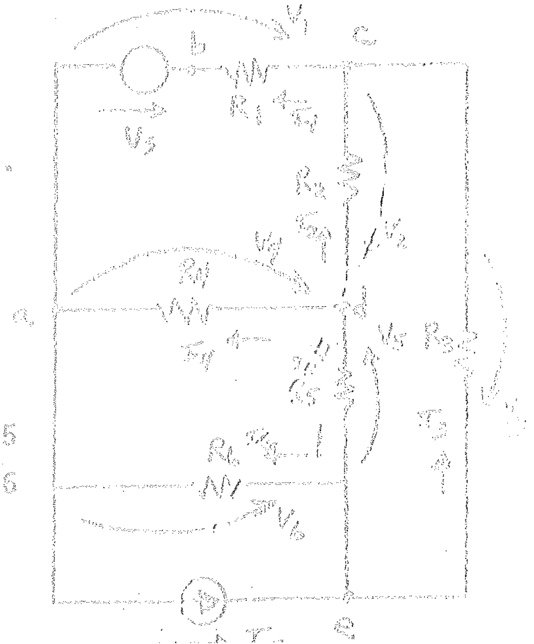
$V_4 - V_5 - V_6 = 0$

$V_3 - V_5 - V_2 = 0$

4) Write ohms law relations for each branch voltage

$V_1 = V_S + I_1 R_1$ $\quad$ $V_3 = I_3R_3$ $\quad$ $V_5 = I_5R_5$

$V_2 = I_2R_2$ $\quad$ $V_4 = I_4R_4$ $\quad$ $V_6 = I_6R_6$



5. Write KCL for each major node

Node C: $-I_1 + I_2 + I_3 = 0$

Node D: $I_2 + I_4 + I_5 = 0$

Node E: $I_s + I_5 - I_6 - I_3 = 0$

6. Solve the above 12 equations for the particular unknowns of interest.

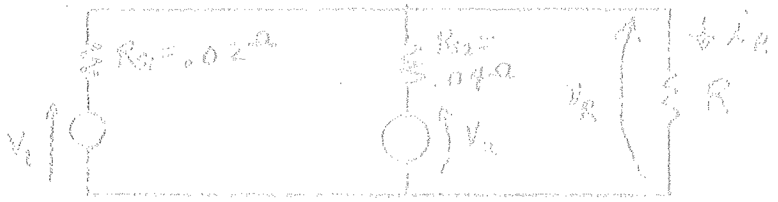
PROBLEM

a) Write the determinent for the voltage $V_4$.

b) Write the determinant for the current $I_7$.

c) What compiler language is best suited for the solution of equations of part (a) or (b)?

25.



$V_1 = 400$ volts

Two generators are supplying power to an industrial plant, represented by $R = 0.5$ ohms. The voltage $v_R$ is to be 392 volts.

a) Find the value of $v_2$ needed to provide the required $v_R$.

b) Find the power supplied by each source. (Subtract the loss in $R_{s1}$ or $R_{s2}$).

c) Express the power loss in each generator as a percent of the power absorbed by the load.

d) Find Efficiency.

25. Generator 2($V_2$) in problem 24, is removed from the circuit, (open circuited).

a) Find $V_1$ needed to provide 392 volts to the load.

b) If the maximum voltage for $V_1$ is 410 volts, what will be the maximum value of $v_R$?

27. In the circuit of problem 24, $V_2$ = 400 volts:

a) What value will $V_R$ have?

b) What power will each generator be supplying?
(subtract power loss in $R_{s1}$ or $R_{s2}$.)

28. A 12 battery is discharged when its terminal voltage is 10.8 volts. It has internal resistance of 0.01 ohms. A source is connected in series with the battery in order to charge it.

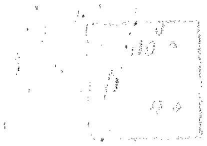
in the

a) Draw the circuit and indicate the polarity of the battery and charging source.

b) What charging voltage is needed to provide 5 amperes of charging current?

c) After one hour's time, the battery voltage has risen to 13.2 volts. What charging voltage is needed to maintain the 10 amperes charging current?

29.



(a)

(b)

Several power supplies of each type depicted in the figure are available in a laboratory.

a) How should two supplies of the Fig. (a) type be connected to provide simultaneous voltages of 0, +10, and +20 volts? Indicate the reference node in the connection: Draw the connections.

b) Show how to connect two supplied of Fig. (b) to provide simultaneous voltages of: 0, +20, +40, -20, -40 volts.

c) Show the connections required to provide simultaneous voltages of -40, -20, 0, +10 volts.

Marks

[illegible] Lab [illegible]

for the week of [illegible]

report on [illegible], [illegible]

9:30 AM, (if you can) to

assemble equipment and perform

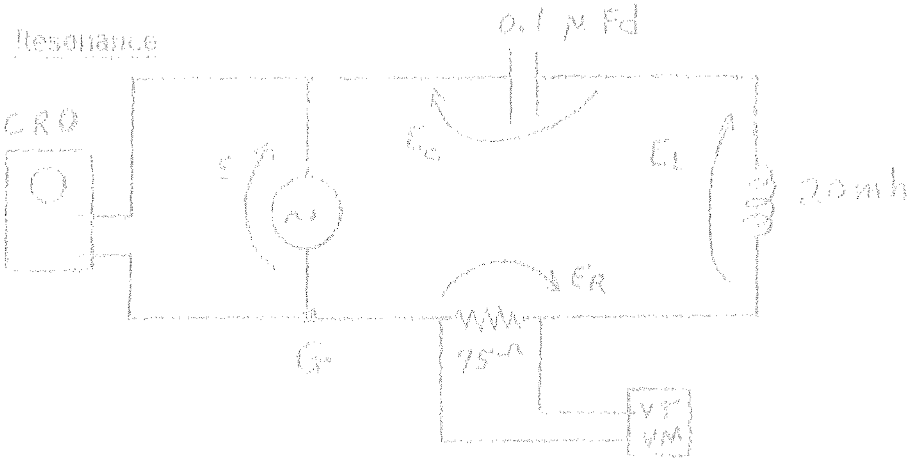
the experiments.

T. [illegible]

[illegible]

The instruments of interest in this experiment are the variable frequency audio oscillator, the HP 400 vacuum tube voltmeter (VTVM), and the oscilloscope (CRO). The VTVM is a high impedance voltmeter with reasonable accuracy over the audio frequency range. Learn to use the oscilloscope to measure voltage, frequency and to observe the actual waveforms. Current resonance in the series circuit and voltage resonance in the parallel circuit will be observed as the source frequency is varied.

Series Resonance



A) Connect the circuit shown. (Caution) Since the CRO and VTVM are each grounded through the a.c. line, be sure the ground terminal of each is connected to point G of the circuit. E is the audio oscillator with the amplitude dial set to give 8 volts peak-to-peak. Use the oscilloscope to measure E and the VTVM to measure $E_R$.

B) Vary the frequency until resonance (Max. $E_R = E_{R0}$) occurs. At resonance record the frequency, $E_R$, and E. Keep E constant for parts B, C, D, and E. Measure the frequency using the CRO.

C) Disconnect the CRO (both terminals), and measure $E_L$ and $E_C$ at resonance with VTVM.

D) Reconnect the meters as in part (A), and with $E_R$ set at each half power point (.707$E_{R0}$), record the readings of part (B).

[illegible]

[illegible] parallel [illegible] circuit [illegible] [illegible] frequency [illegible] [illegible] the [illegible] [illegible] [illegible] [illegible]

[illegible] time of the oscillator dial [illegible] equipment [illegible] [illegible] Use the VTVM to measure $E_0$ and the [illegible] to measure $E_s$ [illegible]

[illegible] Verify that $E_s$ remains constant over the frequency range [illegible] by measuring $E_s$ ($R_s$ [illegible] $E_s$ 50 K) at several frequencies [illegible] measure $E_0$ with the VTVM and note the frequency [illegible]

[illegible] plot a resonant curve [illegible] $E_0$ vs $f$ [illegible] half power points [illegible]

## Report

[illegible] the type of [illegible] [illegible] impedance ([illegible]) [illegible]

[illegible] the type of oscilloscope used [illegible] minimum and maximum sweep [illegible]

[illegible] Sketch [illegible] oscilloscope [illegible]

[illegible] curves and calculate the [illegible]

[illegible] from the curve [illegible] [illegible]

EE 233

Exp. #1

## Meters Used in A.C. Circuits

This experiment is to acquaint the student with ammeters and voltmeters as used in a.c. circuits. The measurements will verify phasor relationships existing among the voltages and currents. Power will be obtained using the circuit of Fig. 1. The auto-transformer is an inductor connected in parallel with the power line, and has a variable tap, so that the source voltage $V_s$ can be set to any value up to about 150 volts RMS.

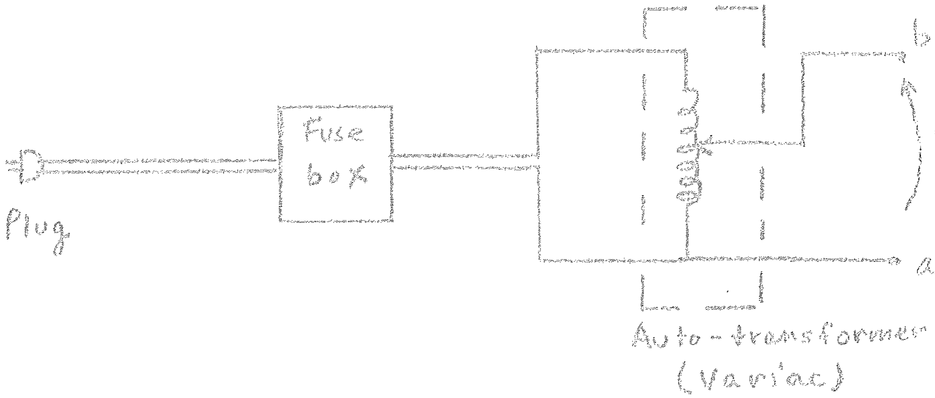
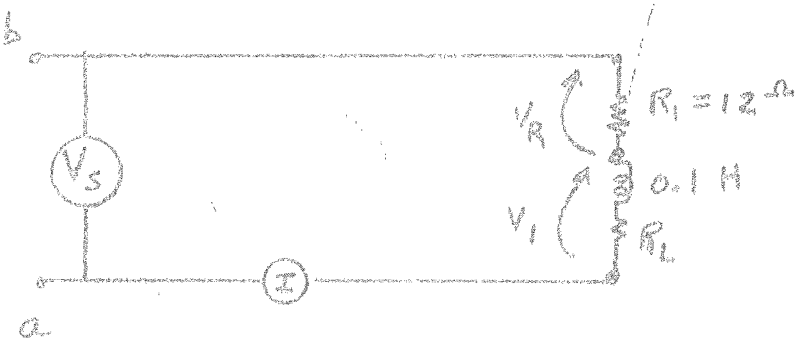


Fig. 1

Make all connections with the circuit unplugged and variac set to zero. After the lab instructor has checked the connections, the circuit can be plugged in and variac increased gradually to the proper value.

1. Series R-L Circuits



a) Connect the circuit shown and have the instructor check connections. Then energize the circuit and increase $V_s$ to 60 volts (RMS) and record meter readings for I, $V_s$, $V_1$ and $V_R$.

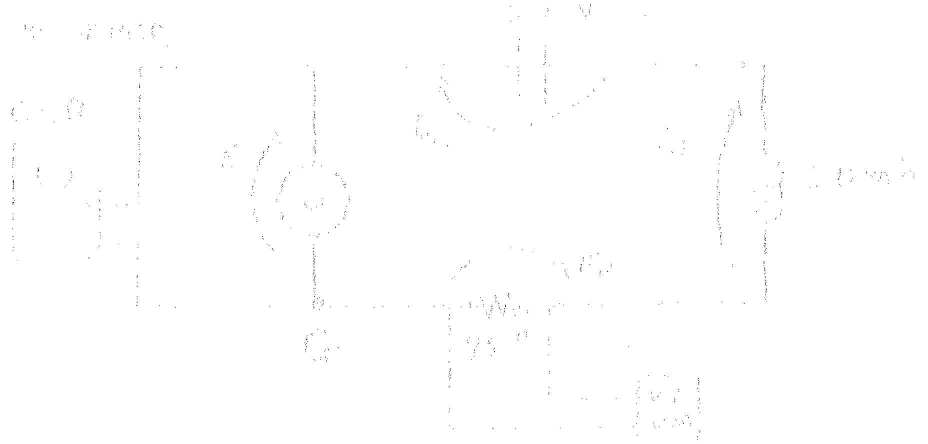
b) Measure the D.C. resistance of $R_1$ and of the coil ($R_L$).

[illegible]

[illegible] and capacitance [illegible] which [illegible]

[illegible] and to [illegible] the circuit [illegible] tuned [illegible] voltage [illegible] will be [illegible] accurately recorded.

[illegible]



(a) Connect the circuit shown. [illegible] Have the CRO and [illegible] grounded through the a.c. line. Be sure the ground terminal of [illegible] is [illegible] to point [illegible] of the circuit. [illegible] the audio oscillator [illegible] to give 5 volts peak to peak. Use the oscillator [illegible] and the CRO to measure $E_g$.

(b) Vary the frequency until resonance (i.e. $E_c = E_{ab}$) occurs. [illegible] the frequency, $f_R$, and [illegible] found [illegible]. Check the frequency using the CRO.

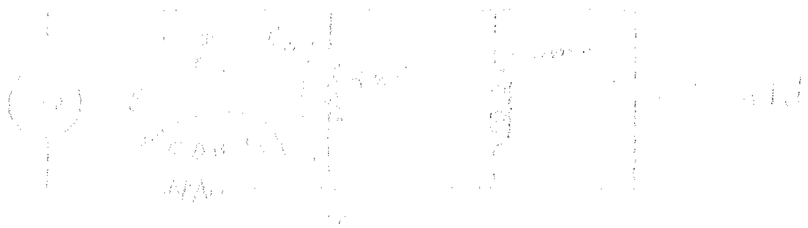
(c) [illegible] the CRO [illegible] and measure $E_c$ and $E_L$ [illegible]

(d) [illegible] frequency [illegible]

[illegible]

[illegible]

[illegible] series [illegible] circuit [illegible] should be [illegible] the voltage [illegible] resonant frequency [illegible] the circuit [illegible] by using [illegible] the given [illegible]



Set the amplitude of the oscillator at 1 to 2 [illegible] and keep it at this value throughout the experiment. Use the VTVM to measure $V_s$ and the CRO to measure $V_R$. [illegible]

A) Confirm that $V_s$ remains constant over the frequency range [illegible] be [illegible] possible by measuring $V_s$ ($V_R$ or $V_C$) at several frequencies. [illegible] observe $V_R$ with the VTVM and note the frequency [illegible] resonance.

B) Use data to plot a resonance curve ($V_R$ vs f). Be sure to [illegible] the resonant point and the half power points. Measure f using the CRO.

Report

A) Give the type of VTVM used, the ranges of voltages [illegible] and [illegible] input impedance (see instruction manual).

B) Record the type of oscilloscope used, the [illegible] and vertical settings and H. with [illegible] minimum and maximum sweep speed and [illegible] time base [illegible] speed.)

C) [illegible] a sketch of the [illegible] oscillator [illegible]

D) From the [illegible] curves [illegible]

marks

SYLLABUS - 2344/2334 AUTOMATION SPRING, 1977

Text: Smith, Circuits devices and Systems, Wiley Vines, Automation of Petroleum and Chemical Systems, Tech Printed, Tech Bookstore

| Teaching | Chapter | Topics |
|---|---|---|
| 1 | Ch. 1 (Vines) | Overview of Automation Smith last Ch. |
| 2 | Ch. 2 (Vines) | Rise time, freq. resp. reliability |
| 3 | Ch. 3 (Vines) | Smith ch Transducers |
| 4 | Quiz | Transducers |
| 5 | | Transducers and signal conditioning |
| 6 | Ch. 4 (Vines) | Telemetry, communications |
| 7 | | Telemetry |
| 8 | Quiz | Vines Ch. 5 Computers ✓ |
| 9 | | Computers |
| 10 | | Programming |
| 11 | Quiz | Vines Ch. 6 Motors and Controls |
| 12 | | Motors |
| 13 | | Vines Ch. 1 Systems Overview |
| 14 | Quiz | Systems Overview |

EE 2344 Tour an automated Petrochemical Plant in groups of 3 or 4 no earlier than March [illegible]

Write report and present to class if required in last week.

EE 2344 Write a computer Program to test 4 wells, produce into 2 seperators, dump oil/water into tanks, don't overflow!

EE 2344 Five labs to be conducted with class, suggested times 7:30-9:30 as required.

EE 2344 Two library reports each week for articles related to topic of discussion. Do not repeat these in annotated Bibliography

EE 234 Labs as scheduled

EE 234 Tour may be optional

HOMEWORK GRADING

$m$ = # PROBLEMS ASSIGNED

$q$ = # " NOT ATTEMPTED

$n$ = # " GRADED $\geq m/2$

$p_i$ = # POINTS GIVEN ON $i^{th}$ PROBLEM, $i = 1 \ldots n$

$I(d)$ = NEXT HIGHEST INTEGER $\geq d$

$0 \leq p_i \leq 10$

SCORE = $I(d)$ WHERE

$$d = \left(\sum_{i=1}^{n} p_i\right)\left(\frac{m-q}{n}\right)$$

$$d_{MAX} = I_{MAX} = 10m$$

Syllabus, EE 234 Electronic Instrumentation Fall 1976

Text: Circuits, Devices and System's by Ralph Smith Third Edition (Second Edition)

| Topic | Ch | Pages |
|---|---|---|
| 1 Semiconductor diodes | 11 (9) | 290-303 (267-280) |
| 2 Diode Models & Application | 12 (10,12) | 311-319 (311-315, 391-396) |
| 3 Field Effect Transistor (FET) | 13 (9) | 335-340 (286-288) |
| 4 Bipolar Junction Transistor (BJT) | 13 (9) | 340-349 (289-293, 297-300) |
| 5 Integrated Circuits | 13 (9) | 348-354 (293-295) |
| 6 Practical Amplifiers | 16 (11) | 409-413 (343-348) |
| 7 Biasing BJT | 16 (11) | 419-423 (352-356) |
| 8 Power Amplifiers | 16 (11) | 423-431 (357-364) |
| 9 Other Amplifiers | 16 (11) | 431-433 (379-382) |
| 10 Triodes & Pentodes | 10 (9) | 274-278 (282-287) |
| 11 Two Port parameters | 8, 17<br>(8, 10) | 217-218, 445-446<br>(223-224, 316-317) |
| 12 FET parameters & model | 17 (notes) | 446-450 |
| 13 BJT Parameters & Model | 17 (10) | 452-459 (327-335) |
| 14 RC Coupled Amplifiers | 18 (11) | 465-481 (364-375) |
| 15 Multistage Amplifiers | 18 (11) | 481-484 (375-379) |
| 16 Modulation | 17 (12) | 440-443 (407-412) |
| 17 A Communication System | 17 (12) | 443-458-9 (412-14) |
| 18 Operational Amplifiers | 19 (20) | 506,512 (641-44, notes) |
| 19 Analog Computer | 19 (20) | 523-28 (645-50) |
| 20 Instrumentation | 27 (21) | 709-735 (653-681) |
| 21 A. C. Machines | 25 (18) | 659-679 (577-596) |
| 22 D. C. Machines | 24 (18) | 631-648 (557-573) |

SPRING 1977

TEXAS TECH UNIVERSITY
STUDENT INFORMATION SYSTEM

PAGE 1
7549

- PRELIMINARY CLASS ROLLS -

PR001

DEPARTMENT 590 (E E ) COURSE 234 SECTION 004

INSTRUCTOR ~~WISE~~ Marks ~~GARY~~ Bob L

| STUDENT NUMBER | LAST NAME | FIRST NAME | MI | SCHOOL | CLASS | SEX |
|---|---|---|---|---|---|---|
| 496 70 8304 | ABU-SARRIS | FAHMI | H | 04 | 4 | 1 |
| 462 84 0851 | ANTHONY JR | WILLIAM | R | 04 | 9 | 1 |
| 460 92 8241 | BOU-CHEBL | SABA | S | 04 | 4 | 1 |
| 456 80 1932 | CAGLE | BILLY | R | 04 | 2 | 2 |
| 460 04 6744 | CAVINESS | WYNDELL | R | 04 | 4 | 1 |
| 454 08 9465 | DUNN ✓ | TIMOTHY | M | 04 | 4 | 1 |
| 366 72 3166 | EL-SABAALY | BOUTROS | G | 04 | 4 | 1 |
| 459 88 3465 | HENDRIX | ROBERT | E | 04 | 3 | 1 |
| 465 76 3151 | HILL | WILLIAM | B | 04 | 4 | 2 |
| 463 80 8812 | HOLSOMBACK | THEODORE | W | 04 | 4 | 2 |
| 465 11 7454 | MOORE | KEITH | W | 04 | 3 | 1 |
| 466 90 8616 | MOORE | MICHAEL | L | 04 | 4 | 2 |
| 466 06 8496 | PRATHER | RICKY | K | 04 | 3 | 1 |
| 452 02 7517 | PUCKETT ✓ | KENT | S | 04 | 4 | 1 |
| 465 04 7489 | ROACH | GARY | B | 04 | 2 | 1 |
| 466 08 3306 | SAUER | PAUL | W | 04 | 4 | 1 |
| 454 15 4927 | SAVAGE | KELLY | B | 04 | 3 | 1 |
| 328 38 9752 | SCIALO | ANTHONY | M | 04 | 4 | 2 |
| 478 80 0190 | TU | QUI | H | 04 | 4 | 4 |
| 459 92 2358 | WHITE | GARY | L | 04 | 4 | 1 |

*TOTAL NUMBER OF STUDENTS 20

TEXAS TECH UNIVERSITY
STUDENT INFORMATION SYSTEM

- PRELIMINARY CLASS ROLLS -

marks

DEPARTMENT 590 (E E ) COURSE 234 SECTION 004

INSTRUCTOR WISE GARY L

| STUDENT NUMBER | LAST NAME | FIRST NAME | MI | SCHOOL | CLASS | SEX |
|---|---|---|---|---|---|---|
| 496 70 8304 | ABU-SARRIS | FAHMI | H | 04 | 4 | 1 |
| 462 84 0851 | ANTHONY JR | WILLIAM | R | 04 | 9 | 1 |
| 460 92 8241 | BOU-CHEBL | SABA | S | 04 | 4 | 1 |
| 456 80 1932 | CAGLE | BILLY | R | 04 | 3 | 2 |
| 460 04 6744 | CAVINESS | WYNDELL | R | 04 | 4 | 1 |
| | DEHKORDI | FAHSH. | | | | |
| 454 08 9465 | DUNN | TIMOTHY | M | 04 | 4 | 1 |
| 366 72 3166 | EL-SABAALY | BOUTROS | G | 04 | 4 | 1 |
| 459 88 3465 | HENDRIX | ROBERT | E | 04 | 3 | 1 |
| 465 76 3151 | HILL | WILLIAM | B | 04 | 4 | 2 |
| 463 80 8812 | HOLSOMBACK | THEODORE | W | 04 | 4 | 2 |
| | LUNSFORD | | | | | |
| 465 11 7454 | MOORE | KEITH | W | 04 | 3 | 1 |
| 466 90 8616 | MOORE | MICHAEL | L | 04 | 4 | 2 |
| | NAPIER | BUDDY | | | | |
| 466 06 8496 | PRATHER | RICKY | K | 04 | 3 | 1 |
| | PAKRAVAN | FARHAD | | | | |
| 452 02 7517 | PUCKETT | KENT | S | 04 | 4 | 1 |
| | PIERCE | JOHN | | | | |
| 465 04 7489 | ROACH | GARY | B | 04 | 2 | 1 |
| | ROSS | GLYDEN | | | | |
| 466 08 3306 | SAUER | PAUL | W | 04 | 4 | 1 |
| 454 15 4927 | SAVAGE | KELLY | B | 04 | 3 | 1 |
| 328 38 9752 | SCIALO | ANTHONY | M | 04 | 4 | 2 |
| | THAXTON | SABER | | | | |
| 478 80 0190 | TU | QUI | H | 04 | 4 | 4 |
| * 459 92 2398 | WHITE | GARY | L | 04 | 4 | 1 |

*TOTAL NUMBER OF STUDENTS 20

# TEXAS TECH UNIVERSITY
OFFICE OF THE REGISTRAR
## CLASS ROLL

FACULTY Marks

02011 AS OF 02/01/77 0174

| SEMESTER | DEPARTMENT | NUMBER | SECTION | PAGE NO. |
|---|---|---|---|---|
| SPRING 1977 FEB 01, 1977 | 590 ( ) | 234 | 004 | 1 |

| INSTRUCTOR | DESCRIPTIVE TITLE |
|---|---|
| PAN CHING T (1) | ELECTRONIC INSTRUMENTATION |

| SOC. SEC. NO. | STUDENT'S NAME | | | SCH. | CLASS | REMARKS |
|---|---|---|---|---|---|---|
| 496 70 8304 | ABU-SAPOIS | FAHMI | H | 04 | 4 | |
| 462 8[illegible] 0811 | ANTHONY JR | WILLIAM | R | 04 | [illegible] | |
| 460 92 4241 | BUI-CHISL | SAMA X | S | 04 | 4 | |
| 456 80 1932 | EAGLE | BILLY | P | 04 | 3 | |
| 460 04 [illegible]744 | ~~[illegible]~~ | WYNDELL X | | 04 | 4 | DROP |
| 462 66 6757 | DEHKOPCI | SHAHROKH | | 04 | 4 | |
| 4[illegible] 08 [illegible] | DUNN | TIMOTHY | M | 04 | [illegible] | |
| 366 72 [illegible]166 | EL-SABAALY | BOUTROS | G | 04 | 4 | |
| 459 88 [illegible]465 | ~~[illegible]~~ | ROBERT X | E | 04 | 3 | DROP |
| 465 76 3151 | HILL | WILLIAM | B | 04 | 4 | |
| 463 80 8812 | HOLSOMBACK | THEODORE X | W | 04 | 4 | |
| 450 11 1744 | LUNSFORD | JAY | L | 04 | 4 | |
| 465 11 7454 | MOORE | KEITH | W | 04 | 4 | |
| 465 90 8616 | MOHRE | MICHAEL | L | 04 | 4 | |
| 463 13 7394 | NAPIER | HARRIS X | G | 04 | 4 | |
| 119 50 5642 | PAKRAVAN | FARHAD | | 04 | 4 | |
| 461 94 25[illegible] | PIERCE | JOHN | W | 04 | 4 | |
| 466 06 3496 | ~~[illegible]~~ | RICKY X | K | 04 | [illegible] | DROP |
| 452 02 7517 | PUCKETT | KENT | S | 04 | | |
| 438 08 2609 | RAHCAMIFAR | HUSHMAND | | 04 | 3 | |
| 465 04 7480 | ROACH | GARY | D | 04 | 2 | |
| 466 72 1440 | ROSS JR | GLYNDON | G | 04 | 3 | |
| 466 08 [illegible]306 | SAUER | PAUL | W | 04 | 4 | |
| 4[illegible] 1[illegible] [illegible]027 | SAVAGE | KELLY | B | 04 | 3 | |
| 328 38 0752 | ~~SETALH~~ | ~~ANTHONY~~ | H | 04 | 4 | DROP |
| 535 92 3425 | THAXTON | SABRA | K | 04 | 3 | |
| 478 80 0100 | YU | QUI | H | 04 | 4 | |
| 459 92 2358 | WHITE | GARY | L | 04 | 4 | |
| TOTAL | 28, ACTIVE | 28, CREDIT HOURS | 84 | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

INSTRUCTOR'S SIGNATURE Ching-Tsau Pan

TELEPHONE EXT. 742-3528

DATE Feb 14, 77

marks.

EE 2346, References

| Topic | Vine's Book | Smith's Book | |
|---|---|---|---|
| | | 2nd Edition | 3rd Edition |
| Relay | 3-4 | 541 | 616 |
| FET | | 277-78 | 336 |
| Load Line | | Similar to Ex 9, p.297 | Similar to Ex 5, p281 |
| BJT | 3-4,5 | 232-3 | 345-6 |
| Load Line | | p. 239 Ex 10 | p. 349 Ex. 5 |
| Transducers | 3-5 to 3-15 | p. 667-679 | p. 722-733 |
| Fabricating Integrated Circuits | | p. 293-4 | p. 348-350 |
| Motors and Controls | Ch. 6 | Ch. 18 | Ch. 24-25 |
| Op. Amps. | 3-18-20 | Ch. 20 | Ch. 19 |

TS.

Marks

Texas Tech University

Registrar P.O. Box 4570 Lubbock, Texas 79409 Phone (806) 742-2201

April 1, 1977

Department Chairman and Faculty Member:

Attached are your Revised Class Rolls for the Spring 1977 semester.

PLEASE CHECK THIS ROLL IN CLASS.

A. If Students are attending this class and their name does not appear on this roll, advise them to see their Academic Dean immediately.

B. If a student's name is on your roll who is not attending your class, notify the student's Academic Dean that he is not attending. (Refer to General Catalog, Pages 56 and 57.)

C. Students may not change courses or sections except by the official "Change in Registration" form initiated and approved by their Academic Dean.

This is the final check point for correcting all class rolls before producing the Final Grade Roll. We request that you check these rolls carefully, since it will be most difficult and time consuming to make additions to the Final Grade Roll. A student whose registration has not been cleared for a particular course and section, will not appear on the Final Grade Roll, thus causing a serious inconvenience to you, the student and the Dean's Office.

The Department Chairman is furnished two (2) copies of this class roll, one of which is forwarded to the professor. We do not want a copy of this class roll returned to the Registrar's Office. Departments and faculty are requested to use it for the sole purpose of correcting all discrepancies so the Final Grade Roll will be correct.

Students who registered but did not pay their registration fees are not shown on this roll.

Sincerely,

Don Wickard

Don Wickard
Associate Registrar

DW/gw

4177-1700

```
RN029                                   04/02/77                06569

SPRING 1977    REVISED CLASS ROLL 590 (E E )   234      004          1   1

PAN                CHING             T (1)  ELECTRONIC INSTRUMENTATION

  496 70 8304  ABU-SARRIS      FAHMI          H      04 4                1
  462 84 0851  ANTHONY JR      WILLIAM        P      04 9                2
  460 92 8241  BOU-CHEBL       SABA           S      04 4                3
  456 80 1932  CAGLE           BILLY          R      04 3                4
3 460 04 6744  CAVINESS        WYNDELL        R      04 4  W OR WF       5
  585 16 6289  DAVIS           JODIE          L      04 4                6
  442 66 6757  DEHKORDI        SHAHROKH              04 4                7
  454 08 9465  DUNN            TIMOTHY        M      04 4                8
  366 72 3166  EL-SABAALY      BOUTROS        G      04 4                9
  459 88 3465  HENDRIX         ROBERT         E      04 3  W OR WF      10
  465 76 3151  HILL            WILLIAM        B      04 4               11
  463 80 8812  HOLSOMBACK      THEODORE       W      04 4               12
  450 11 1764  LUNSFORD        JAY            L      04 4               13
  465 11 7454  MOORE           KEITH          W      04 3               14
  466 90 8616  MOORE           MICHAEL        L      04 4               15
  463 13 7394  NAPIER          HARRIS         G      04 4               16
  119 50 5642  PAKRAVAN        FARHAD                04 4               17
  461 94 2555  PIERCE          JOHN           W      04 3               18
```

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RRC29                                        04/02/77              06570

SPRING 1977   REVISED CLASS ROLL 590 (E E )   234      004         2   1

PAN               CHING            T (I)  ELECTRONIC INSTRUMENTATION

3 466 06 8496  PRATHER          RICKY          K      04 3   W OP WF     1
  452 02 7517  PUCKETT          KENT           S      04 4               2
  438 08 2600  RAHMANIFAR       HOSHMAND              04 3               3
  465 04 7489  ROACH            GARY           R      04 2               4
  466 92 3440  ROSS JR          GLYNDON        G      04 3               5
  466 08 3306  SAUER            PAUL           W      04 4               6
  454 15 4927  SAVAGE           KELLY          B      04 3               7
2 328 38 9752  SCIALO           ANTHONY        M      04 4   WITHDREW    8
  585 92 5429  THAXTON          SABER          K      04 3               9
  478 80 0190  TU               GUI            H      04 4              10
  459 92 2358  WHITE            GARY           L      04 4              11
     TOTAL STUDENTS    29,  ACTIVE STUDENTS    25
```

| | |
|---|---|
| GARY WHITE ✓ | — |
| Paul Sauer ✓ | 797 - 2006 |
| SÄBA BOU-CHEBL ✓ | 742-4550 |
| Rick Prather ✓ | 744-1928 |
| Rob Hendrix ✓ | 944-1928 |
| JOHN PIERCE ✓ | 747 - 3901 |
| KEITH MOORE ✓ | 744-5218 |
| Mike Moore ✓ | 795-5659 |
| BUD HILL ✓ | 793-0985 |
| Wyndell Caviness ✓ | 797-0187 |
| Bill Cagle ✓ | 797-5474 |
| KELLY SAVAGE ✓ | 797-3142 |
| BILL ANTHONY ✓ | 762 -5756 |
| ~~[illegible]~~ | |
| Ted Holsombeck ✓ | 799-7797 |
| Tony Sciale ✓ | 799-7687 |
| QUI TU ✓ | 762-1235 |
| GARY ROACH ✓ | 765-5411 |
| Fahmi Abu-Sarris ✓ | 747-7675 |
| Farhad Pakravan ✓ | 765-5998 |
| EL-SABAALY, BOUTROS ✓ | 744 - 6780 |
| TIM DUNN ✓ | 799-1519 |
| DEHKORDI SHAHROKH ✓ | 742-4066 |
| Qiamir Hoshmand, Rahmanifar ✓ | 747 - 3530 |
| Glyndon Ross ✓ | 762-1478 |
| Saber Thaxton ✓ | 765-9128 |
| Jodie Davis ✓ | 744-3032 |
| KENT S PUCKETT ✓ | 742-5067 |
| BUDDY NAPIER ✓ | 744-2981 |
| LEA LUNSFORD ✓ | 747-5865 |

# MEMORANDUM

Office of the Dean of Engineering
Texas Tech University
Lubbock, Texas 79409

TO: PROFESSOR (SEE BELOW)
DATE: APRIL 18, 1977
SUBJECT: ABSENCE OF STUDENT
FROM: ROBERT L. NEWELL, ASSOCIATE DEAN OF ENGINEERING

John William Pierce, Social Security No. 461-94-2555, is enrolled in one of the classes taught by you, as noted below.

We have just learned from a telephone conversation with his father, that Mr. Pierce is in the hospital under doctor's care (effective April 11, 1977), and will remain there for an extended period of time and will not be able to return to school this semester.

Because Mr. Pierce is a good student, and because of this particular situation, we are requesting that a grade of Incomplete (I), be given the student. We understand that he will be contacting all his instructors after May 15th.

Thank you for your attention to this matter.

| | | |
|---|---|---|
| Mr. Tom Sawyer | for | BA 3391-002 |
| Mr. Sam Boyd | for | BA 3391-PPP |
| Mr. Bob Marks | for | EE 234-004 |
| Dr. Charles Burford | for | IE 3334-001 |
| Mr. Robert E. Martin | for | ME 3342-002-B |

Robert L. Newell
Robert L. Newell

RLN:ad

CC: Mr. William C. Pierce
9714 Lanward Drive
Dallas, Texas 75238

## I. SEMICONDUCTOR DIODES

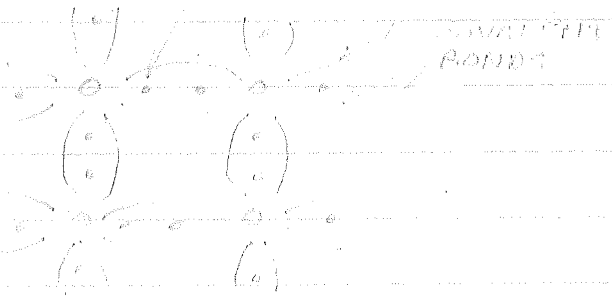
### A. CONDUCTION IN SOLIDS

1, COMMONEST SEMICONDUCTORS: GERMANIUM & SILICON

VALENCE OF FOUR

BONDING: COVALENT

[illegible]



CONDUCTION IN A SEMICONDUCTOR IS DUE TO ELECTRON AND HOLE CURRENT.

HOLE = AN VACANCY LEFT BY AN ELECTRON.

WE TREAT A HOLE LIKE AN ELECTRON WITH A POSITIVE CHARGE.

IN A PURE SEMICONDUCTOR

$n = p$

$n$ = ELECTRON CONCENTRATION

$p$ = HOLE CONCENTRATION

$n = p = n_i$

$n_i$ = INTRINSIC CONCENTRATION

Si: $n_i = 1.5 \times 10^{16} / m^3$

Ge: $n_i = 2.4 \times 10^{19} / m^3$

2. DOPED SEMICONDUCTOR

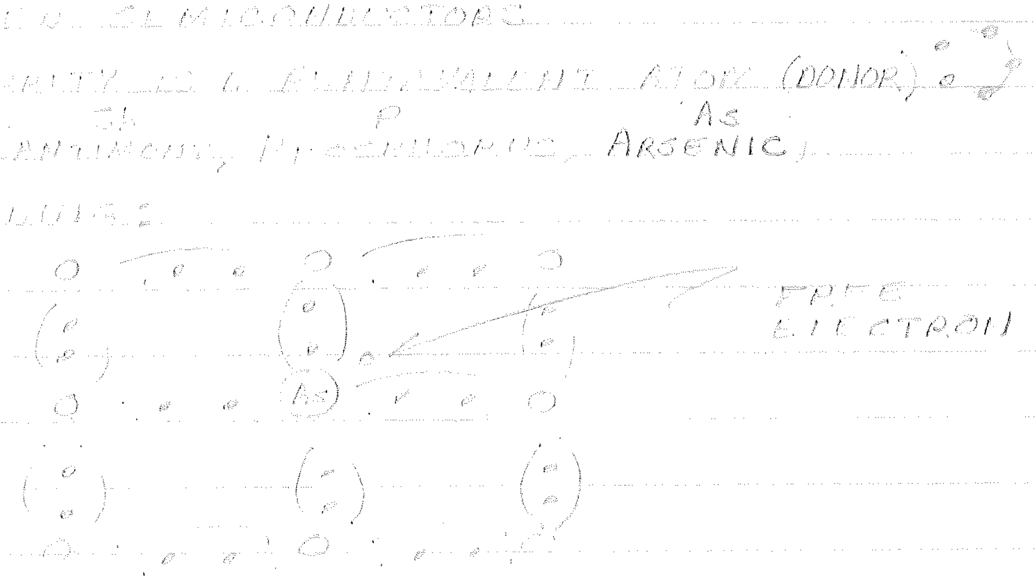
ADDITIONAL "IMPURITY" ATOMS ARE ADDED TO THE SEMICONDUCTOR TO PRODUCE EXTRA FREE HOLES OR ELECTRONS.

N-DOPED SEMICONDUCTORS

IMPURITY IS A PENTAVALENT ATOM (DONOR)

Sb P As
(ANTIMONY, PHOSPHORUS, ARSENIC)

BONDING:

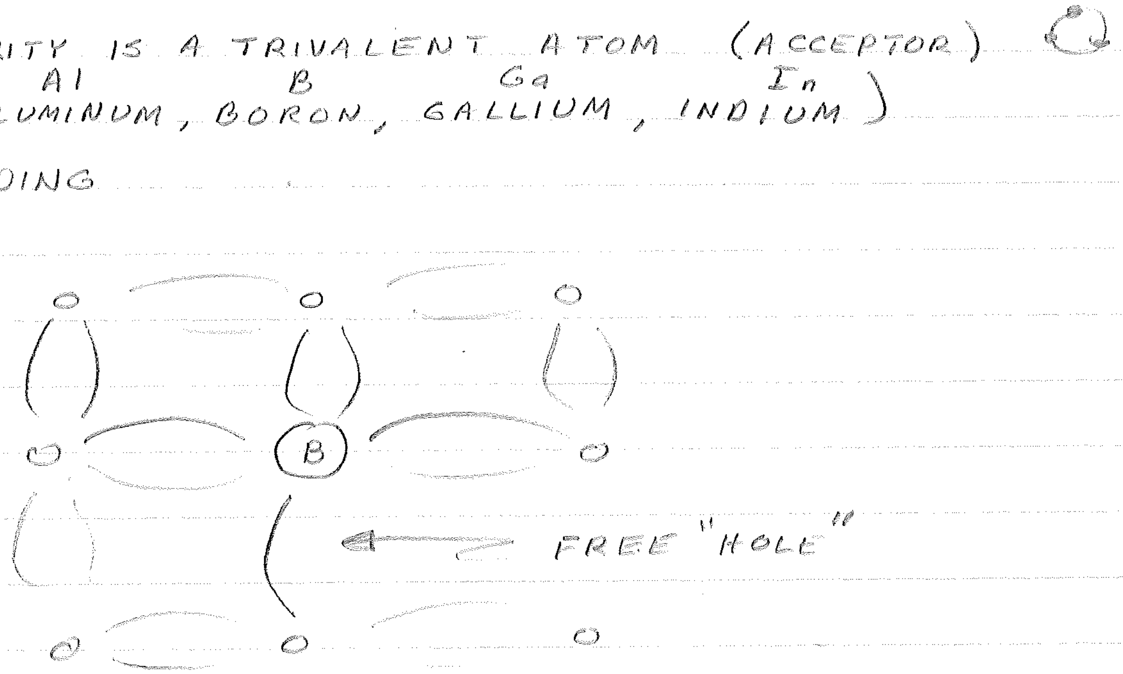


P-DOPED SEMICONDUCTORS

IMPURITY IS A TRIVALENT ATOM (ACCEPTOR)

Al B Ga In
(ALUMINUM, BORON, GALLIUM, INDIUM)

BONDING



## 3. CONDUCTION

IMPURITIES INCREASE A SEMICONDUCTOR'S CONDUCTANCE.

### a. MASS - ACTION LAW

$R = r n p$

$R$ = RECOMBINATION RATE $\left(\frac{e \cdot h \text{ PAIRS}}{s - m^3}\right)$

$n$ = ELECTRON CONCENTRATION $\left(\frac{\#}{m^3}\right)$

$p$ = HOLE " $\left(\frac{\#}{m^3}\right)$

$r$ = PROPORTIONALITY CONSTANT

R MEASURES THE RATE AT WHICH ELECTRON-HOLE PAIRS ARE RECOMBINING. — IT SAYS: RATE OF REC. IN PRO. TO # OF REACTING ELEMENTS.

REGENERATION, $g$, MEASURES THE RATE AT WHICH ELECTRON HOLE PAIRS ARE BEING FORMED.

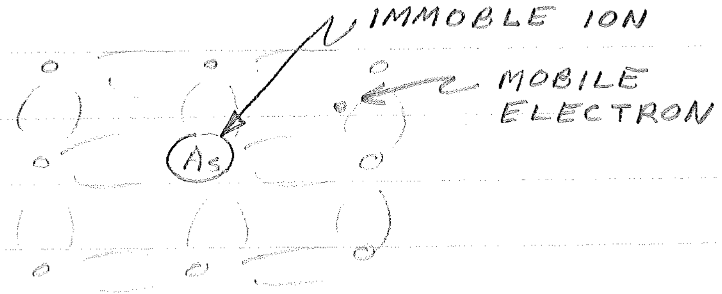
IN A PURE SEMICONDUCTOR, $n_i = p_i$

$$\Rightarrow R = g = r n_i^2$$

THIS IS ALSO ~~ROUGHLY~~ TRUE IN A DOPED SEMICONDUCTOR ~~SINCE~~

~~# IMPURITY ATOMS << # SEMICONDUCTOR ATOMS~~

b. A DOPED SEMICONDUCTOR IS, OVERALL, ELECTRICALLY NEUTRAL



DEFINE

$N_d$ = # OF DONOR IONS (+)

$N_a$ = # OF ACCEPTOR ION (−)

IN GENERAL ⇒ $p + N_d = n + N_a$

FOR n DOPED SEMICOND., $N_a = 0$ AND

$$n_n = N_d + p_n$$

IN PRACTICAL CASES, $N_d >> p_n$ AND

$$n_n \simeq N_d \qquad ①$$

THE HOLE DENSITY IS GIVEN BY

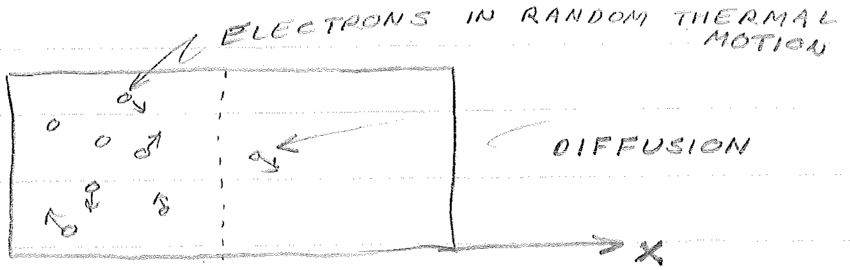
$$n_n p_n = n_i^2$$

$$p_n = n_i^2 / n_n \simeq \frac{n_i^2}{n_n} \qquad ②$$

HOMEWORK #1: DERIVE THE APPROPRIATE EQUATIONS FOR $p_p$ AND $n_p$ IN A p DOPED SEMICONDUCTOR.

4. DIFFUSION (LIKE PERFUME, SMOKE IN A ROOM)

- A STATISTICAL REDISTRIBUTION
- OCCURS IN SEMI CONDUCTORS WHEN THERE IS AN ABRUPT CHANGE IN DOPING FROM ONE AREA TO ANOTHER



$J_n$ = CURRENT DENSITY FOR ELECTRONS

$$= e D_n \frac{dn}{dx}$$

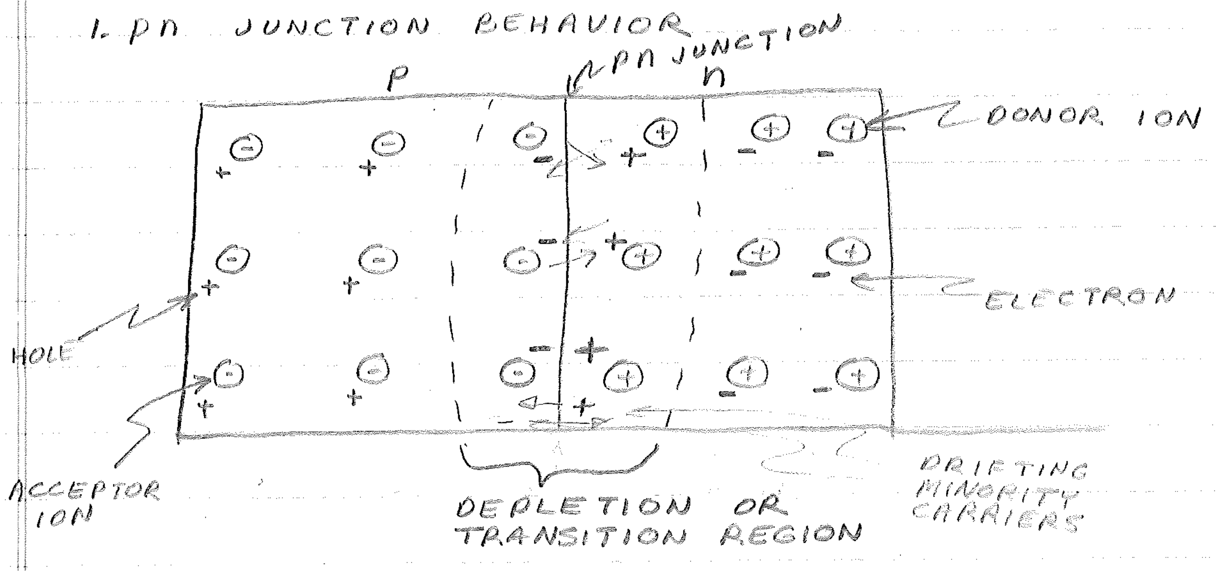
$D_n$ = ELECTRON DIFFUSION CONSTANT

ALSO, FOR HOLES

$$J_p = -e D_p \frac{dn}{dx}$$

## B. JUNCTION DIODES

### 1. pn JUNCTION BEHAVIOR



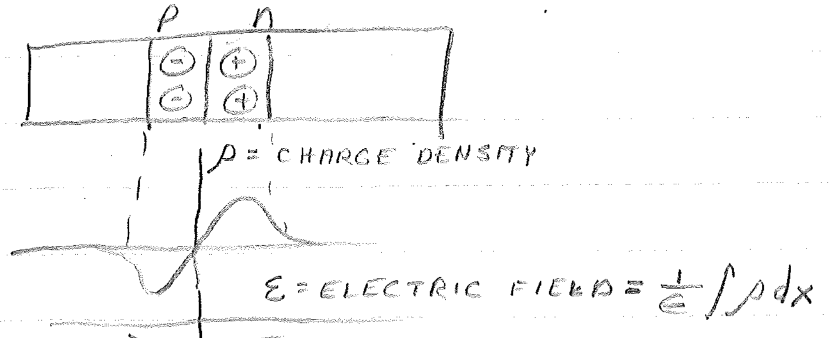
MAJORITY CARRIERS - ELECTRONS (HOLES) IN THE n (p) REGION.

MINORITY CARRIERS - ELECTRONS (HOLES) IN THE p (n) REGION (DUE TO THERMAL AGITATION)

OUR CONUCTION MECHANISMS ARE

1. DIFFUSION
2. DRIFT - UNDER E FIELD, MINORITY CARRIERS TEND TO DRIFT ACROSS JUNCTION

WITH NO APPLIED VOLTAGE, THERE IS STILL A POTENTIAL DIFFERENCE ACROSS DIODE

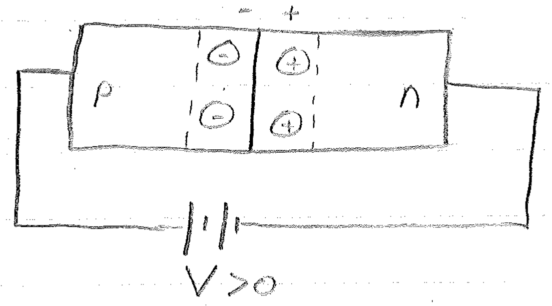


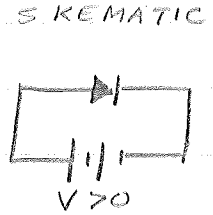
$\mathcal{E}$ = ELECTRIC FIELD = $\frac{1}{\epsilon}\int \rho dx$

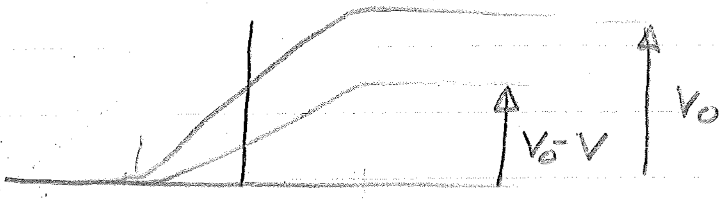
THE "POTENTIAL HILL" TENDS TO OPPOSE MAJORITY CARRIER DIFFUSION AND ENCOURAGE MINORITY CARRIER DRIFT.

## 2. BIASED DIODES

### a. FORWARD BIAS (CONDUCTION)

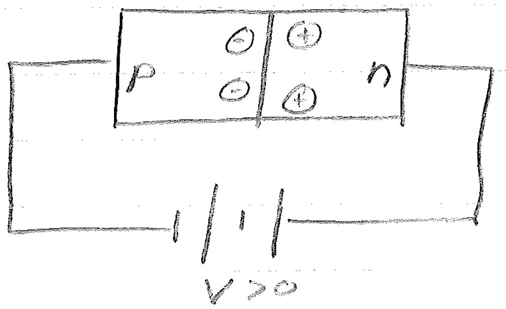


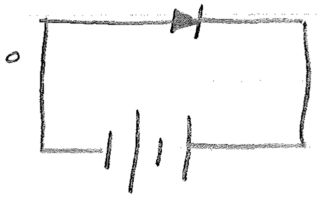




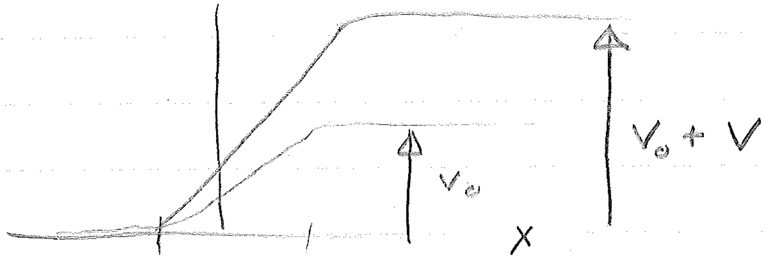
- THE HILL IS REDUCED.
- MAJORITY CARRIERS ARE NOW ENCOURAGED TO FLOW WHERE THEY ARE MINORITY CARRIERS. HENCE, CONDUCTION: DIODE ACTS ESSENTIALLY AS SHORT CIRCUIT.
- CURRENT (POSITIVE CHARGE) FLOWS FROM $p$ TO $n$.

b. REVERSE BIASED DIODES





HERE, THE HILL IS MADE "STEEPER".

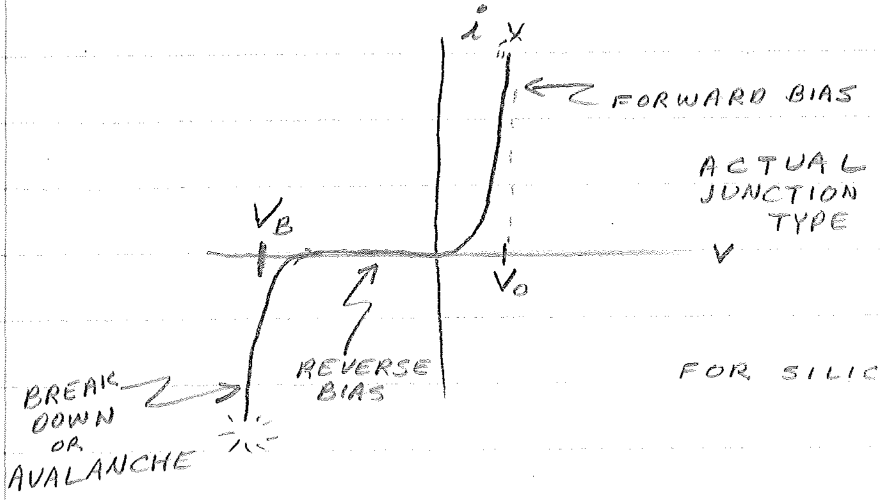


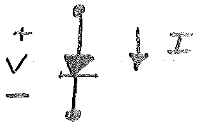
- THE NET DIFFUSION OF MAJORITY CARRIERS IS REDUCED TO PRACTICALLY ZERO.
  - ⇒ NO CONDUCTION AND DIODE ACTS AS AN OPEN CIRCUIT.

SATURATION CURRENT: A REVERSE (n TO P REGION) CURRENT DUE TO MINORITY CARRIERS WHICH IS INSENSITIVE TO APPLIED BIAS AND WHICH IDEALLY IS ZERO.

## C. DIODE MODELS

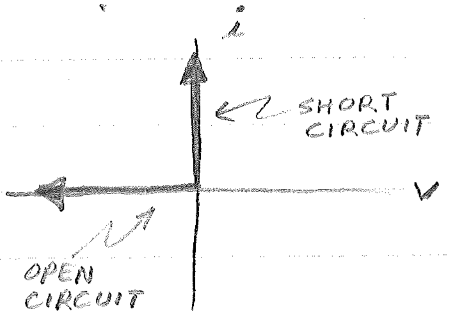
V-$i$ CURVES OF DIODE

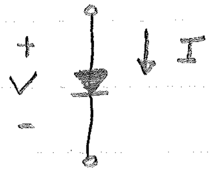




FOR SILICON, $V_0 \sim 0.7$ v

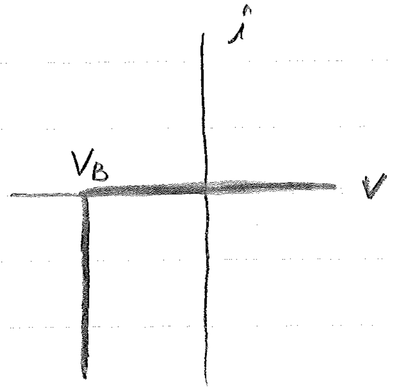
a. IDEAL ~~JUNCTION~~ DIODE





b. BREAKDOWN OR ZENER DIODE

BREAKDOWN OCCURS WHEN JUCTION POTENTIAL IS HIGH ENOUGH TO BREAK e's FROM COVALENT BONDS.



c. TUNNEL DIODES - DISPLAY TUNNELING EFFECT PREDICTED BY QUANTUM MECHANICS. CAN ACHEIVE NEGATIVE RESISTANCE $ OSCILLATION

d. SCHOTTKY DIODE : USES METAL SEMICONDUCTOR INTERFACE. VERY FAST SWITCHING.

e. LIGHT-EMITTING DIODES ON e-h RECOMBINATION, PHOTON IS EMITTED IN CERTAIN SEMICONDUCTORS.

EE 234 SEC 4 SPRING, 1977

"ELECTRONICS, INSTRUMENTATION

TEXT: AUTOMATION OF PETROLEUM AND CHEMICAL SYSTEMS by VINES, GUSTAFSON, & PASSMORE

GRADING:

QUIZES: 40%

HOMEWORK: 10%

LAB: 20%

FINAL: 30%

(STRICT CURVE)

INSTRUCTOR: BOB MARKS

ROOM EE 216

OFFICE HRS: 2:30-3:30 MWF

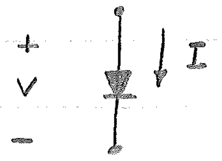
CLASS POLICIES

1. ALL GRADES FINAL

2. NO MAKE UP TESTS

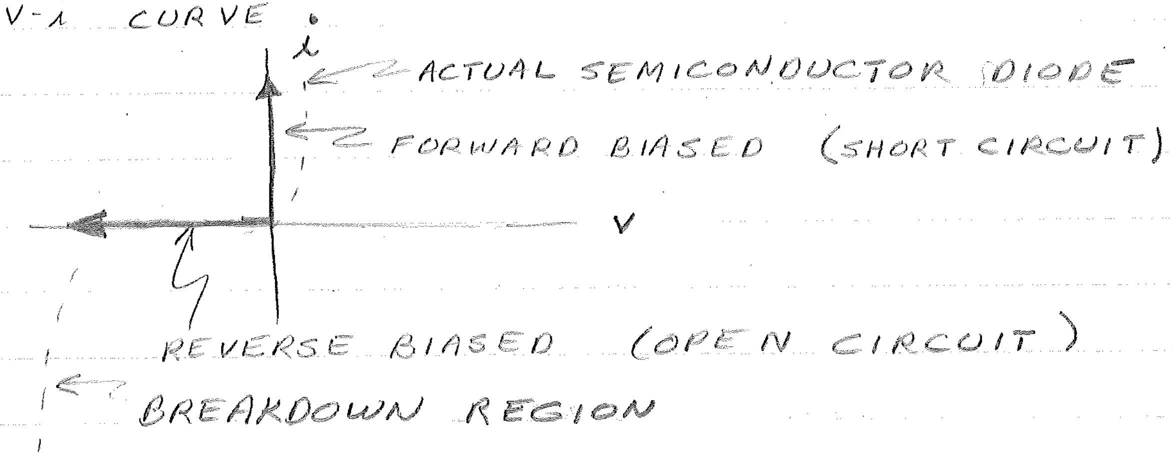
## THE IDEAL DIODE

SKEMATIC:



THE IDEAL DIODE IS A NONLINEAR LUMPED CIRCUIT ELEMENT THAT EITHER ACTS AS A SHORT CIRCUIT OR AN OPEN CIRCUIT.

V-i CURVE



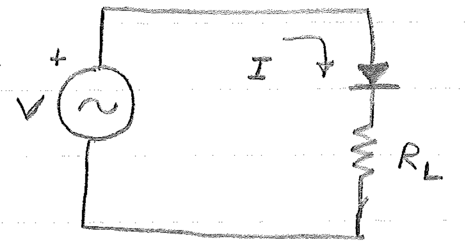
NOTE ON THEORY APPLICATION:

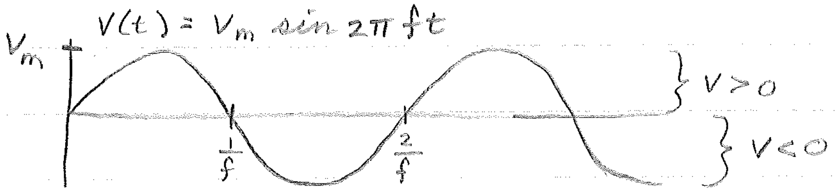
(a) LINEAR THEORY: SUPERPOSITION, THEVININ'S & NORTON'S THEOREM, & IMPEDANCE TO NOT APPLY (IN THE GENERAL SENSE) TO NONLINEAR CIRCUITS

(b) GENERAL THEORY: KIRCHOFF'S LOOP AND NODE LAWS

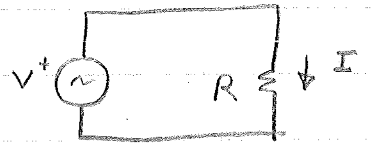
RECTIFIER: A CIRCUIT USED TO OBTAIN
UNIDERECTIONAL CURRENT (OR VOLTAGE)
(p. 315 SMITH)

1. HALF WAVE RECTIFIER



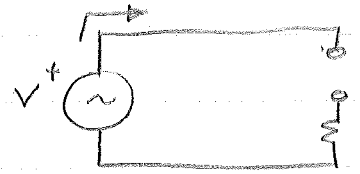


WHEN V > 0, THE DIODE IS FORWARD BIASED AND
ACTS LIKE A SHORT CIRCUIT:

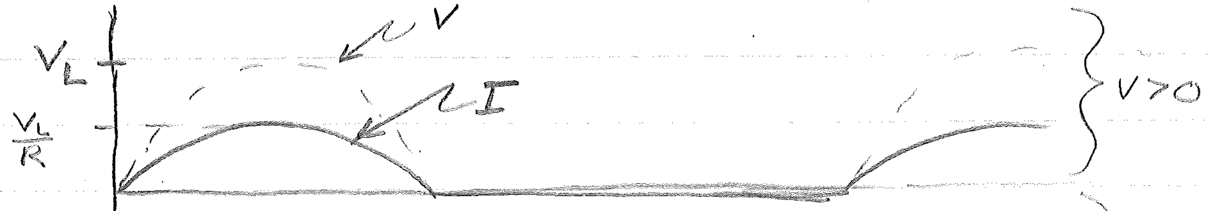


THUS, $I = \frac{V}{R}$ FOR V > 0

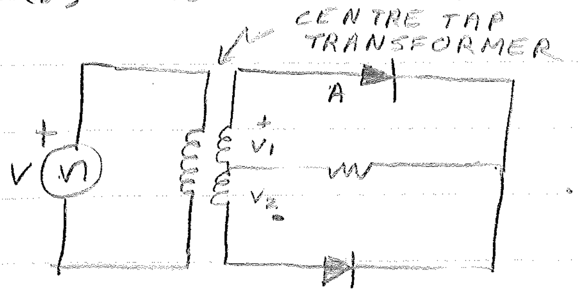
WHEN V < 0, THE DIODE IS REVERSE BIASED AND
ACTS LIKE AN OPEN CIRCUIT:



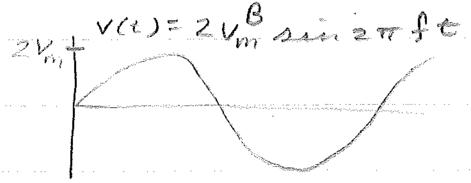
THUS, I = 0 FOR V < 0

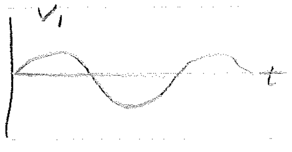


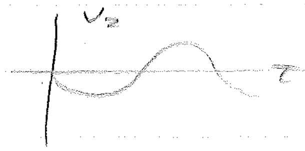
## (b) PHASE INVERTER FULL WAVE RECTIFIER



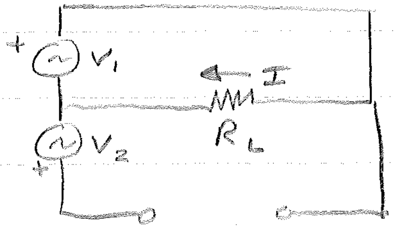
ASSUME $V_1 = -V_2 = \frac{V}{2}$







WHEN $V_1 > 0$ $(\Rightarrow V_2 < 0)$, DIODE A IS FORWARD BIASED AND B IS REVERSE BIASED:

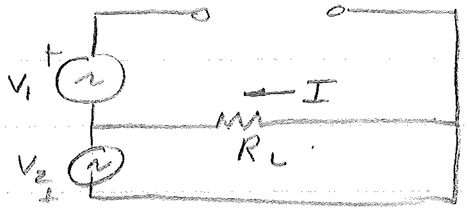


$$I = \frac{V_1}{R_L} \quad ; V_1 > 0$$

OR

$$= \frac{V}{2R_L} \quad V > 0$$

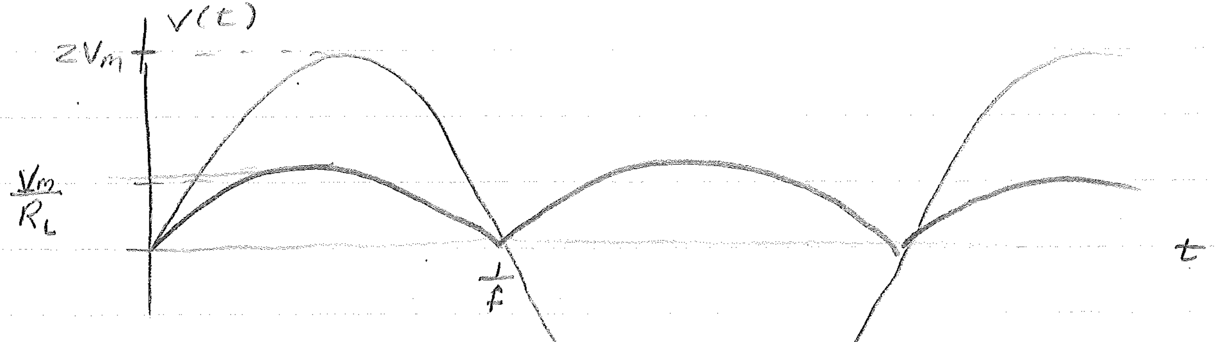
FOR $V_1 < 0$ $(\Rightarrow V_2 > 0)$



$$I = \frac{V_2}{R_L} \quad ; V_2 > 0$$

OR

$$= \frac{-V}{2R_L} \quad ; V < 0$$



RIPPLE FACTOR: MEASURE OF THE "BUMPINESS" OF A RECTIFIED WAVEFORM

$$r = \frac{I_{ac}}{I_{dc}} = \frac{V_{ac}}{V_{dc}} = \frac{\text{rms VALUE OF a.c. COMPONENT}}{\text{D.C. COMPONENT}}$$

LET $V(t)$ BE RECTIFIED SIGNAL, THEN

$$V_{ac}^2 = V_{RMS}^2 - V_{DC}^2$$

WHERE

(a) $V_{RMS} = V_{EFF} = \left[ \frac{1}{T} \int_T V^2(t)\,dt \right]^{\frac{1}{2}}$

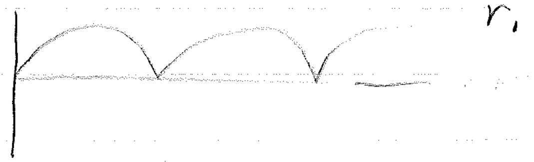
(b) $V_{DC} = V_{AVE} = \frac{1}{T} \int_T V(t)\,dt$

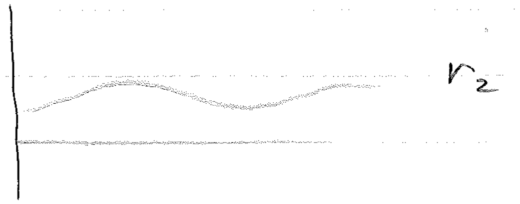
SINCE $V_{ac} = \sqrt{V_{RMS}^2 - V_{DC}^2}$

THEN

$$r = \frac{\sqrt{V_{RMS}^2 - V_{DC}^2}}{V_{DC}} = \left[ \left( \frac{I_{RMS}}{I_{dc}} \right)^2 - 1 \right]^{\frac{1}{2}}$$

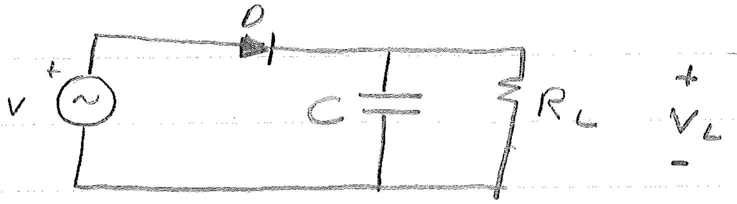
A LOW RIPPLE FACTOR IS GOOD





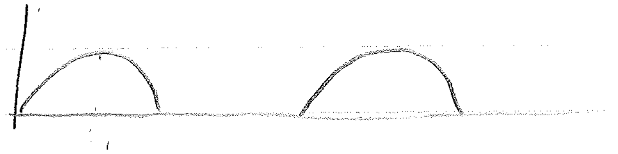
$r_1 > r_2$

CAPACITIVE FILTER (DECREASES r)

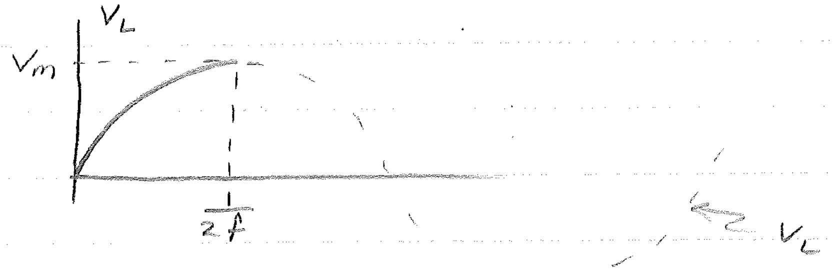


$V = V_m \sin 2\pi f t$

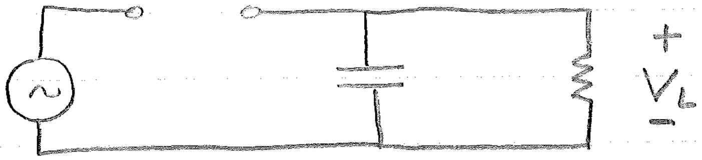
[WITHOUT CAPACITOR ⇒ ½ WAVE RECTIFIER.]



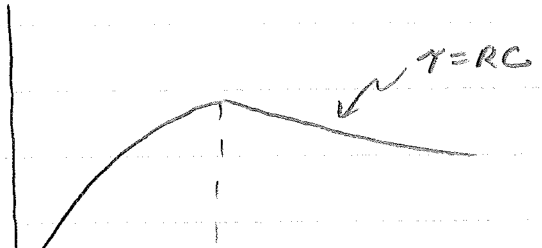
D WILL CONDUCT ONLY WHEN $V \geq V_L$. UNTIL V REACHES ITS FIRST PEAK, $V_L = V$ (TRANSIENT)



WHEN $V_L$ STARTS TO GO DOWN AGAIN, D WILL OPEN



THE VOLTAGE, $V_m$ IN C WILL EXPONENTIALLY DRAIN THRU $R_L$ WITH $\tau = RC$

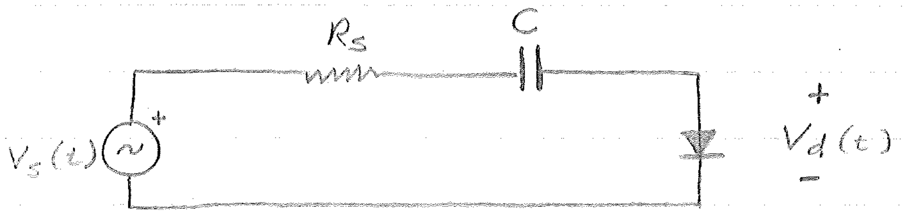


HOMEWORK # 1 (DUE 2/1/76)

1. (a) FOR THE FOLLOWING CIRCUIT, FIND $V_d(t)$ GIVEN THAT $V_s(t) = V_m \sin \omega t$. SKETCH YOUR RESULT AND EXPLAIN YOUR REASONING. ~~ASSUME $R_s$ IN NEGLIGI~~

(b) WHAT IS THE RIPPLE FACTOR OF $V_d(t)$

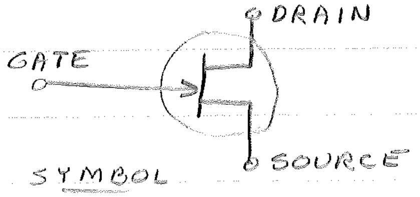
(c) EXPLAIN WHY THE CIRCUIT IS CALLED A "DIODE CLAMPER"

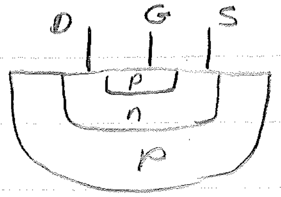


2. FOR THE HALF WAVE RECTIFIER WITH CAPACITIVE FILTER, SKETCH THE SOURCE VOLTAGE, DIODE VOLTAGE AND DIODE CURRENT ON THE SAME GRAPH. DOCUMENT YOUR RESULTS

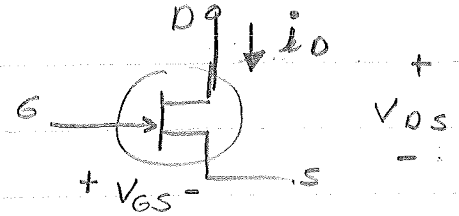
## III. FIELD EFFECT TRANSISTORS.

### A. JFET (JUNCTION GATE FET'S)

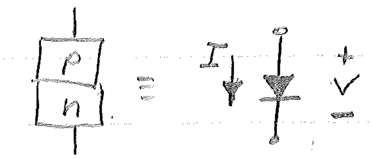


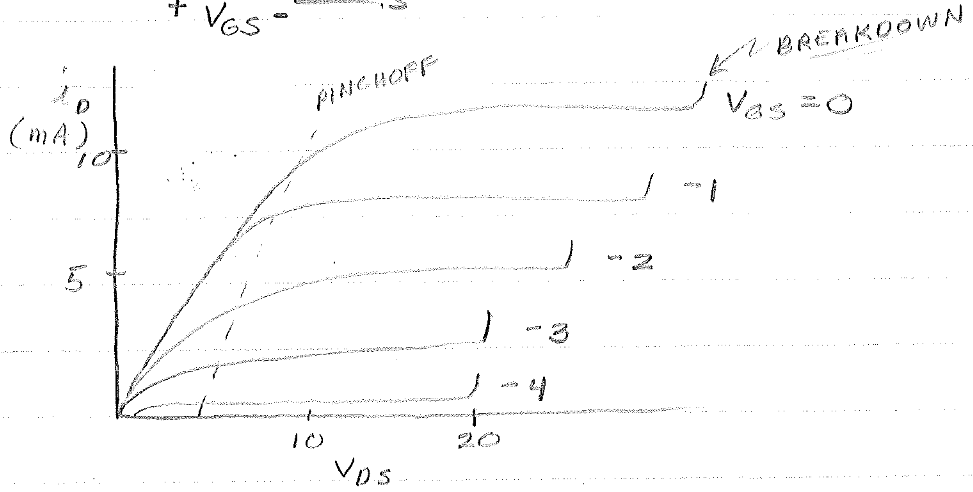


V-i CURVE

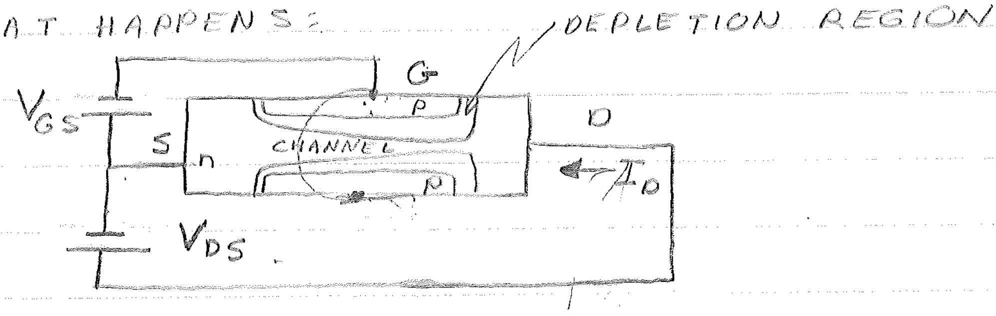


RECALL DIODE





WHAT HAPPENS:



$I_D$ (FROM S TO D) FOR A GIVEN $V_{DS}$, DEPENDS ON THE CHANNEL DIMENSION. IF BOTH pn JUNCTIONS ARE REVERSED BIASED, THE CHANNEL GETS SMALLER. PINCHOFF OCCURS @ ABOUT 5 v = $V_{GS}$

## PART I

ANSWER EACH OF THE FOLLOWING QUESTIONS WITH A "T" OR AN "F". AMBIGUOUS MARKS, LIKE "T̶F" WILL NOT BE GRADED. DO NOT GUESS. THERE WILL BE A PENALTY FOR WRONG ANSWERS. IF YOU DO NOT KNOW AN ANSWER, IT IS BEST TO LEAVE THE SPACE BLANK. (NO ANSWER IS -2. WRONG ANSWER IS -3. CORRECT ANSWER IS +3).

1. A DIODE IS A NONLINEAR DEVICE. . . . . . . . . . ______
2. THEVININ'S THEOREM CANNOT BE APPLIED TO DIODE TYPE CIRCUIT ELEMENTS. . . . . . . . . ______
3. KIRCHHOFF'S VOLTAGE AND CURRENT LAWS CANNOT BE APPLIED TO A DIODE-TYPE CIRCUIT. . . . . ______
4. A REVERSE BIASED DIODE CONDUCTS. . . . . . . . . ______
5. A RECTIFIER CAN TAKE A PERIODIC WAVEFORM OF ZERO AVERAGE VALUE & RECTIFY IT TO GIVE ANOTHER PERIODIC WAVEFORM WITH NON-ZERO AVERAGE POWER. . . . . . . . . . . . . . . . . . ______
6. RECTIFIER TYPES INCLUDE FULL AND HALF WAVE RECTIFIERS . . . . . . . . . . . . . . . . ______
7. A LOW RIPPLE FACTOR DENOTES A MORE "BUMPY" WAVEFORM . . . . . . . . . . . . . . ______
8. CAPACITIVE FILTERS ARE USED TO INCREASE THE RIPPLE FACTOR OF A RECTIFIED WAVEFORM. . ______
9: ~~THE~~ THE TERMINALS OF A FET ARE GATE, SOURCE, & DRAIN. ______
10. THE FET IS MODULATED BY CONTROLLING THE SIZE OF THE CONDUCTING CHANNEL. . . . . . . . ______
1. DE MASFET MEANS "DEPLETION EFFECT METAL OXIDE SEMICONDUCTOR FIELD EFFECT TRANSISTOR". . . . ______
1. IN NORMAL BJT USE, THE EMITTER JUNCTION IS REVERSE BIASED. . . . . . . . . . . . . . ______

THE LAPLACE TRANSFORM IS A LINEAR OPERATION ______

ALL LINEAR NON-CAUSAL SYSTEMS ARE LINEAR. . . ______

ALL KNOWN SYSTEMS ARE CAUSAL IN THE PHYSICAL WORLD. . . . . . . . . . . . . . . . . . . . ______

A LINEAR TIME-INVARIANT SYSTEM'S TRANSFER FUNCTION IS DEPENDENT ON THE SYSTEM INPUT. ______

A BANDLIMITED SIGNAL HAS INFINITE BANDWIDTH. ______

A SIGNAL OF BANDWIDTH 200HZ MUST BE SAMPLED AT LEAST AT A RATE OF 400 SAMPLES PER SECOND IF WE WISH TO LOSE NO INFORMATION ______

A FOURIER SERIES DECOMPOSES A PERIODIC WAVE FORM INTO ITS COMPONENT HARMONICS ______

"MTBF" DENOTES "MEDIAN TIME BETWEEN FAILURES" ______

THE TOTAL MTBF OF A SYSTEM COMPOSED OF A NUMBER OF ELEMENTS CONNECTED IN SERIES IS SIMPLY THE SUM OF THE ELEMENTS' MTBF'S ______

THE RECIPRICAL OF MTBF IS FAILURE RATE ______

THE BATHTUB CURVE IS A PLOT OF FAILURE RATE VS. TIME . . . . . . . . . . . . . . . . . . . ______

1. MAINTAINABILITY IS NOT A PROBABALISTIC MEASURE ________
25. AVAILABILITY IS THE RATIO BETWEEN MTBF & MTTR. ________
26. MTTR IS A MEASURE OF MAINTAINABILITY. . . . . ________
27. QUIESCENCE DENOTES THE NO SIGNAL OPERATING
POINT OF A TRANSISTOR CIRCUIT . . . . . . . . . ________
28. KIRCHHOFF'S LAWS CANNOT BE USED WHEN
ANALYZING NONLINEAR TRANSISTOR CIRCUITS. . ________
29. THE PARAMETERS OF A BJT ARE RELATIVELY
INSENSITIVE TO AMBIENT TEMPERATURE. . . . ________
30. BJT'S CAN EITHER BE npn OR pnp. . . . . . . . . ________
31. A CRUDE BJT CAN BE MADE FROM TWO DIODES. . ________
32. WHEATSTONE BRIDGES ARE USED FOR
MEASURING RESISTANCES TO HI PERCISION. . ________
33. A MAXWELL BRIDGE IS CAPABLE OF
MEASURING TWO UNKNOWN COMPONENTS IN
A SINGLE BALANCE OF THE BRIDGE. . . . . . ________
34. AN IDEAL OP AMP HAS AN INPUT IMPEDANCE OF 0 ________
3. ANALOG COMPUTERS IN GENERAL ARE MORE
EXACT THAN DIGITAL COMPUTERS. . . . . . . . ________
6. OP AMPS CAN BE USED TO SUM VOLTAGES AND
PERFORM VOLTAGE WAVEFORM INTEGRATION. . . ________
7. OP AMPS ARE GENERALLY SEMICONDUCTOR
DEVICES . . . . . . . . . . . . . . . . . . . . . . . ________
8. AN UNMODULATED AM CARRIER IS SIMPLY A
UNIFORM SQUARE WAVE. . . . . . . . . . . . . . ________
1. THE AMPLITUDE ENVELOPE OF A MODULATED FM
CARRIER VARIES WITH THE APPLIED SIGNAL. . . ________
2. WHEN WE SELECT AN AM OR FM STATION ON
OUR RADIOS, WE ARE SIMPLY SELECTING THE
CARRIER FREQUENCY OF THAT STATION. . . ________
. PAM IS THE DIGITAL EQUIVALENT OF AM. . . . . ________
1. PAM DENOTES "PHASE AMPLITUDE MODULATION". ________
1. PDM DENOTES "PHASE DURATION MODULATION". ________
1. MULTIPLEXING MEANS THE ACT OF SENDING TWO
OR MORE SIGNALS OVER THE SAME CHANNEL. . . ________
. PPM DENOTES "PULSE POSITION MODULATION". . ________
. ONLY ANALOG SIGNALS CAN BE MULTIPLEXED. ________
. AN "APRIORI" PROBABILITY MEANS A
"BEFOREHAND" PROBABILITY. . . . . . . . . ________
. THE PHRASE "I WILL BE HERE OR THERE"
CONTAINS AN EXCLUSIVE OR. . . . . . . . . . . . ________
. EVENTS "A" AND "$\bar{A}$" PLACED AS INPUTS TO
AN (INCLUSIVE) OR GATE WILL ALWAYS GIVE
A LOGIC ZERO AS OUTPUT. . . . . . . . . . . . . ________

50. WITH A SINUSOID INPUT, THE OUTPUT OF A DIODE CLAMPER CIRCUIT HAS A ZERO D-C VALUE. . . . . . . . . . . . . . ______

51. THE EXISTANCE OF A FEEDBACK CIRCUIT ASSURES THAT THE OUTPUT WILL NOT OSCILLATE. . . . . . . . ______

52. LAPLACE TRANSFORMS CAN BE USED TO REDUCE THE CONVOLUTION OPERATION TO MULTIPICATION. . . . . . ______

53. THE FREQUENCY RESPONSE OF A LINEAR TIME INVARIANT SYSTEM CAN BE OBTAINED FROM THE SYSTEM'S TRANSFER FUNCTION. . . . . . . . . . . ______

54. THE BALANCING POINT OF ALL IMPEDANCE BRIDGES IS INDEPENDENT OF THE SOURCE FREQUENCY. . . . ______

55. IN ORDER TO DOUBLE THE db GAIN OF AN AMP, WE MUST MULTIPLY THE ACTUAL AMP GAIN BY 20. . . ______

56. A BALANCED MAXWELL BRIDGE IS INDEPENDENT OF BOTH THE SOURCE FREQUENCY AND AMPLITUDE. ______

57. ALL IMPEDANCE BRIDGES CAN BE BALANCED. . . . ______

58. A POSITIVE REACTANCE IS AN INDUCTIVE REACTANCE. ______

59. A GAIN OF 1 IS THE SAME THING AS A db GAIN OF ZERO. . . . . . . . . . . . . . . . . . . . . . . ______

60. AN EIGHT-WAY LIGHT SWITCH CANNOT BE IMPLEMENTED USING ANY KNOWN TECHNIQUE. . . . . . . . . . . . . . ______

61. AN EVEN ONES PARITY CODE IS AN ERROR DETECTION CODE AND NOT A CORRECTION CODE. . . . . . . . . . . . ______

62. A HAMMING CODE IS AN ERROR CORRECTION CODE. . ______

63. A HALF ADDER PERFORMS BINARY ADDITION AND DIVIDES THE RESULT BY TWO (IN BINARY). . . . . . ______

64. TWO SWITCHES IN PARALLEL CAN BE USED AS AN AND GATE. . . . . . . . . . . . . . . . . . . . . . . ______

65. IF MASS IS TAKEN AS THE MECHANICAL DUAL OF CAPACITANCE, THEN COMPLIANCE IS THE MECHANICAL DUAL OF INDUCTANCE. . . . . . . . . . . . . . . . . . ______

66. IF THE VELOCITY OF A CHARGE MOVING IN A UNIFORM MAGNETIC ($\bar{B}$) FIELD IS PARALLEL TO THAT FIELD, THERE IS NO RESULTING FORCE ON THE CHARGE. . . . ______

67. THERE IS FORCE ON A CURRENT CARRYING WIRE IN A $\bar{B}$ FIELD. . . . . . . . . . . . . . . . . . . . . . ______

68. HAMMING, THE ORIGINATOR OF THE HAMMING CODE, ALSO ORIGINATED HAMMIN'EGGS . . . . . . . . . . . . . . . . . . ______

69. A BIASED TRANSISTOR IS A BIGOTED TRANSISTOR. . . ______

70. AN ELECTROMAGNET PRODUCES A $\bar{B}$ FIELD. . . . . . . . . ______

71. THE FORCE RESULTING FROM MOTION OF A CHARGE IN A $\bar{B}$ FIELD IS PERPENDICULAR TO THE PLANE DEFINED BY THE VELOCITY DIRECTION AND THE UNIFORM $\bar{B}$ FIELD DIRECTION. . . . . . . . . . . . . . . . . . ______

72. ONE CAN MAKE A MOTOR BY APPROPRIATELY USING THE PROPERTIES OF A MAGNETIC FIELD. SUCH IS NOT THE CASE FOR AN ELECTRIC FIELD. . . . . . ______

73. IN d'ARSONVAL MOVEMENT, THE RESULTING TORQUE ON THE NEEDLE IS PROPORTIONAL TO THE APPLIED INDUCTANCE. . . . . . . . . . . . . . . . . . . . . . ______

4. IF WE PASS A SQUARE WAVE OF FREQUENCY 30KHZ THRU
A LOW PASS FILTER THAT ONLY PASSES FREQUENCIES
UP TO 75KHZ, OUR OUTPUT WILL BE A SINUSOID
RIDING ON A D-C BIAS TERM. . . . . . . . . . . . . . ______

5. FOR THE ABOVE, IF THE CUT OFF IS AT 25KHZ, WE WILL
HAVE ONLY A D-C TERM IN THE OUTPUT. . . . . . . . . ______

6. THE FOURIER SERIES OF THE SIGNAL V(t) = 4 VOLTS HAS
TWO TERMS . . . . . . . . . . . . . . . . . ______

ONLY WAY TO COMBAT CHANNEL NOISE IS TO CHANGE ALL
7. ONE'S TO ZERO'S IN OUR CODE . . . . . . . . . . . ______

IF A SIGNAL IS UNDERSAMPLED, THEN, ACCORDING TO THE
SAMPLING THEOREM, HIGH FREQUENCIES ARE DISTORTED. . ______

ONE WAY TO INCREASE RELIABILITY IS REDUNDANCY . . . ______

CHANNEL NOISE IS A PRODUCT OF NATURE THE EFFECTS
OF WHICH CANNOT BE REDUCED BY MAN'S CLEVERNESS . . . ______

ALL TRANSISTOR'S ARE FET'S . . . . . . . . . . . ______

ALL FET'S ARE TRANSISTORS. . . . . . . . . . . . ______

AN INDUCTOR IS A DIFFICULT COMPONENT TO INCLUDE
ON AN INTEGRATED CIRCUIT CHIP. . . . . . . . . . . ______

WHEN WE MODEL A MECHANICAL CIRCUIT, LAPLACE TRANS-
FORMS CANNOT BE USED IN THE SOLUTION . . . . . . . ______

A DIODE IS A TIME-VARIANT ELECTRONIC COMPONENT . . . ______

A SMOKE DETECTOR IS A TIME-VARIANT SYSTEM. . . . . ______

A HAMMING CODE CAN DETECT AN ERROR IN A PARITY BIT. ______

LOGIC CIRCUITS CAN BE DESIGNED DIRECTLY FROM
TRUTH TABLE. . . . . . . . . . . . . . . . . . ______

TWO TYPES OF "OR" GATES ARE IRON AND COPPER . . . . ______

WE MAY FABRICATE A "NOT" GATE BY CONNECTING THE
TWO INPUT TERMINALS OF AN "AND" GATE. . . . . . . . ______

XCEEDING 100% MODULATION IN AM CAUSES DISTORTION. ______

N IDEAL DIODE IS EITHER A SHORT OR AN OPEN CIRCUIT. ______

LTHOUGH NECESSARY FOR OPERATION, BRUSHES ON A
C MACHINE DO NOT CONDUCT ANY CURRENT. . . . . . . ______

NE WAY TO INCREASE THE FREQUENCY ON AN INDUCTION
MACHINE IS TO INCREASE THE NUMBER OF POLES. ______

D/A CONVERTER CONVERTS A DIGITAL INPUT INTO
N AM MODULATED SIGNAL . . . . . . . . . . . . . ______

LIP RINGS ROTATE . . . . . . . . . . . . . . . . ______

PLIT SLIP RINGS CAN RECTIFY. . . . . . . . . . . . ______

IPPING SPLIT SLIP RINGS SLURP SLOP ON SPLITTING SLIPS. ______

ATER FLOATS ON OIL . . . . . . . . . . . . . . . ______

HIS IS THE LAST TRUE-FALSE QUESTION ON THIS TEST . . . ______

A CREDIT:
E ANSWER TO THIS QUESTION IS FALSE. . . . . . . . ______

# PART II

1. A SINGLE PROTOTYPE MACHINE IS PUT ON TEST FOR 1100 HRS. IN THAT TIME, THERE WERE 2 FAILURES. THE TIMES TO REPAIR THE MACHINE FROM THESE TWO FAILURES WERE 60 HRS AND 40 HRS. WE ASSUME THAT, WHILE OPERATING, THE MACHINE EXPERIENCES A CONSTANT FAILURE RATE.

a) WHAT IS THE MACHINE'S MTBF?

b) " " " " FAILURE RATE?

c) " " " " MTTR?

d) WHAT IS THE PROBABILITY THE MACHINE WILL HAVE NO FAILURES IN 200 HRS. OF USE?

e) IN 500 HRS OF USE?

f) WHAT LENGTH OF TIME COULD WE USE THE MACHINE AND HAVE A 50-50 (ie 50%) CHANCE OF IT'S NOT FAILING?

50%

2. AT A RECEIVER, YOU RECEIVE THE FOLLOWING 15 BIT STRING OF BINITS WHICH YOU KNOW IS AN 11 BIT HAMMING CODE WITH FOUR PARITY BITS. (ASSUME EVEN ONES PARITY).

(a) HAS THERE BEEN AN ERROR IN TRANSMITTING THE CODE? HOW DO YOU KNOW?

(b) ASSUMING ONLY ONE BINIT ERROR WAS MADE, CORRECT THIS CODE.

RECEIVED CODE:

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

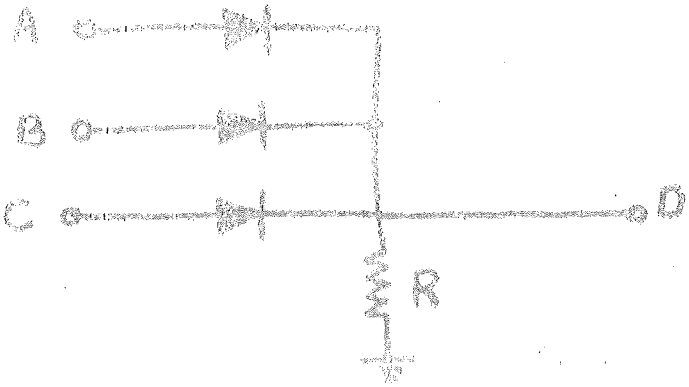
(c): ASSUME WE RECEIVED THIS CODE OVER A BINARY SYMMETRIC CHANNEL, BEARING IN MIND YOUR ANSWER IN (a), WHAT IS THE PROBABILITY OUR CORRECTED CODE IS THE CODE SENT? THAT IS, COMPUTE:

$P_r$[1 BINIT ERROR / AN ERROR HAS OCCURED]

ASSUME $p_1 = p_0 = 1/2$ AND $p = q = 0.99$.

3.

50%



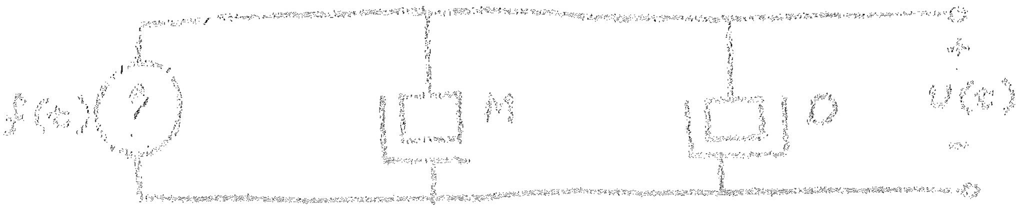
IN THE ABOVE LOGIC CIRCUIT, A, B, AND C ARE AT A LOGIC ZERO WHEN THERE IS NO APPLIED VOLTAGE AND AT A LOGIC ONE WHEN 5 VOLTS IS APPLIED. THE SAME IS TRUE FOR THE GATE OUTPUT, D.

(a) IN THE SPACE PROVIDED BELOW, DETERMINE THE TRUTH TABLE FOR THIS GATE.

(b) WHAT TYPE OF LOGIC GATE IS THIS?

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | |
| 0 | 0 | 1 | |
| 0 | 1 | 0 | |
| 0 | 1 | 1 | |
| 1 | 0 | 0 | |
| 1 | 0 | 1 | |
| 1 | 1 | 0 | |
| 1 | 1 | 1 | |

4.



0/4

CONSIDER THE ABOVE MECHANICAL CIRCUIT. A MASS M, IS SUBJECTED TO AN APPLIED FORCE, $f(t)$. D DENOTES MECHANICAL RESISTANCE. ASSUME $f(t) = f_0 \mu(t)$ WHERE $\mu(t)$ IS THE UNIT STEP FUNCTION AND $f_0$ IS CONSTANT. FURTHER ASSUME ZERO INITIAL CONDITIONS (i.e., THE INITIAL VELOCITY IS ZERO).

(a) FIND THE RELATIONSHIP FOR THE VELOCITY, $u(t)$, (IN TERMS OF M, D, AND $f_0$) AS A FUNCTION OF TIME.

(b) GIVEN $M = 5$ kg, $D = 1 \frac{\text{NT-SEC}}{m}$, AND $f_0 = 30$ NT., HOW LONG WILL IT TAKE THE MASS TO ACHEIVE A VELOCITY OF 10 METERS/SEC?

c) ● IN TERMS OF $f_0$ AND D AND M, WHAT IS THE SPEED, $u(t)$, IN STEADY STATE (AFTER A "LONG TIME")

● WHAT IS THE STEADY STATE VALUE OF $u(t)$ FOR THE PARAMETERS GIVEN IN (b)?

d) DETERMINE THE REQUIRED FORCE, $f_0$, THAT IS REQUIRED TO ACHEIVE A VELOCITY OF 100 METER/SEC IN 10 SECONDS. USE

$D = 1 \frac{\text{NT-SEC}}{M}$ AND $M = 5$ kg.

# EE 234 FINAL SOLUTIONS by Marks! (MAY 1975)

1. T
2. T
3. F
4. F
5. T
6. T
7. F
8. F
9. T
10. T
11. F
12. F
13. T
14. T
15. T
16. F
17. F
18. T
19. T
20. F
21. F
22. T
23. T
24. F
25. F
26. T
27. T
28. F
29. F
30. T
31. T
32. T
33. T
34. F
35. F
36. T
37. T
38. F
39. F
40. T
41. T
42. F
43. F
44. T
45. T
46. F
47. T
48. T
49. T
50. F
51. F
52. T
53. T
54. F
55. F
56. T
57. F
58. T
59. T
60. F
61. T
62. T
63. F
64. F
65. T
66. T
67. T
68. F (NG)
69. F (NG)
70. T
71. T
72. F
73. F
74. T
75. T
76. F
77. F
78. T
79. T
80. F
81. F
82. T
83. T
84. F
85. F
86. T
87. T
88. T
89. F (NG)
90. F
91. T
92. T
93. F
94. F
95. F
96. T
97. T
98. F (NG)
99. F
100. F (NG)

(NG) = NOT GRADED — AUTOMATIC CREDIT.

1. MACHINE ON TIME = 1000 HRS
MACHINE REPAIR TIME = 100 HRS
# FAILURES = 2

(a) $MTBF = \frac{1000 \text{ HRS}}{2 \text{ FAILURES}} = 500$ HRS

(b) $\lambda = \frac{1}{MTBF} = 0.002$ FAILURES/HR

(c) $MTTR = \frac{100}{2} = 50$ HRS

(d) $R = e^{-t/MTBF} \Rightarrow R(200) = e^{-\frac{200}{500}} = 0.67 \Rightarrow 67\%$

$R(500) = e^{-500/500} = \frac{1}{e} \Rightarrow 37\%$

e $0.5 = e^{-t/500}$

$\frac{t}{500} = \ln 2$

$t = 500 \ln 2$

$= 347$ HRS

2.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| | | | | | | | $P_3$ | | | | $P_2$ | | $P_1$ | $P_0$ |

(b) OUR RECEIVED PARITY BITS ARE

$P_3P_2P_1P_0 = 1001$

ASSUMING CORRECT CODE, OUR $P_0$ PARITY BIT SHOULD BE

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 |
| $P_0$ | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

7 ONES $\Rightarrow P_0 = 1$

FOR $P_1$:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | 3 | 6 | 7 | 10 | 11 | 14 | 15 |
| $P_1$ | 1 | 0 | 1 | 0 | 1 | 0 | 1 |

4 ONES $\Rightarrow P_1 = 0$

FOR $P_2$:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | 5 | 6 | 7 | 12 | 13 | 14 | 15 |
| $P_2$ | 1 | 0 | 1 | 0 | 1 | 0 | 1 |

4 ONES $\Rightarrow P_2 = 0$

FOR $P_3$:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| $P_3$ | 1 | 0 | 1 | 0 | 1 | 0 | 1 |

4 ONES $\Rightarrow P_3 = 0$

RECEIVED: $P_3P_2P_1P_0 = 1001$
SHOUD BE $\xrightarrow{\hspace{2cm}}$ $\underline{0001}$
DIFFERENCE: $1000 \Rightarrow$ ERROR IN BIN 8.

(a) THE CODE HAD TO BE WRONG SOMEWHERE BECAUSE THE PARITY BITS DIDN'T CHECK.

(c) $P_r$[1 BINIT ERROR / AN ERROR HAS OCCURED]

$$= \frac{P_r[\text{1 BINIT ERROR \underline{AND} AN ERROR HAS OCCURED}]}{P_r[\text{AN ERROR HAS OCCURED}]}$$

$P_r$[1 BINIT ERROR $\underline{\text{AND}}$ AN ERROR] =

$= P_r$[1 BINIT ERROR] $= 15\,p^{14}(1-p)$

$= 0.1303$

$P_r$[AN ERROR HAS OCCURED]

$= 1 - P_r$[NO ERROR HAS OCCURED]

$= 1 - p^{15} = 0.1399$

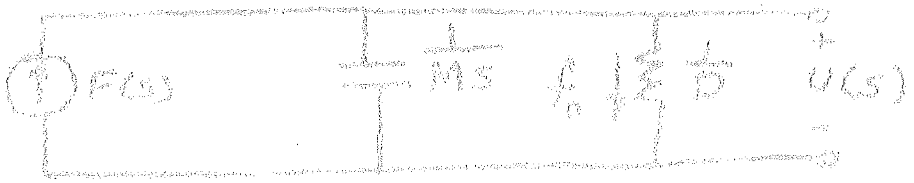
$\Rightarrow P_r$[1 BINIT ER / AN ERROR] $= \frac{0.1303}{0.1399} = 0.9312$

3. THIS IS AN "OR" GATE SINCE ANY TIME A, B OR C ARE FORWARD BIASED BY THE APPLIED E [illegible] ALL OF THE VOLTAGE APPEARS ACROSS THE RESISTOR R. (SEE p.366 OF SMITH, FIG. 14.[illegible]) OUR TRUTH TABLE IS:

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

| YOUR LAB GRADE | TOTAL % FINAL | RANK IN CLASS | YOUR FINAL GRADE IN EE 321 |
|---|---|---|---|
| | | | |

4. FIRST, TRANSLATE CIRCUIT INTO LAPLACE DOMAIN



(a) BY CURRENT DIVIDER:

$$f_D = \frac{1/MS}{1/D + 1/MS} F(s) = \frac{DF(s)}{D+MS}$$

AND $U(s) = \frac{1}{D} f_D = \frac{F(s)}{D+MS}$

NOW $f(t) = f_0 \mu(t) \Rightarrow F(s) = \frac{f_0}{s} \Rightarrow U(s) = \frac{f_0}{s(D+MS)}$

$$U(s) = \frac{f_0/M}{s(D/M + s)} = \frac{f_0}{M}\left(\frac{M/D}{s} - \frac{M/D}{(s + D/M)}\right)$$ (⟸ FROM HINT (PARTIAL FRACTION))

$$= \frac{f_0}{D}\frac{1}{s} - \frac{f_0}{D}\frac{1}{s + D/M}$$

INVERSE LAPLACING:

$$U(t) = \frac{f_0}{D}\mu(t) - \frac{f_0}{D} e^{-t/M/D}\mu(t)$$

$$= \frac{f_0}{D}\left(1 - e^{-t/M/D}\right)\mu(t)$$

(b) $10 = \frac{30}{1}\left(1 - e^{-t/30}\right)$

$e^{-t/30} = 2/3 \Rightarrow t = 30 \ln\frac{3}{2} = 12.16$

(c) $U(t) = \frac{f_0}{D}\left(1 - e^{-t/M/D}\right)\mu(t)$

$\Rightarrow U(\infty) = f_0/D = \frac{30}{1} = 30$ m/sec

(d) $U = \frac{f_0}{D}\left(1 - e^{-tD/M}\right)$

$$\Rightarrow f_0 = \frac{UD}{1 - e^{-t/M/D}} = \frac{(100)(1)}{1 - e^{-10/30}}$$

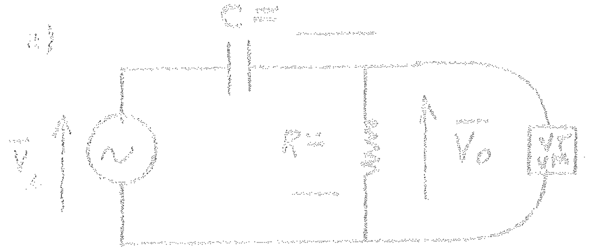
$= 352.8$ NEWTONS

marks

CE 234 Lab Session

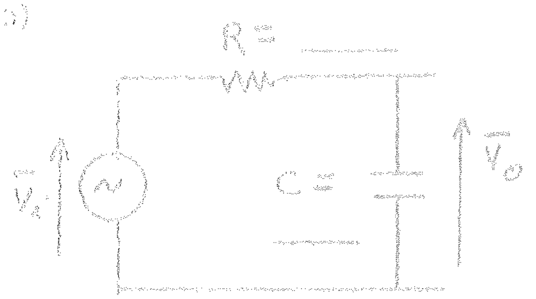
Frequency Response time constant and fourier series.

1. Frequency response. For the circuits shown, measure $v_o$ using a sinusoidal input signal set at 2 volts, and vary the frequency from 20 HZ to 5 KHZ. Be sure to include the half power point (cut-off frequency) as one of the measurements.



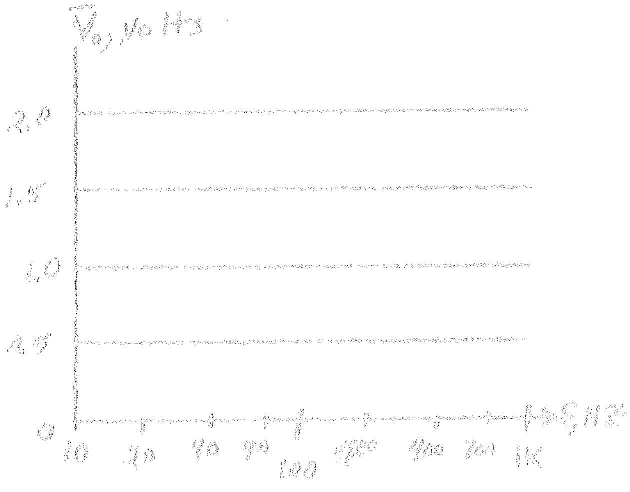
| f | $V_o$ |
|---|---|

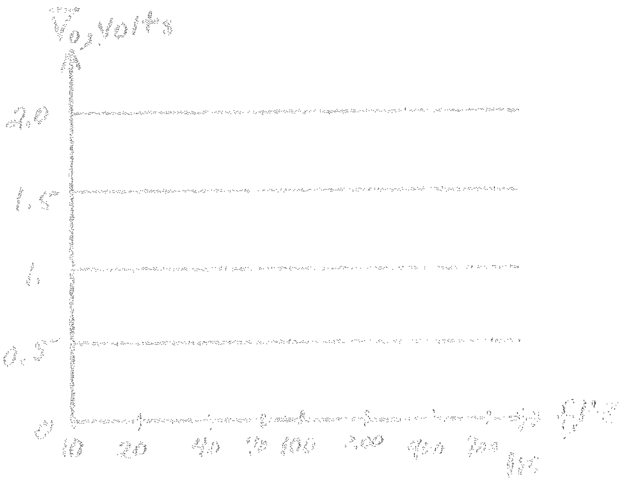
cut-off frequency ($w_{co}$) = ________ rad/s.



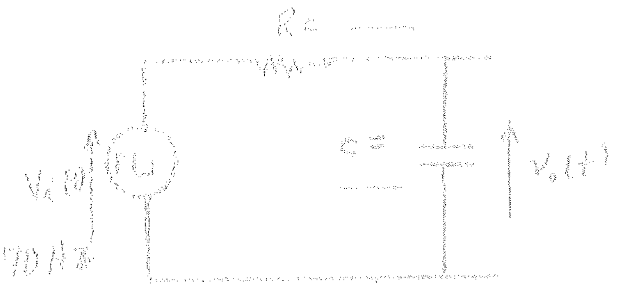
| f | $V_o$ |
|---|---|

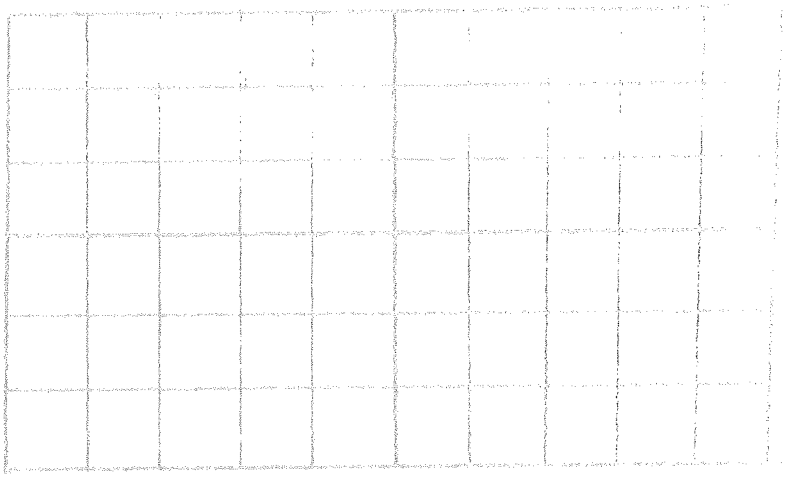
cut-off frequency ($w_{co}$) = ________ rad/sec





(c) Use a square wave input signal with the amplitude that [illegible] in part 1 and a frequency input of 70 Hz. Use the circuit of part 1(b) and observe $v_c$ with a CRO. Set the horizontal sweep so only one cycle appears on the screen. Then switch the horizontal display knob from "Normal" to "x10." Record the waveform below and calculate the time constant.





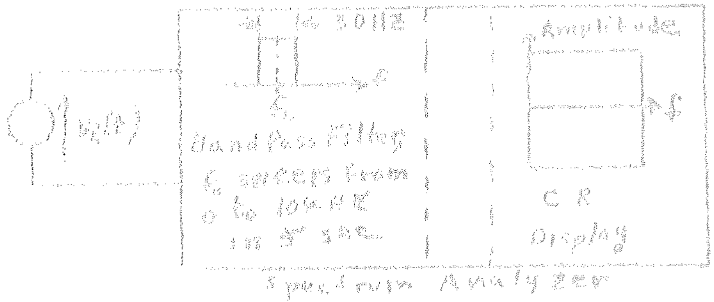
Time constant ($t_c$) = ____________

RC = ____________

$\frac{L}{R_{eq}}$ (from part 1(a) = ____________

3) Fourier Series

A 1 KHZ square wave signal is applied to the input of an HP 3580A Spectrum Analyzer, which displays the harmonics of the signal vs. frequency.



Record the amplitude and frequency of each harmonic. Repeat for the triangular and sinusoidal waves.

Wave

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| square | amplitude | | | | | | | |
| | frequency | | | | | | | |
| triangular | amplitude | | | | | | | |
| | frequency | | | | | | | |
| sinusoidal | amplitude | | | | | | | |
| | frequency | | | | | | | |

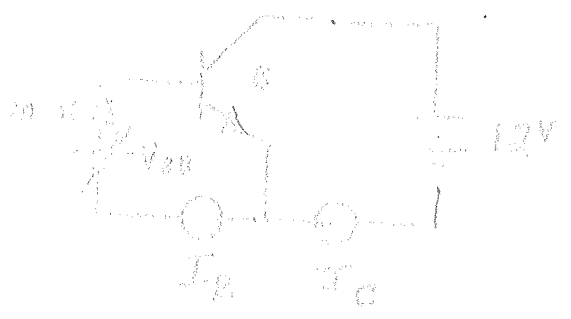
Marks

Lab 3 [illegible]

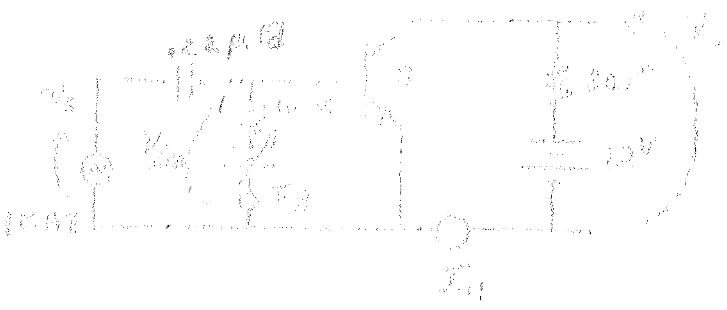
Transistor (BJT) and JFET Amplifier.

The purpose of this experiment is to measure the current and voltage gain of a transistor amplifier, and the voltage gain of a JFET amplifier. The [illegible] of each device are shown below:

(1) BJT amplifier



(a)

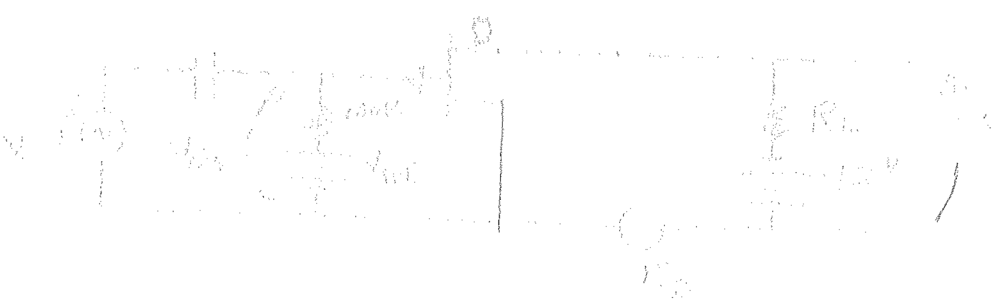


(b)

(a) Connect the circuit of Fig. (a), and [illegible]. For each of the following values of $I_B$(mA): [illegible] measure $I_C$ and $V_{BE}$.

(b) Connect the circuit of Fig. (b) and adjust $I_B$ to [illegible], measure $I_C$. [illegible] to the output and gradually increase $V_s$ until $v_o$ [illegible]. Reduce the input slightly until the output becomes undistorted. Measure $V_o$ and [illegible] with the [illegible]

(2) JFET amplifier



1. Connect the above circuit with the following values: $V_S = 0$, $R_L = 0$. Measure $I_D$ for each of the following values of $V_{GG}$ (volts): 3, 2, 1, 0.5, .1, 0.

2. Set $V_{GG}$ to 2 volts and $R_L$ to 3 k ohms. Connect a CRO to the output and gradually increase $V_S$ until $V_0$ appears distorted. Reduce the input until distortion is eliminated. Measure $V_0$ and $V_{in}$ (peak to peak) with the CRO.

## Report

Part A (1). a) Calculate the d.c. beta (current gain) for $I_B = 0.2$ ma.
b) Calculate the a.c. current gain (a.c. beta) as follows:

$$B = \frac{\Delta I_C}{\Delta I_B} \quad (V_{CE} \text{ constant}).$$

use the .2 to .3 change for $\Delta I_B$.
A (2). Calculate the voltage gain.

B (1). The amount of control that the gate voltage has over the drain current is measured by the change in $I_D$ per volt change in $V_{GG}$. This is called $g_m$(mhos) and is expressed as

$$g_m = \frac{\Delta I_D}{\Delta V_{GG}} \quad (\text{constant } V_{DS}).$$

Calculate $g_m$ using data for $V_{GG}$ change from 0.5 to 1 volt.

B (2). Calculate the voltage gain.

marks

EE 234 (4)

# Recording Instruments

The purpose of the laboratory is to demonstrate:

1. The basic ideas of operation of the most commonly used recording instruments,
2. Ways to calibrate recording instruments,
3. Frequency limitations of instruments,
4. Sensitivity of the instruments and noise effects at high sensitivity positions of the instruments.

Equipment:

1. Strip chart recording
2. X-Y plotter
3. Function generator
4. D.C. Power Supply

## Lab Procedure

### A. X-Y plotter

Connect the function generation (sine wave) to the X-Y plotter. Set the function generator frequency to 0.1 HZ, and the plotter sensitivity to 1 volt/division. Increase the generator output until the recorder output produces 5 inches of deflection (peak to peak).

1. Keep the generator voltage constant (use a CRO or a digital voltmeter to measure it). Plot a curve of deflection vs. frequency (frequency response curve), using frequencies of 0.1, 1, 2, 3, 4, and 5 HZ, or until the half power point is found.
2. Replace the generator with d.c. source. Increase the d.c. voltage to get 1 inch of deflection. Calibrate the recorder. (Note that this is a d.c. amplifier). Use this reading for calculating sensitivity.
3. Remove the source from the input to the plotter. Set the sensitivity to maximum. Touch the input terminals with the fingers. Not the results.
4. Set the function generator to produce a ramp at .1 HZ. Use the plotter to get a graph of this voltage vs. tima. Use a 1 V/division sensitivity setting.
5. Repeat for triangle and square wave.

Strip Chart Recorder

1. Set the input of the recorder to the 5 volt range. Connect the function generator to the recorder and set the generator amplitude to produce a peak-to-peak deflection of 3 inches. Set the chart speed to 8 inches/minute. Note the type of marking pen used. How does it differ from the X-Y plotter pen?
2. Repeat steps 1 through 5 of part A, for the strip chart recorder.

Report:

1. Describe a galvanometer type recorder.
2. For the X-Y plotter, describe the mechanism and associated circuits used to move the pen in the X direction. What is the maximum speed that the pen will move?
3. Plot a curve of maximum deflection vs. frequency for the X-Y plotter and strip-chart recorder.
4. Describe a capillary ink writing system and a heated stylus system.
5. Define sensitivity and calculate it for the strip-chart recorder and X-Y plotter.

References:

Principles of Modern Instrumentation - Spitzer, Howarth

Guide to Electronic Measurements and Laboratory - Stanley Wolf

Electrical Measurements and Instrumentation - Oliver and Page

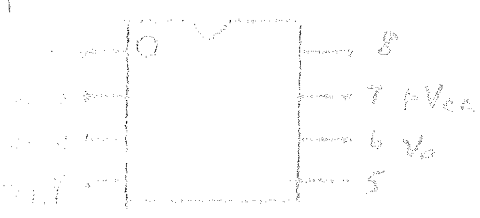
Marks

# Expt. 12, EE 2141

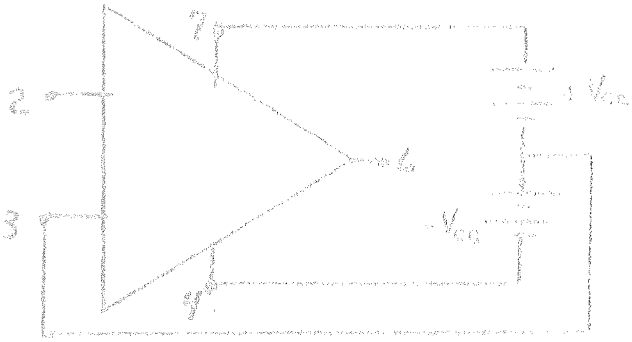
## IC OP AMPS

This experiment will provide an introduction to integrated circuit operational amplifiers (IC Op-Amps). Today op-amps are used in a wide range of analog signal processing including signal amplification, wave shaping, servo and process control, compensation and also in many non-linear applications such as comparators, analog to digital and digital to analog converters and non-linear function operators. We will be concerned with the uses of an op-amp as an amplifier, a summer, and an integrator.

In this experiment you will be using type 741 op-amps. They have a gain of about 200,000 open circuited and a bandwidth of about 1 MHz. for unity gain. The 741 is an integrated circuit, meaning that the op-amp is implemented by transistors and resistors grown or deposited on a single chip of semiconducting material (in this instance it is silicon).



(Top view 741-8 pin)



(Pin 2 is the inverting input
pin 3 is non-inverting input)

### Power Supplies

In order to achieve the ability to produce both positive and negative voltages the op-amp requires both $+V_{cc}$ and $-V_{cc}$ supplies. The 741 will operate on supply voltages of from ±9v to ±22v. We will use ±12v for our work. The two power supplies are connected as shown above and need not be disconnected (though they should be turned off while changing circuits) during the experiment. Thus the power connections will not be shown on subsequent diagrams.

## Scope Triggering

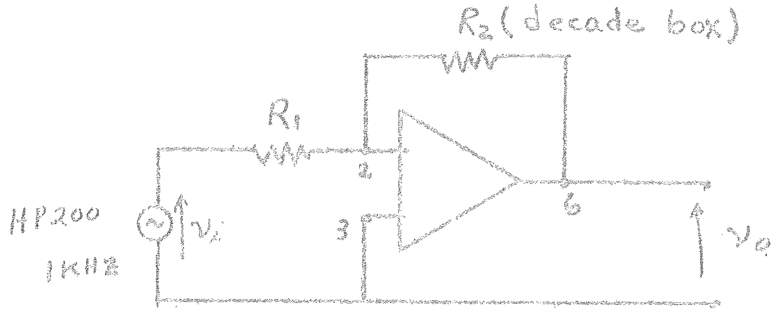
To observe the inversion of the input signal by the op-amp it will be necessary (on a one channel scope) to synchronize the scope trigger from some reference - usually the output of the signal generator. This is done by connecting the scope trigger input to the ungrounded side of the signal generator and putting the scope trigger source control on ext + or - and the trigger coupling control on AC or DC - and then adjusting the trigger level control. The lab instructor will review this with the class before beginning the experiment.

If a two channel scope is available, connect the amplifier input to one channel, and the output to the other, and observe the inversion.

## Amplifiers

### A. Inverting Amplifier

Connect the op-amp as shown below:



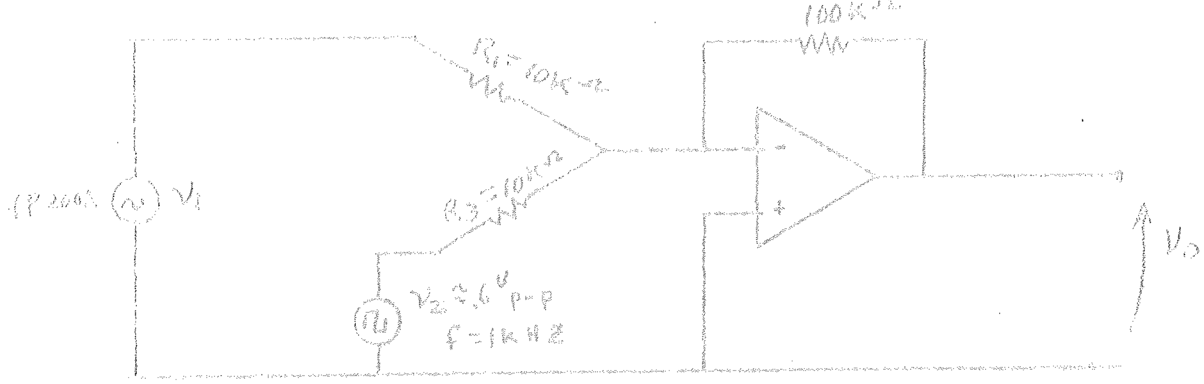
a) Use 5K ohms for $R_1$, and set $R_2$ to give theoretical gains of 10, 20, 40 and 80. Set the input signal to give about 12 volts peak-to-peak for $v_o$. Adjust the input to eliminate distortion. Measure the gain in each case, using the CRO as a voltmeter.

Q1. How does the measured gain compare with the theoretical gain?

b) With the x80 theoretical gain setting, increase the signal input until you observe clipping on both the upper and lower portions of the output. Measure the voltage difference between the upper and lower clipping points on the output. The clipping is caused by the op-amp reaching its maximum and minimum output voltages (the saturation voltages), which are determined by the power supply voltages. A gain of x100 does not mean that the output will be 100 times the input settings, since the amplifier may reach the saturation voltage (i.e. if gain = 100 and $v_{in}$ = 1v our op-amp would not give 100v but rather $-V_{sat}$ — because it inverts).

## Summer

With the op-amp connected as a x10 amplifier ($R_1$ = 10K, $R_2$ = 100K) connect $R_3$ to the - input terminal (also known as the "summing point") and connect the output of the square wave generator to it as shown.

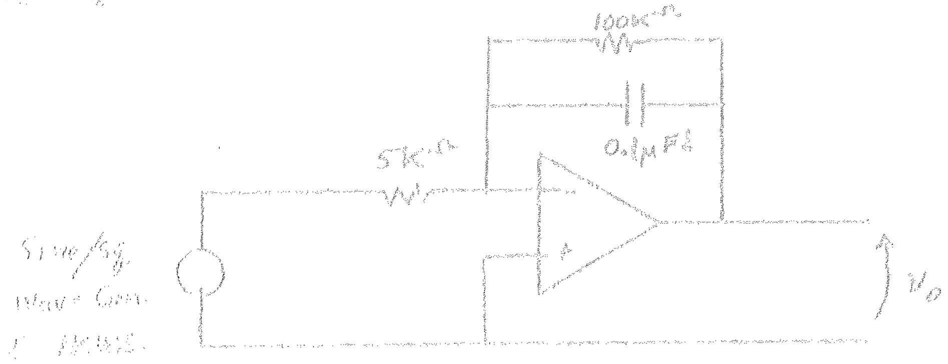


Adjust the square wave generator so $v_2$ is 0.6 v p to p. Observe $v_o$ with the scope synched to the square wave and sketch the waveform. Now connect the H-P oscillator, set its freq. to 4KHz and slowly increase its amplitude to about 1/2 the amplitude of $v_2$, and sketch $v_1$. Slowly change the frequency of $v_1$ until a steady pattern results in $v_o$.

Q: Sketch the output with both generators connected. Is it the sum of the two inputs?

## C. Integrator

For integration a capacitor is added in the feedback loop, as shown below. The 100K resistor is present for d.c. stabilization of the op-amp and is not considered, here, as a part of the feedback loop.



a) Connect the circuit as shown. Set the generator for a square wave output, f = 1KHz, $V_{in}$ = 5v. p to p. Observe the output.

Q3 Sketch output waveform - what sort of wave is this? Is it the integral of the input? Explain?

b) Switch the generator to sine wave output, increase its output maximum. Observe the output $v_o$. Use ext. trigger for the CRO

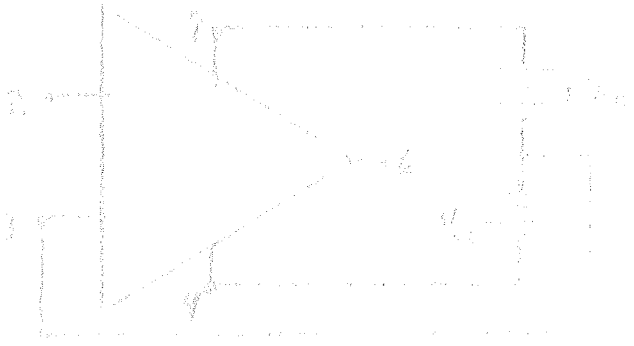
Q4 What output does an integrator produce if the input is a sine wave? Did this circuit really integrate? Explain.

[illegible]

[illegible] amplifier [illegible] wave shaping [illegible] and also in many non linear applications [illegible] analog to digital and digital to analog conversion [illegible] function generators. We will be concerned [illegible] as an amplifier, a summer, and [illegible]

[illegible] you will be using the 741 op-amp [illegible] gain of about 200,000 open circuited and a band[illegible] 1 MHz for unity gain. The 741 is an integrated [illegible] realize that the op-amp is implemented by transistors [illegible] piece of [illegible] as a single chip of [illegible] (in this instance it is silicon).

[illegible] plot



[illegible] inverting input
[illegible] non-inverting input)

[illegible]

[illegible] the ability to produce both positive [illegible] op-amp requires both $+V_{cc}$ and $-V_{cc}$ [illegible] will operate on supply voltages of from [illegible] power supplies are connected [illegible] not be disconnected (though they should [illegible] and will not be shown on subsequent diagrams.

[illegible]

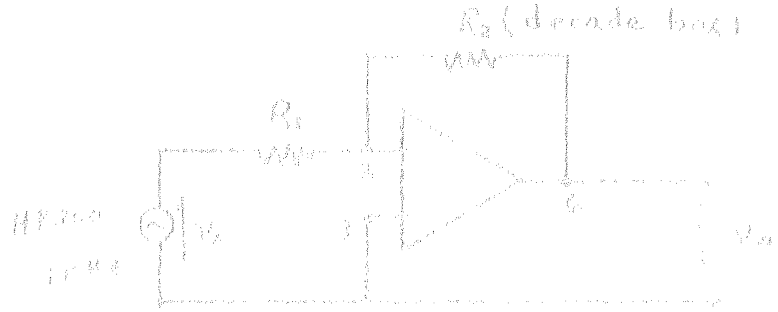
[illegible] trigger [illegible] the output [illegible] This is done by connecting the scope [illegible] to the ground part of the signal generator [illegible] the trigger control [illegible] and the trigger coupling [illegible] and then adjusting the trigger level control. [illegible] Instructor will review this with the class before beginning the experiment.

If a two channel scope is available, connect the amplifier input to one channel, and the output to the other, and observe the waveforms.

Amplifiers

1. Inverting Amplifier

Connect the op-amp, as shown below:



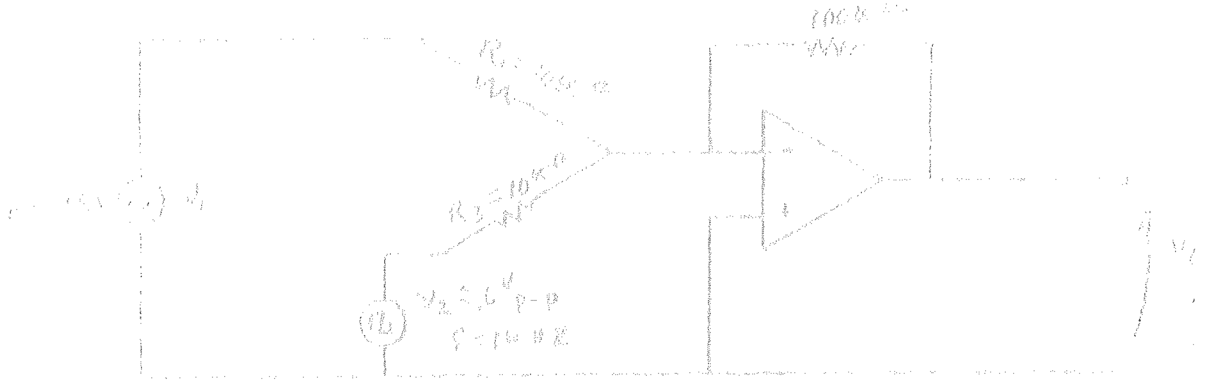
(a) Use 1K ohm for $R_1$, and set $R_2$ to give theoretical gains of 10, 20, 40 and 80. Set the input signal to give about 0.1 volts peak-to-peak for $v_i$. Adjust the input to avoid distortion. Measure the gain in each case, using the CRO as a voltmeter.

(b) How does the measured gain compare with the theoretical gain?

(c) With the x40 theoretical gain setting, increase the signal input until you observe clipping on both the upper and lower portions of the output. Measure the voltage difference between the upper and lower clipping points on the output. The clipping is caused by the op-amp reaching its maximum and minimum output voltages (the saturation voltages) which are determined by the power supply voltages. A gain of x100 does not mean that the output will be 100 times the input

[illegible]

[illegible] the [illegible] connected to a X10 amplifier [illegible] input terminal [illegible] the output of the square wave generator [illegible]

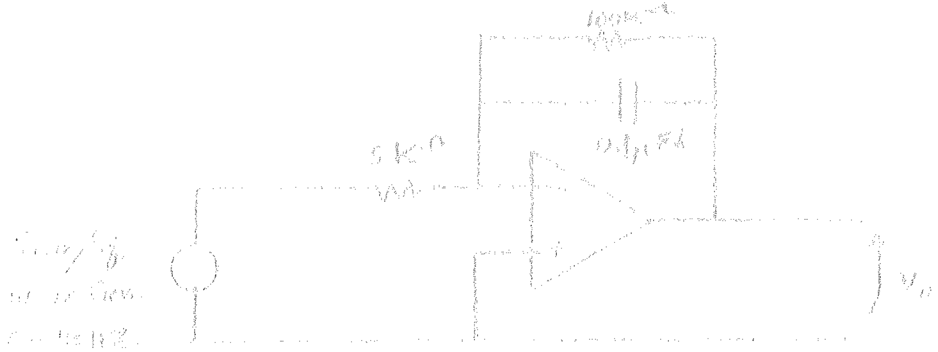


Adjust the square wave generator so $v_2$ is 0.6 v p-p [illegible]. Observe $v_o$ with the scope synched to the square wave and sketch the wave form. Now connect the R-C oscillator, set its freq. to 1kHz and slowly increase its amplitude to about 1/2 the amplitude of $v_2$ and sketch $v_o$. Slowly change the frequency of $v_1$ until a steady pattern results in $v_o$.

Sketch the output with both generators connected. Is it the sum of the two inputs?

C. Integrator

For integration a capacitor is added in the feedback loop, as shown below. The 100K resistor is present for d.c. stabilization of the op-amp and is not considered, here, as a part of the feedback loop.



[illegible]

[illegible] output waveform. What sort of wave is this? [illegible] the integral of the input? Explain.

[illegible] Switch the generator to sine wave output, [illegible] 10 [illegible] Observe the output $v_o$. [illegible]

[illegible] What output does an integrator produce for an input of a sine wave? Did this circuit really integrate? Explain.

# OILFIELD AUTOMATION SIMULATION

May 9, 1975

By Mark Carpenter

# OILFIELD AUTOMATION SIMULATION

This program is a dynamic simulation of an oilfield to be utilized as a teaching aid in the understanding of digital control systems. The complete systems dynamics are incorporated in the program so that the user may write a control program for the field.

## Designation of Program Variables

The following is a list of matrix variables, their dimensions, and usage in the program.

| | | |
|---|---|---|
| Q(4) | Well | |
| | Q(K)=J | |
| P(4) | Well Status | P(K)=1 then Well K is on<br>P(K)=0 then Well K is off |
| X(4) | [illegible] of well in a fractional number | |
| Y(4) | [illegible] of a well in a fractional number | |
| W(4) | Manifold Status | W(K)=1 means Well K feeds Separator 1<br>W(K)=2 means Well K feeds Separator 2 |
| Z(4) | Complement of W(K)-1 | |
| B(6) | Total tank capacities for the two separators, two oil holding tanks, and two water holding tanks | |
| L(14) | Various valves in the oilfield | |

| | |
|---|---|
| C(14) | Pump capacities of the pumps |
| W(2) | Water outlet levels in the two separators |
| F(2) | Oil outlet levels in the two separators |
| T(6) | Total fluid volume in the six tanks |
| O(2) | Oil volume in the two separators |
| I(2) | Water volume in the two separators |

The letter T designates the sample time in hours, and T9 is a counter to keep up with the total time period accumulated. Also used in the program are O1, O2, O3, O4, I1, I2, I3, I4, , S5, S6, S7, S8, W1, W2, K, and K6. Care should be taken in the writing of the control program to prevent an overlapping of variables.

The Oilfield

The oilfield (Figure 1) has four wells, two separators, two oil holding tanks, and two water holding tanks. The valves are designated by X and are numbered. The pump locations are marked with a V and have the same subscript number as the valves at that location. For instance, C(6), or pump number 6, is located at valve L(6), where at valve number 9, L(9), there is no pump.

T(1) and T(2) are Separator 1 and Separator 2, T(3) and T(4) are the water holding tanks, and T(5) and T(6) are the oil holding tanks.

The entire control scheme centers around the two separators. Figure 2 shows a separator and various outlet locations.

Since the tanks are cylindrical, the volume is directly proportional to the height of the fluid. The main program sets F(K) at 50% and E(K) at 33.3% of the total tank height or volume. I(K) is the water level of the tank and T(K) is the total fluid level in the tank.

The control program will contain E(K), F(K), T(K), I(K), and O(K) as fractional portions of the total tank capacity, S(K).

## The Control Program

The control program will be interfaced with the main program so that the main program will record accumulations in the tank and the control program will control the flows into and out of these tanks. Figure 3 shows a flow chart of the relationship between the main and control programs.

When the program is initially started, it goes through the dynamics first and then to the control program. The control program should monitor the tanks and make appropriate valve status changes. After the control operations are completed, the main program will transfer to the system dynamics, and the tank accumulations will again be calculated with the new valve statuses.

## Inputs by the Operator

The following questions will be asked to the operator when the program is initially started:

1. Is Well 1-4 ON or OFF
2. Does Well 1-4 feed Separator 1 or Separator 2
3. What are the tank capacities in barrels
4. What are the Pump Capacities in GPM (the program will convert it to barrels/hour)
5. What is the valve status of L(9) and L(10) (water holding tank manifold)
6. What is your sample time in minutes (the program will convert it to hours)

These values will be asked only once during the program. The sample time will determine how often the control loop will monitor the various tank and interface levels.

The System Dynamics

The system dynamics are simple rate and accumulation equations whose dimensions are barrels and hours. The change in accumulation is calculated by multiplying the difference of the input and output by the sample time. A number of IF statements are used to prevent the mathematical equations from exceeding the system's physical limitations. For instance, the total fluid volume cannot exceed a tank volume. The program will terminate anytime a tank overflows, water gets in the oil tank, or oil gets in the water tank.

Print Out

The main program will print once each sample time. The total accumulated time, the volumes of fluid in all the tanks, on the interface level of the two separators will be printed. Any other information needed by the operator should be printed from the control program.

### 3.5 Rules for Writing the Control Program

1. The variables W(K) and L(K) are the only variables that the control program should alter. All other variables can be compared with a control variable, but they should not be changed.
2. The control program will see the sample time in hours, not minutes.
3. The fluid volumes T(K), interface levels I(K), oil volume O(K), will be given as a fractional part of the total tank capacities R(K).
4. The water outlet level and oil outlet level E(K) and F(K) respectively, are also in a fractional form of the total tank size.
5. The control program should be written from statements 7000 to 8999. Statements 1-10 can be used to initialize counters.
6. The last statement in a control program should be a Remark Statement. Any time the program needs to be transferred to the main program, send it to your last statement. The main program will pick it up at this point.

## Conclusion

This program is set up to aid in the teaching of digital control systems. The program has the potential of demonstrating a user about the operation of digital control systems; however, the amount of understanding derived from the program is proportional to the amount of time and effort put in by the operator.

A group of Chemical Engineering students wrote the first control programs for the system. Two students in particular, Gerald Gruesndorf and Jesse Simpson, did exceptional work, and their control programs aided in the final polishing of the main program.

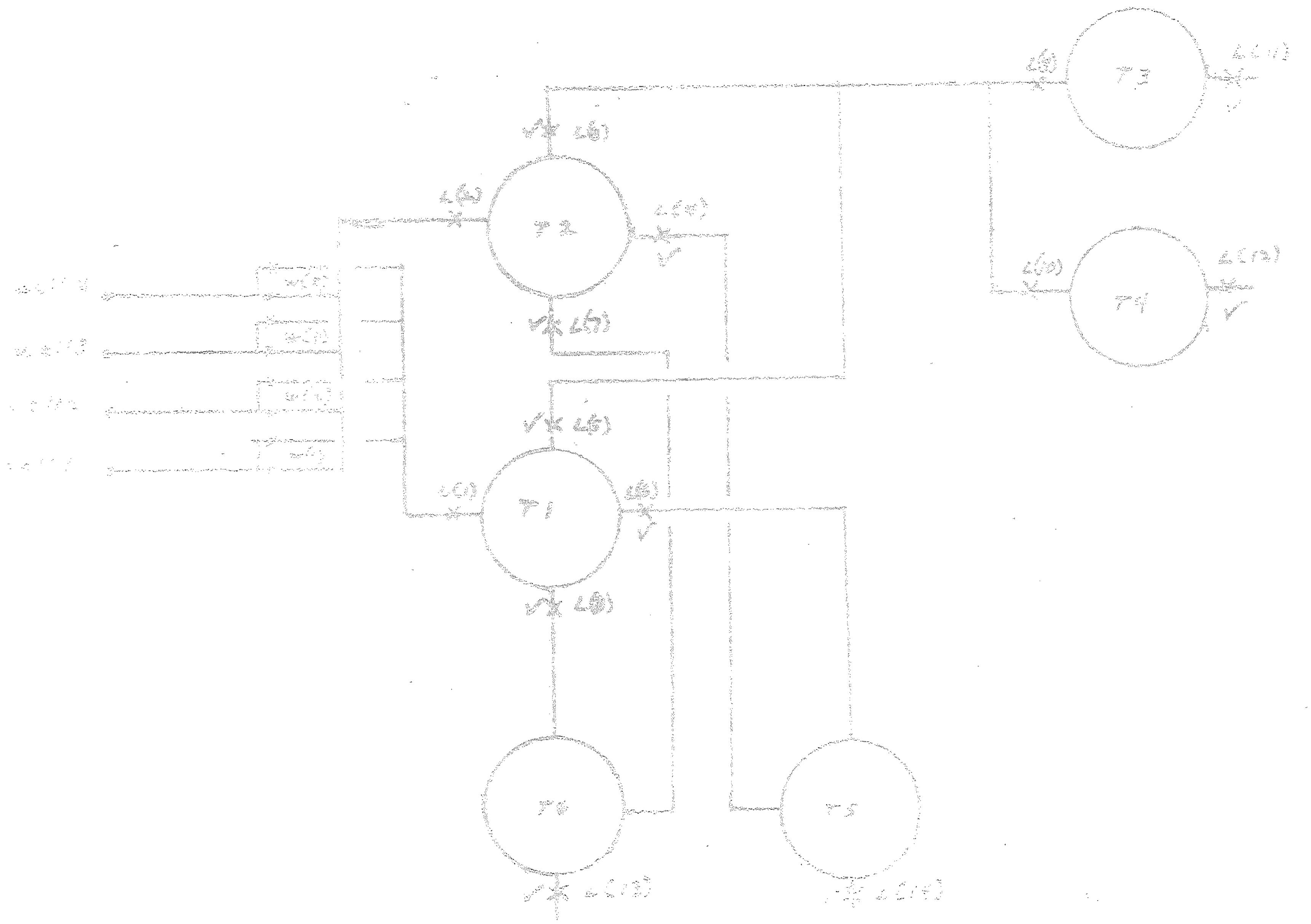


FIGURE 1. [illegible] MODEL

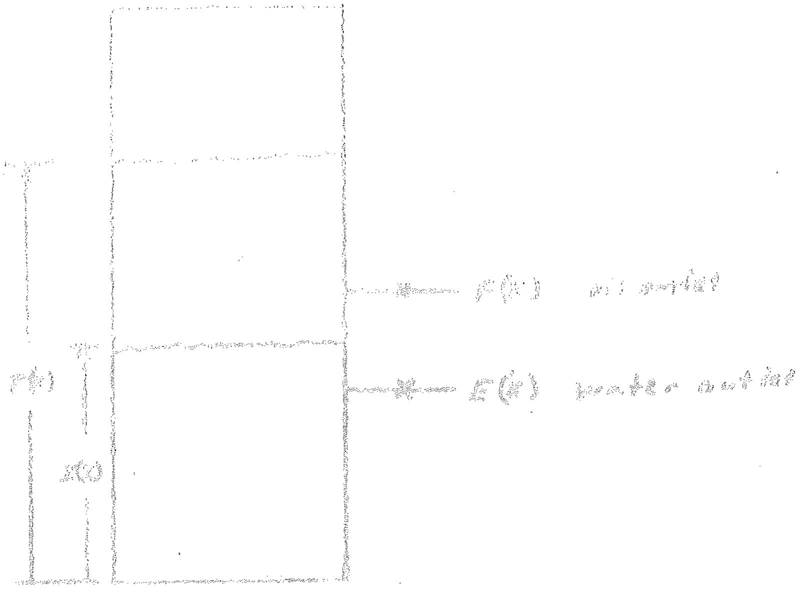


FIGURE 2
A SEPARATOR

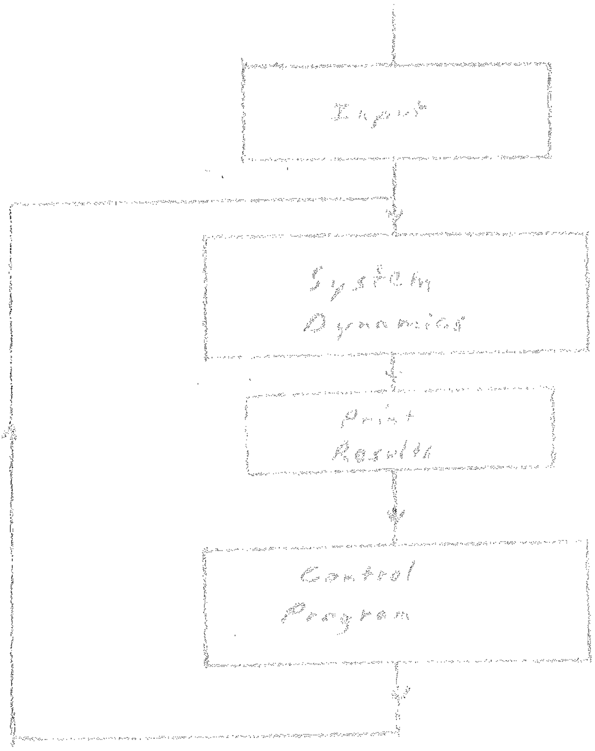


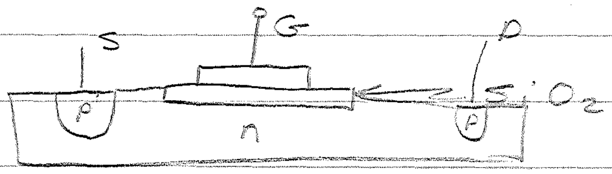
FIGURE 3
PROGRAM FLOW CHART

B. MOSFET

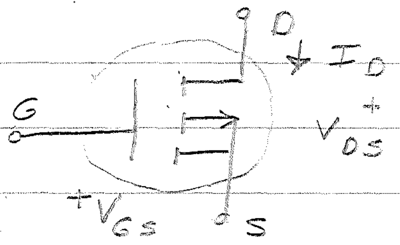
(METAL-OXIDE-SEMICONDUCTOR FET)

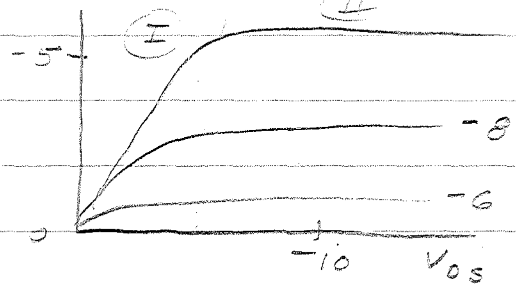
THIN LAYER OF $SiO_2$ SEPARATES GATE FROM CHANNEL

1.



P-CHANNEL ENHANCEMENT-MODE MOSFET

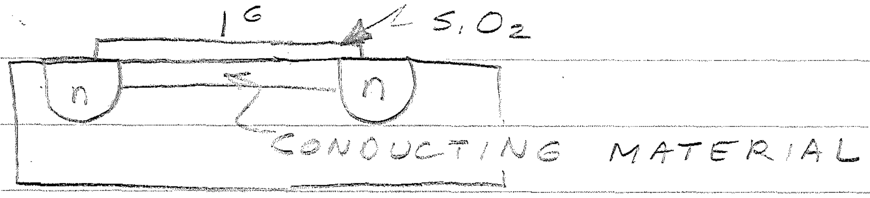




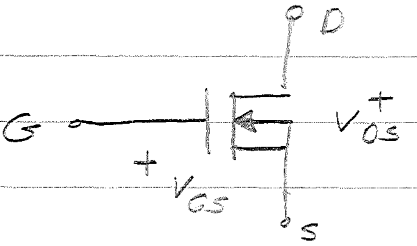
(I) WITH SMALL GATE VOLTAGE ($V_{GS}$), ELECTRONS IN ADJACENT n MATERIAL ARE REPELLED AND A DEPLETION LAYER FORMS.

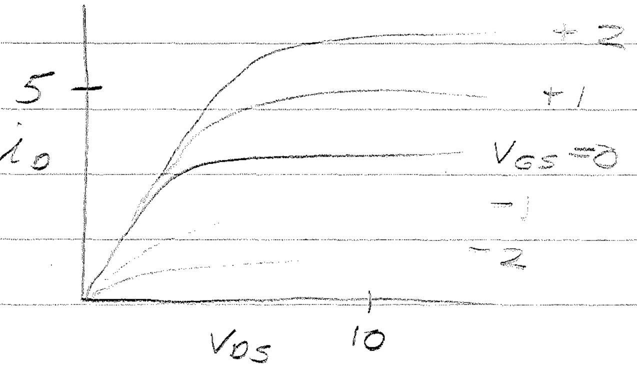
(II) BY MAKING $V_{GS}$ EVEN SMALLER, AN "INVERSIAN LAYER" OF MOBILE HOLES IS FORMED IN THE n MATERIAL, WHICH BECOMES A p MATERIAL. CONDUCTION IS "ENHANCED"

2. DEPLETION-MODE OR ENHANCEMENT MODE MOSFET

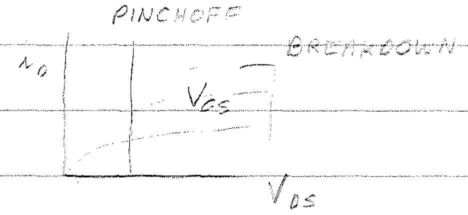


ALLOWS BOTH POS & NEG. $V_{GS}$



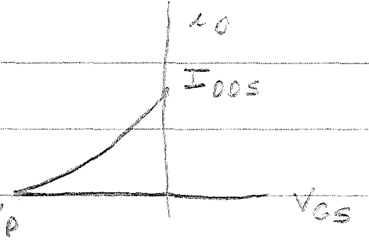


C. TRANSFER CHARACTERISTICS



BETWEEN PINCHOFF & BREAKDOWN, $i_D$ IS ROUGHLY INDEPENDENT OF $V_{DS}$.

JFET

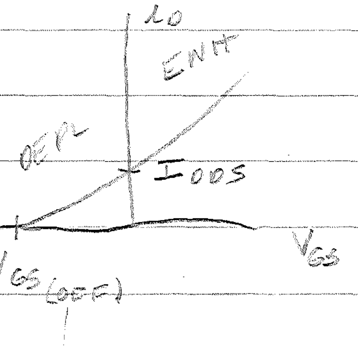


$$i_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

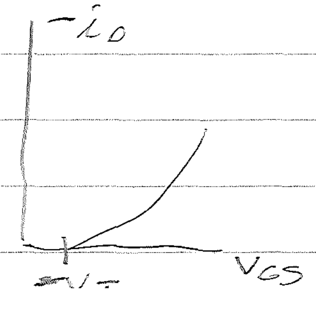
$V_P \sim 5V$

$I_{DSS}$ → DRAIN SHORTED TO SOURCE

DEPLETION-ENHANCEMENT MOSFET



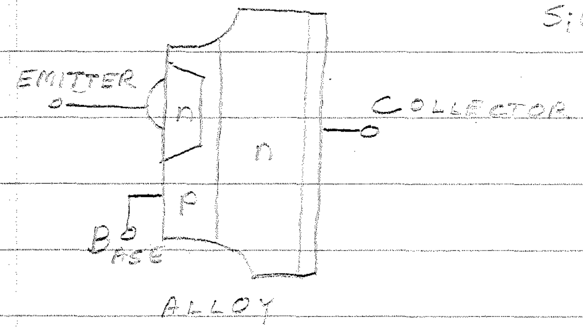
ENHANCEMENT ONLY

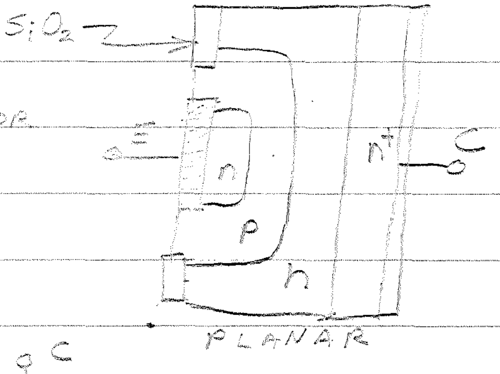


$$i_D = K(v_{GS} - V_T)^2$$

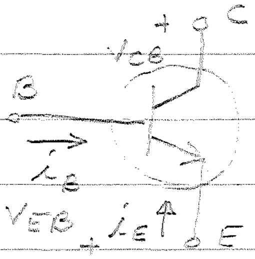
# IV. JUNCTION TRANSISTORS

## A. FABRICATION



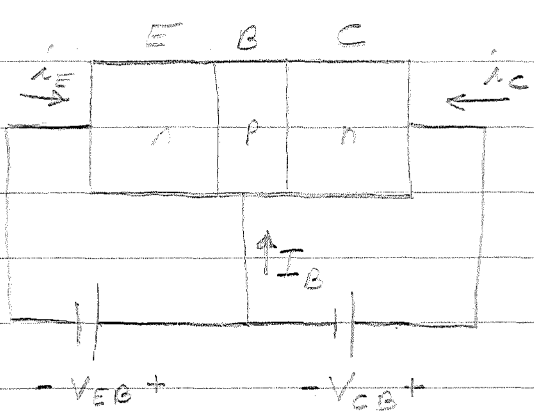


SYMBOL:



ARROW POINTS n MATERIAL.
⇒ THIS IS npn XSISTOR

## B. OPERATION

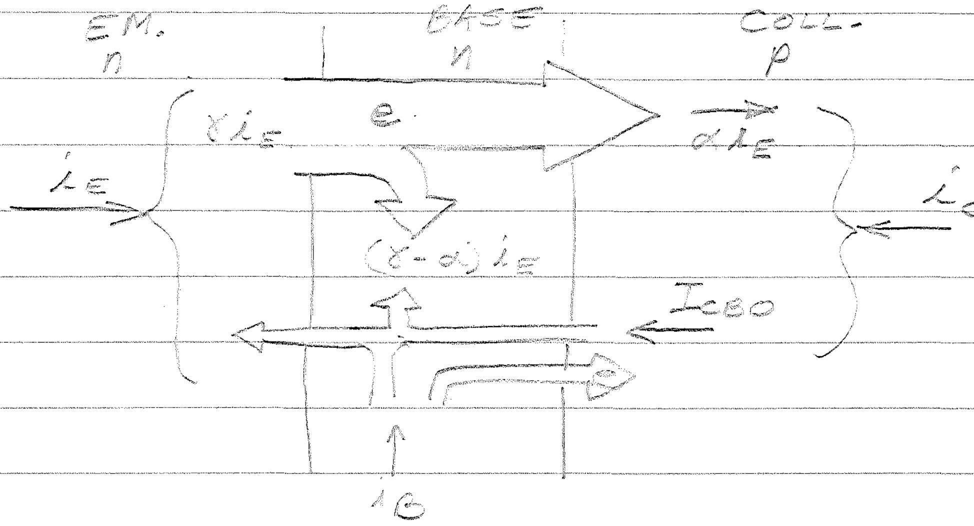


EMITTER JUNCTION FORWARD BIASED
(POTENTIAL BARRIER AT
EMITTER IS REDUCED. THIS
FACILITATES INJECTION OF
e's INTO BASE WHERE
THEY ARE MINORITY CARRIERS)

COLLECTOR JUNCTION IS REVERSE BIASED.
(POTENTIAL BARRIER @ COLLECTOR IS INCREASED.
ALMOST ALL e's FROM EMITTER DIFFUSE ACROSS
THE BASE AND ARE SWEPT UP POTENTIAL HILL
WHERE THEY RECOMBINE WITH BATTERY HOLES)

RESULT: XFER FROM E TO C A CURRENT
INDEPENDENT OF $V_{CB}$. (1) MODULATION OF
E PRODUCES CORRESPONDING CURRENT
CHANGES IN E-C CURRENTS, OR (2) MOD OF BASE
CONTROLS $i_C$ FOR CURRENT AMPLIFICATION

C. D.C. BEHAVIOR



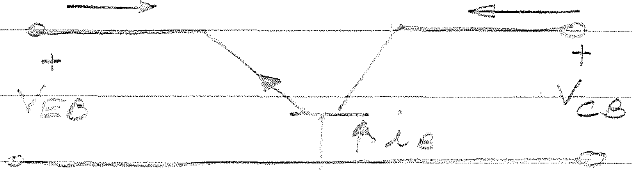
E IS FORWARD BIASED
C IS REV. BIASED

$\gamma$ = EMITTER EFFICIENCY $\lesssim 1$

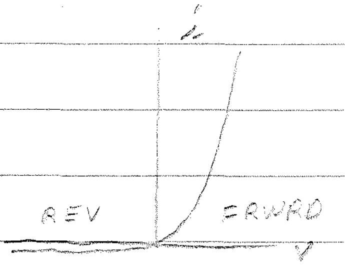
$i_C = -\alpha i_E + I_{CBO}$

$\alpha$ = FORWARD CURRENT XFER RATIO
(INCREASES WITH $V_{CB}$)

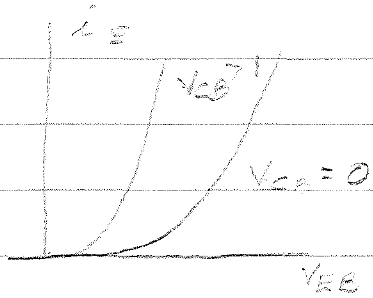
## D. COMMON BASE CHARACTERISTICS



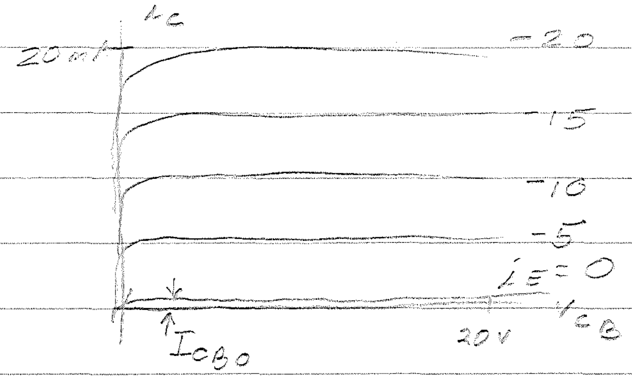
EMITTER-BASE SECTION IS A FORWARD-BIASED DIODE



DIODE

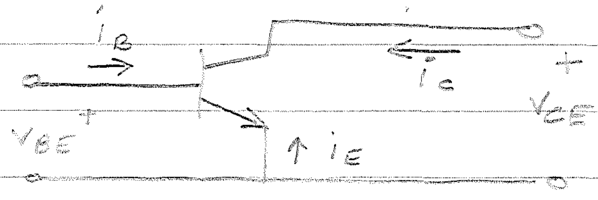


EMITTER CHARACTERISTICS



← CLOSE TO IDEAL CURRENT AMPLIFIER

## E. COMMON-EMITTER CHARACTERISTICS



NOW

$$i_C = -\alpha i_E + I_{CBO} = \alpha(i_C + i_B) + I_{CBO}$$

$$\Rightarrow i_C = \frac{\alpha}{1-\alpha} i_B + \frac{I_{CBO}}{1-\alpha}$$

$$\beta = \frac{\alpha}{1-\alpha} \quad ; \quad \frac{1}{1-\alpha} I_{CBO} = (1+\beta) I_{CBO} = I_{CEO}$$

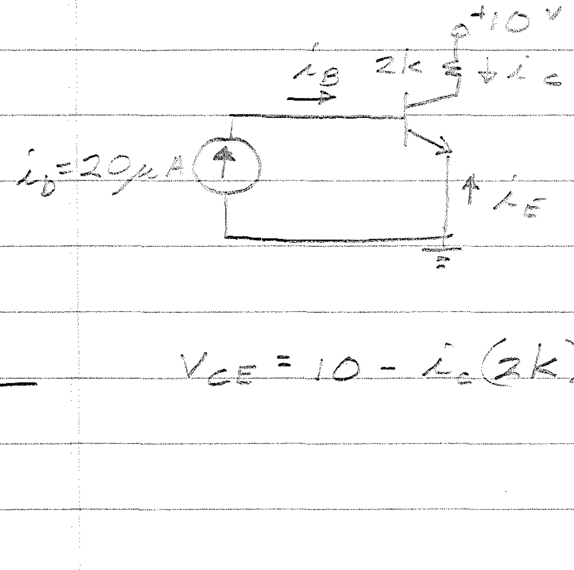
$$\therefore i_C = \beta i_B + I_{CEO}$$

(CONT) →

EXAMPLE:

$\alpha = 0.99$ , $I_{CBO} = 10^{-11}$ A

FIND $i_C$, $i_E$, $V_{CE}$



$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{0.01} = 99$$

$$I_{CEO} = (1+\beta) I_{CBO} = 10^{-9} A$$

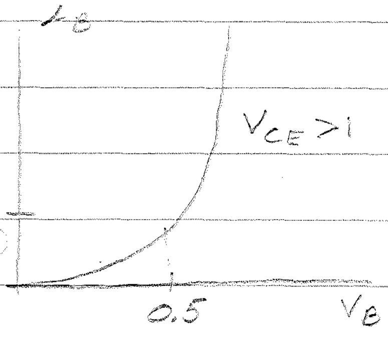
$$i_C = \beta i_B + I_{CEO}$$

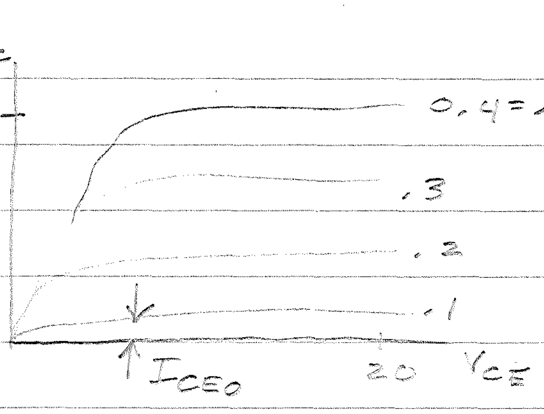
$$= 99(20 \times 10^{-6}) + 10^{-9} = 1.98 mA$$

$$i_E = -(i_C + i_B) = -2 mA$$

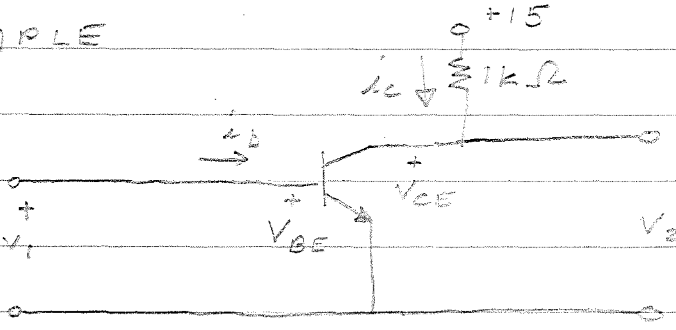
$$V_{CE} = 10 - i_C(2k) = 10 - (1.98)(2) = 6V$$

(CONT) →





EXAMPLE



$\beta = 50$ , $I_{CEO} \approx 10^{-9}$ A

(a) $V_1 = 0.2$ V

FROM GRAPH, $V_1 = V_{BE} = 0.2$ V $\Rightarrow i_B \approx 0$

$i_C = \beta i_B + I_{CEO} \approx I_{CEO} \sim 10^{-9}$ A = 1 nA

$\Rightarrow V_2 = V_{CE} = 15 - i_C(1k\Omega) \approx 15$ V

(b) $V_1 = 0.8$ V

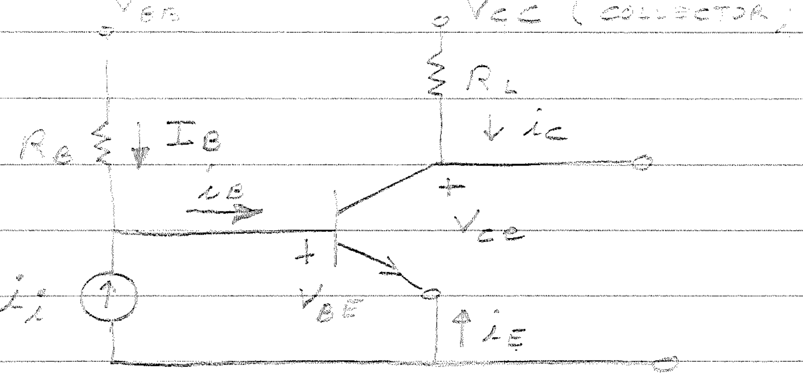
FROM GRAPH, $V_1 = V_{BE} = 0.8$ V $\Rightarrow i_B = 0.4$ mA

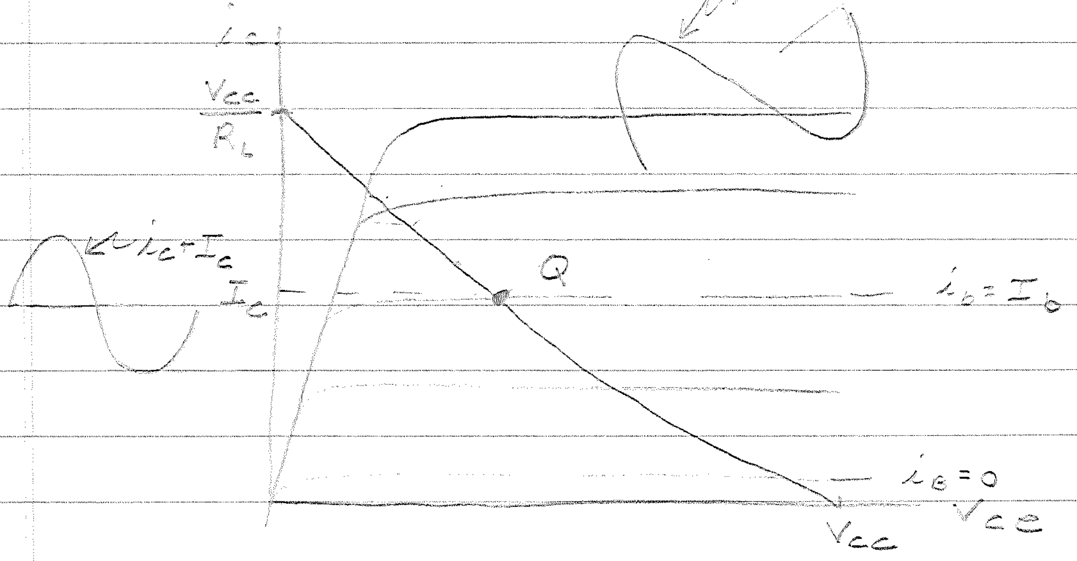
$i_C = \beta i_B + I_{CEO} = (50)(0.4) = 20$ mA

BUT THIS IS IMPOSSIBLE SINCE THERE IS ONLY 15V & A 1 k RESISTOR.

FROM TOP RT. FIGURE, $\beta$ CONCEPT IS NOT VALID FOR SMALL $V_{CE}$. WE HAVE INSTEAD, $V_{CE} \approx 1$ V FOR $V_1 = 0.8$ V

## F. CURRENT AMPLIFICATION





Q = QUIESCENT POINT ($i_i = 0$)

$\Rightarrow i_b = I_B \Rightarrow i_c = I_c$

HERE, $V_{BB} - I_B R_B - V_{BE} = 0$

$V_{BE} \sim 0.7V \Longrightarrow I_B = \frac{V_{BB} - 0.7}{R_B}$

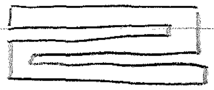
APPLYING SIGNAL CURRENT: $i_b = I_B + i_i$

$V_{CE} = V_{CC} - i_c R_L \Longleftarrow$ LOAD LINE $\Rightarrow i_C = \frac{V_{CE} - V_{CC}}{R_L}$

## V. INTEGRATED CIRCUITS

### A. FABRICATION

$R = \frac{\rho}{t} \frac{l}{w} \simeq R_s \frac{l}{w}$ ⇐ RESISTORS



← TYPICAL

$C = \epsilon \frac{A}{t}$ ⇐ CAPACITANCE

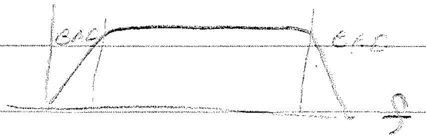
## VI. PRACTICAL AMPLIFIERS

### A. AMPLIFIER CLASSIFICATION

### B. AMPLIFICATION AND DISTORTION

$$A_v = \frac{V_{OUT}}{V_{IN}} = A e^{j\theta}$$

$A = A(f) \Rightarrow$ FREQUENCY DISTOR



$\theta = \theta(f) \Rightarrow$ PHASE DISTORTION

AMPLITUDE DISTORTION (NON-LINEAR)

## LINEAR SYSTEM THEORY

; $y(t) = S[x(t)]$

- LINEAR IF: $S[x_1(t) + x_2(t)] = S[x_1(t)] + S[x_2(t)]$

  $\underline{\underline{\text{AND}}}$ $S[a\,x(t)] = a\,S[x(t)]$

- TIME INVARIANT: IF $S[x(t)] = Y(t)$

  $S[x(t-\tau)] = Y(t-\tau)$

- CAUSAL: THE OUTPUT DOES NOT DEPEND ON SOMETHING THAT'S $\overset{\text{NOT}}{\vee}$ HAPPENED YET IN THE INPUT.

FOR A LINEAR TIME INVARIANT SYSTEM:

$$Y(s) = T(s)\,X(s)$$

$$Y(s) = \mathcal{L}[Y(t)]$$

$$X(s) = \mathcal{L}[x(t)]$$

$T(s)$ = SYSTEM TRANSFER FUNCTION

= FREQUENCY RESPONSE

LAPLACE TRASFORM REVIEW:

$$X(s) = \mathcal{L}[x(t)] = \int_0^\infty x(t)\,e^{-st}\,dt$$

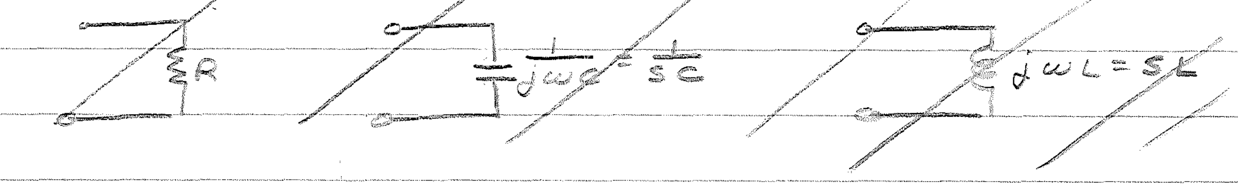
$$x(t) = \mathcal{L}^{-1}[X(s)] = \int_0^\infty X(s)\,e^{st}\,dt$$

TABLE

| $x(t)$ | $X(s)$ |
|---|---|
| $a\,x_1(t) + b\,x_2(t)$ | $a\,X_1(s) + b\,X_2(s)$ |
| $\frac{d^n}{dt^n}x(t) = x^{(n)}(t)$ | $s^n X(s) - s^{n-1}x(0+) - s^{n-2}x^{(1)}(0+) - \ldots - x^{(n-1)}(0+)$ |
| $u(t)$ | $\frac{1}{s}$ |
| $\frac{1}{s+a}$ | $e^{-as}$ |
| $\frac{1}{s^2+a^2}$ | $\frac{1}{a}\sin at$ |
| $\frac{s}{s^2+a^2}$ | $\cos at$ |

~~PHYSICALLY, WE INTERPRET $s = j\omega$~~

~~IMPEDENCES:~~



EXAMPLE: MOTOR

INPUT: LOAD OUTPUT: SPEED (COMPARED TO A FIXED SPEED)

$$T(s) = \frac{-1}{s+a}$$

SUPPOSE LOAD IS ABRUPTLY CHANGED

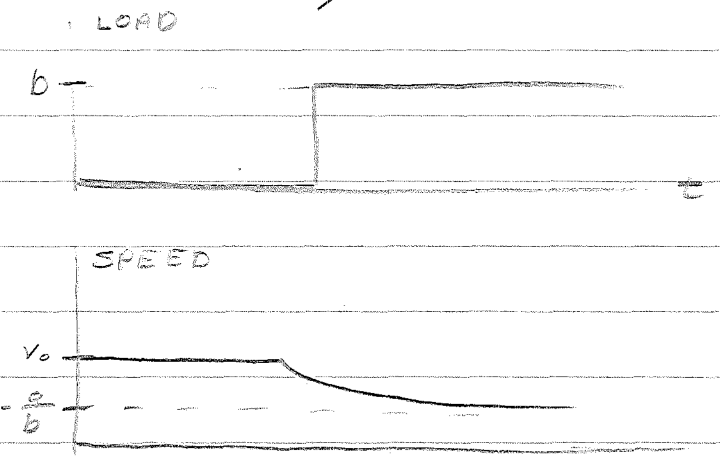
$$x(t) = -b\mu(t) \Rightarrow X(s) = \frac{-1}{s}$$

$$Y(s) = T(s)X(s)$$

$$= \frac{-b}{s(s+a)} = \frac{-b}{as} + \frac{b}{a(s+a)}$$

$$Y(t) = \frac{-b}{\cancel{b}a}\mathcal{L}^{-1}\left[\frac{1}{s}\right] + \frac{b}{a}\mathcal{L}^{-1}\left[\frac{1}{s+a}\right]$$

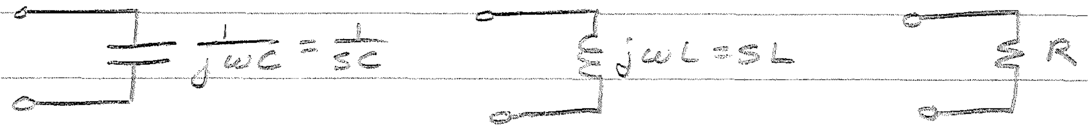
$$= \frac{-b}{a}\left[\mu(t) - e^{-at}\right]$$



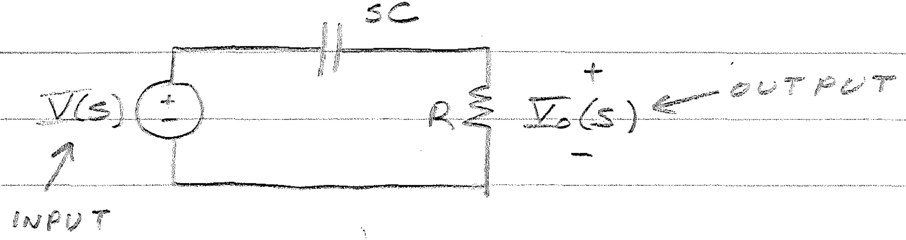
(FIG. 2.# ON Pg. 2-2 SHOULD LOOK LIKE THIS

HERE, $a = \frac{1}{\tau}$, $\tau$ = TIME CONSTANT

WE PHYSICALLY INTERPRET $s = j\omega$



EXAMPLE:



BY VOLTAGE DIVIDER

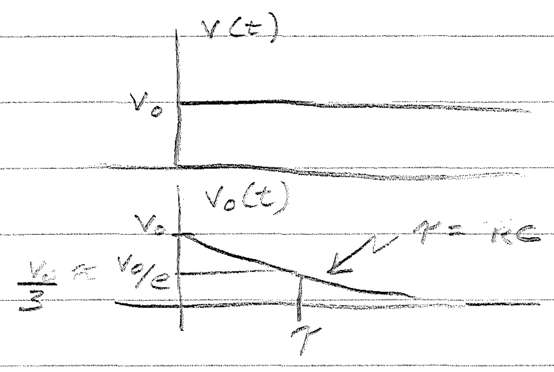
$$V_o(s) = 1 \ \frac{R}{R + \frac{1}{sC}} \ V(s)$$

$$= \frac{s}{s + \frac{1}{RC}} \ V(s)$$

TRANSFER FUNCTION

LET $V(t) = V_o u(t) \Rightarrow V(s) = \frac{V_o}{s}$

$$V_o(s) = \frac{V_o}{s + \frac{1}{RC}} \Rightarrow V_o(t) = V_o e^{-t/RC}$$



THE TRANSFER FUNCTION IS ALSO THE FREQUENCY RESPONSE.

IN PR. EXAMPLE:

$$T(s) = \frac{s}{s + \frac{1}{RC}}$$

$$T(j\omega) = \frac{j\omega}{j\omega + \frac{1}{RC}} =$$

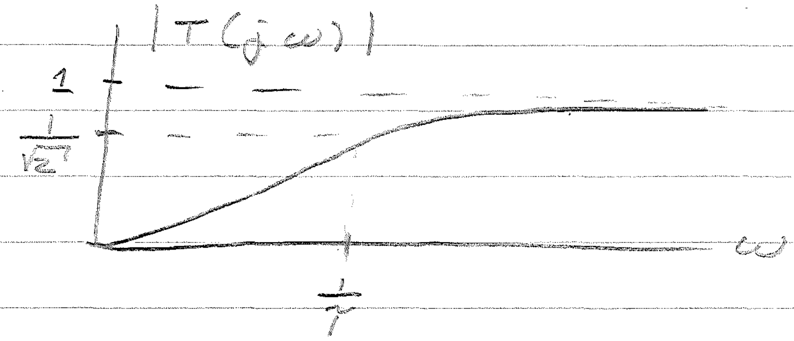
$$|T(j\omega)| = \frac{\omega}{\sqrt{\omega^2 + \frac{1}{(RC)^2}}}$$

$$|T(0)| = 0$$

$$|T(\infty)| = 1$$

$$\left|T\left(\omega = \frac{1}{RC}\right)\right| = \frac{\frac{1}{RC}}{\sqrt{\frac{2}{(RC)^2}}} = \frac{1}{\sqrt{2}} \leftarrow \text{HALF POWER POINT}$$

HERE, HALF POWER POINT IS AT $\omega = \frac{1}{\tau}$



SAMPLING RATES (MOTIVATE)

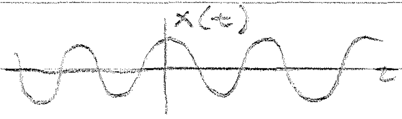
THE FOURIER TRANSFORM:

$$X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt \; ; \; x(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} X(\omega) e^{j\omega t} dt$$

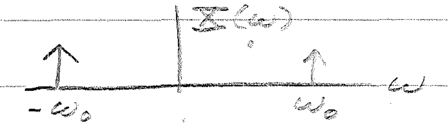
SOMETIMES SAME AS LAPLACE TRANSFORM WITH $s = j\omega$

EXAMPES:

(1) $x(t) = \cos \omega_0 t \Longrightarrow$

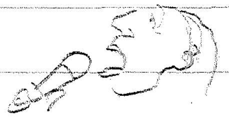


$X(\omega) \Longrightarrow$



⟸ ONE FREQUENCY

(2) $x(t) =$



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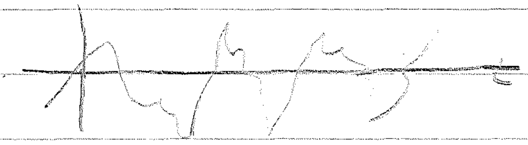
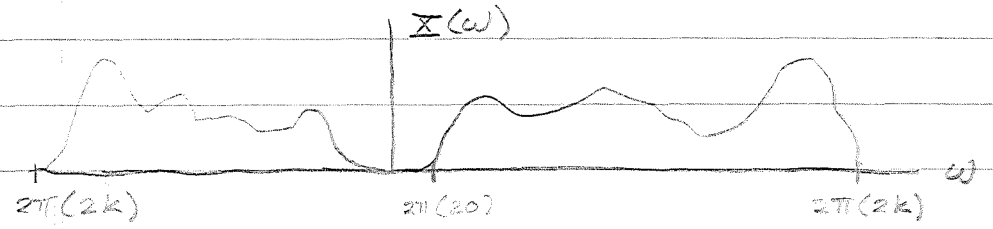
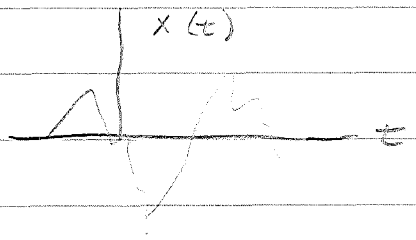


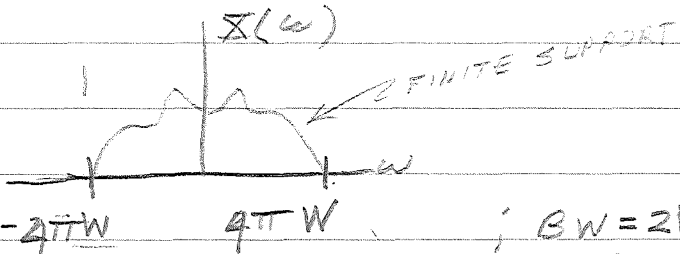
AUDIO FREQUENCIES RANGE FROM ABOUT

20 HZ TO 20 kHZ



DEFN: A SIGNAL (FUNCTION) IS BANDLIMITED IF IT'S FOURIER TRANSFORM HAS FINITE SUPPORT. THE INTERVAL OVER WHICH THE FOURIER XFORM IS NON-ZERO IS THE BANDWIDTH



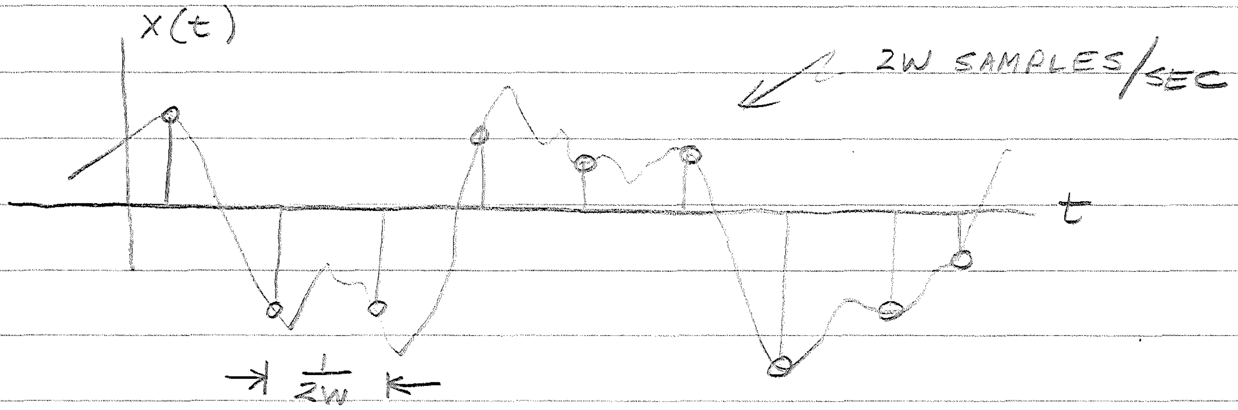


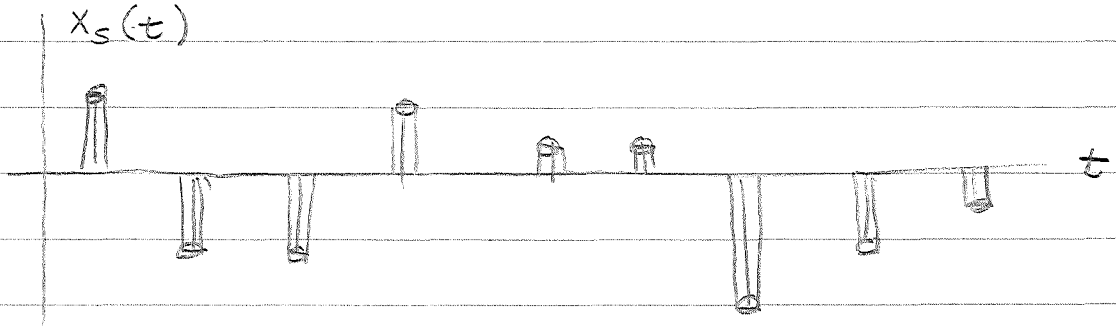
; $BW = 2W$

$BW = 4\pi W \frac{RAD}{SEC} = 2W \frac{RAD}{SEC}$.

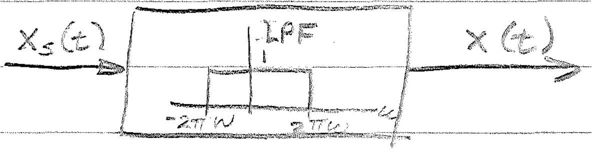
WHITTAKER-SHANNON SAMPLING THEOREM:

A BANDLIMITED FUNCTION, X(t), CAN BE DETERMINED EXACTLY BY SAMPLING IT AT A RATE EQUAL TO THE BANDWIDTH, (=TWICE ITS HIGHEST FREQUENCY

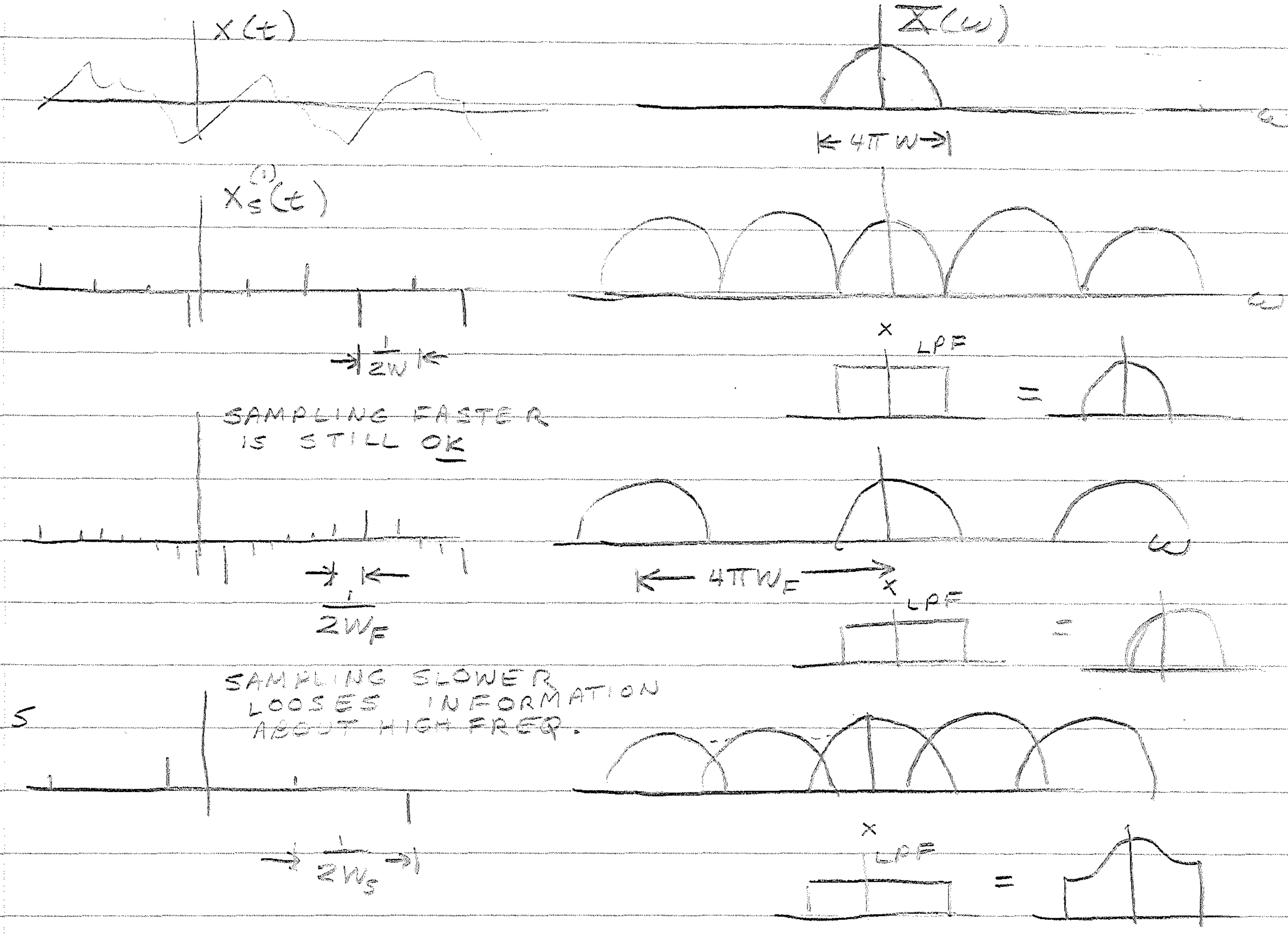




X(t) IS REGAINED BY PASSING $X_S(t)$ THRU A LOW PASS FILTER OF BANDWIDTH 2W



WHATS HAPPENING:

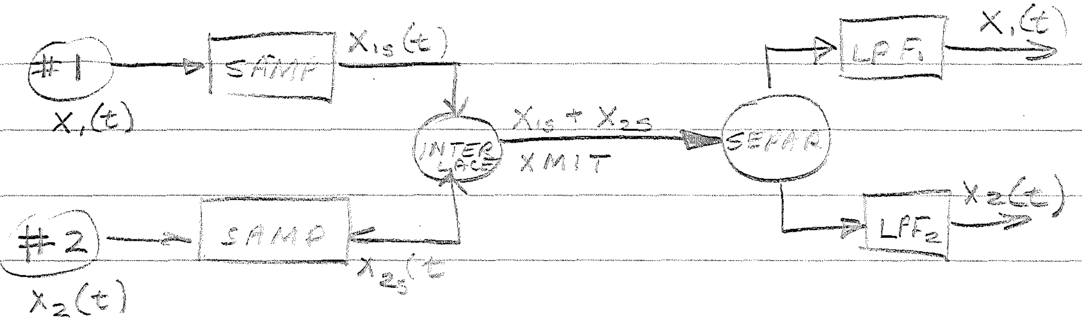


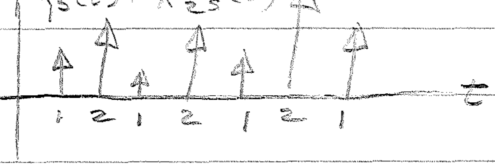
SAMPLING FASTER IS STILL <u>OK</u>

SAMPLING SLOWER LOOSES INFORMATION ABOUT HIGH FREQ.

SAMPLES MAY BE INTERLACED

OIL WELLS





# FOURIER SERIES

DEF: A SIGNAL $X(t)$ IS PERIODIC IF THERE EXISTS A $2T$ SUCH THAT $X(t)=X(t+2T)$ FOR ALL $t$.

$2T$ = PERIOD.

FOURIER SERIES: LET $X(t)$ BE PERIODIC WITH PERIOD $T$. THEN

$$X(t) = \sum_{n=-\infty}^{\infty} \alpha_n e^{j2\pi nt/T}$$

WHERE

$$\alpha_n = \frac{1}{T} \int_{2T} X(t) e^{-j2\pi tn/T} dt$$

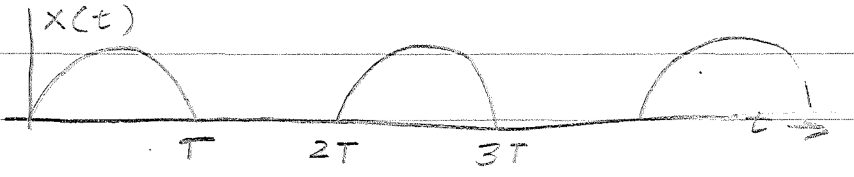
ALTERNATE FORM:

$$X(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos \frac{n\pi t}{T} + b_n \sin \frac{n\pi x}{T}$$

$$\begin{cases} a_n = \frac{1}{L} \int_{2T} X(t) \cos \frac{\pi t n}{T} dt \\ b_n = \frac{1}{L} \int_{2T} X(t) \sin \frac{n\pi t}{T} dt \end{cases}$$

$$\alpha_n = \begin{cases} \frac{1}{2}(a_n - jb_n) & ; n>0 \\ \frac{1}{2}(a_{-n} + jb_{-n} & ; n<0 \\ \frac{1}{2} a_0 & ; n=0 \end{cases}$$

EXAMPLE: HALF WAVE RECTIFIER OUTPUT:



$$X(t) = \begin{cases} \sin \frac{2\pi t}{2T} & ; 0<t<T \\ 0 & ; T<t<2T \end{cases}$$

$$X(t) = X(t-2T)$$

$$\alpha_n = \frac{1}{T}\left[\int_0^T \sin\frac{\pi t}{T} e^{-j2\pi nt/T} dt + \int_T^{2T} (0)\, e^{-j2\pi nt/T} dt\right]$$

$$= \frac{1}{T}\int_0^T \sin\frac{\pi t}{T} e^{-j2\pi nt/T} dt$$

$$= \frac{1}{T}\int_0^T \frac{1}{j2}\left[e^{j\frac{\pi t}{T}} - e^{-j\frac{\pi t}{T}}\right] e^{-j2\pi nt/T} dt$$

$$= \frac{1}{j2T}\left[\int_0^T e^{j\frac{\pi t}{T}[1-2n]} - e^{-j\frac{\pi t}{T}[1+2n]} dt\right.$$

$$= \frac{1}{j2T}\left[\frac{T}{j\pi(1-2n)} e^{-j\frac{\pi t}{T}(1-2n)}\Big|_0^T\right.$$

$$\left. - \frac{T}{j\pi(1+2n)} e^{j\frac{\pi t}{T}(1+2n)}\Big|_0^T\right]$$

$$= \frac{1}{j2T}\left[\frac{T}{j\pi(1-2n)}\left(e^{-j\pi(1-2n)} - 1\right) - \frac{T}{j\pi(1+2n)}\left(e^{j\pi(1+2n)} - 1\right)\right]$$

BUT $e^{j\pi(1\pm 2n)} = (-1)^{1\pm 2n} = (-1)^1(-1)^{2n} = -1$

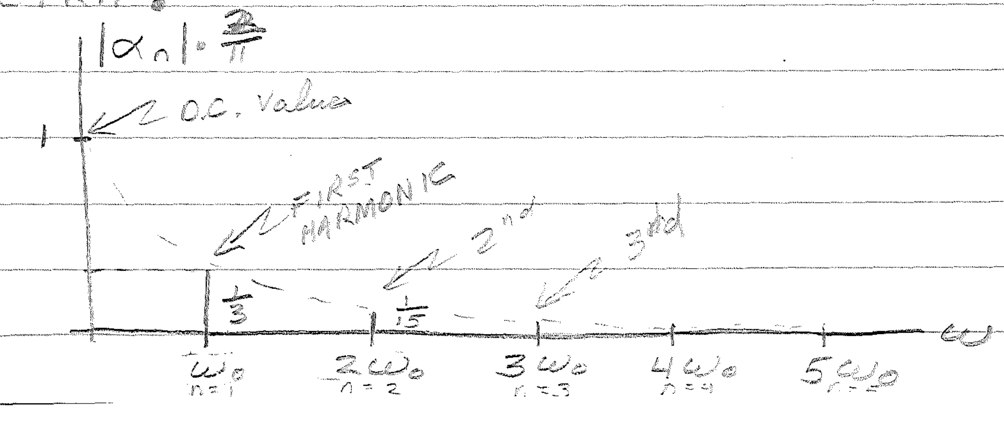
$$\Rightarrow \alpha_n = \frac{1}{j\cancel{2}T}\left[\frac{-2\cancel{T}}{j\pi(1-2n)} + \frac{2\cancel{T}}{j\pi(1+2n)}\right]$$

$$= \frac{1}{+\pi(1-2n)} + \frac{1}{-\pi(1+2n)}$$

$$= +\frac{1}{\pi}\left[\frac{1}{1-2n} + \frac{1}{1+2n}\right] = \frac{2}{\pi(1-2n)(1+2n)}$$

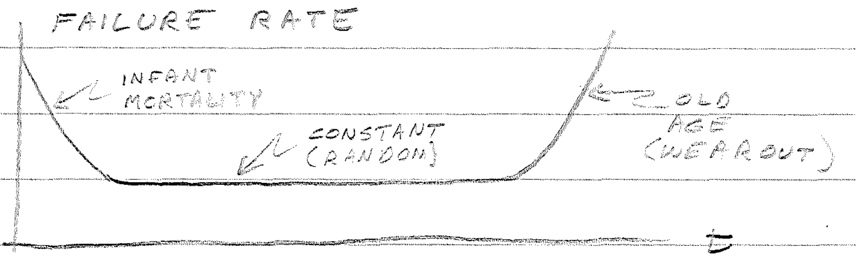
$$\Rightarrow x(t) = \sum_{n=-\infty}^{\infty} \frac{2}{\pi(1-2n)(1+2n)} e^{j2\pi nt/T}$$

HARMONIC
SPECTRA:



# RELIABILITY

BATHTUB CURVE

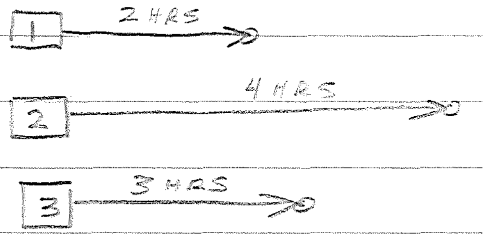


RELIABILITY: THE PROBABILITY THAT A GIVEN UNIT WILL BE OPERABLE AT A GIVEN TIME t

MTBF = MEAN TIME BETWEEN FAILURES

(A RELIABILITY MEASURE) = $\frac{\text{TEST TIME}}{\#\text{ OF FAILURES}}$

EXAMPLE:



$$MTBF = \frac{2+4+3}{3} = 3\ HRS$$

ON THE CONSTANT PART OF BATHTUB CURVE

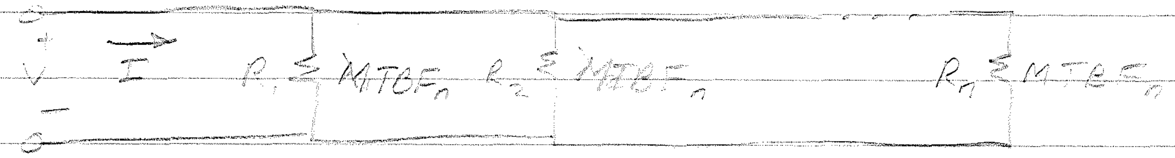
$$R(t) = e^{-\frac{t}{MTBF}} \quad ; t > 0$$

EX. A UNIT HAS A MTBF = 2 YEARS. WHAT IS THE PROB IT WILL BE FUNCTIONAL AFTER 16 YEARS OF USE?

$$R(16\ YEARS) = e^{-\frac{16}{2}} = e^{-8} = 0.00033$$

OR 1 CHANCE IN $e^{8} = 2981$

2. PARALLEL CONNECTION



HERE, LET OPERABLE MEAN THAT A CURRENT HAS A PATH TO FLOW

(∴ FAILURE ⇒ ALL RESISTORS OPEN)

$$MTBF_{SYS} = \sum_{K=1}^{n} MTBF_K$$

$$\frac{1}{\lambda_{SYS}} = \sum_{K=1}^{n} \frac{1}{\lambda_K}$$

PARALLEL (OR REDUNDANT) CONNECTIONS INCREASE RELIABILITY

EXAMPLE: THE MTBF OF UNIT IS 2 YEARS. HOW MANY UNITS SHOULD YOU BUY IF YOU WANT AT LEAST A 50% CHANCE AT LEAST ONE UNIT WILL BE RUNNING 10 YEARS FROM NOW? (ASSUME NO MAITANENCE) $MTBF_S = n\,MTBF_U = 2n$

$$R_S(t) = e^{-t/MTBF_S} = 0.5$$

$$R_S(10) = e^{-10/2n} = e^{-5/n} = 0.5$$

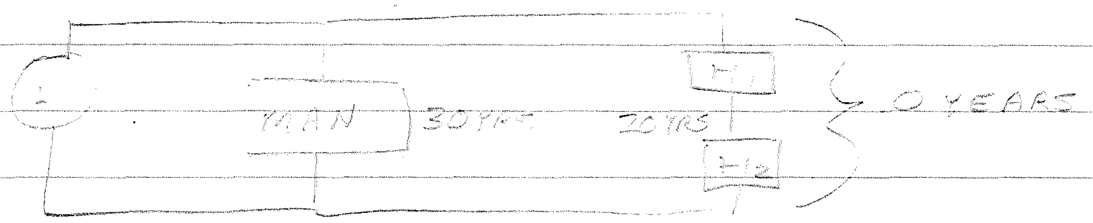
$$-5/n = \ln 0.5$$

$$\Rightarrow n = -5/\ln 0.5 = \frac{-5}{-.693} = 7.2$$

∴ AT LEAST 8 UNITS

NOTE: IN REDUNDANT CONFIGURATION, YOU CAN PERFORM "PREV. MAITAMENSE" ON FAILED UNITS WHILE SYSTEM IS STILL "OPERABLE", THUS, GREATLY INCREASING MTBF

**EX** A MOTOR IS RUN OFF TWO HAMSTERS. (MTBF = 20 YRS) AND A MAN CRANKING A HANDLE (MTBF = 30 YRS). IF EITHER THE HAMSTERS OR THE MAN CAN RUN THE MOTOR, WHAT'S THE SYSTEM MTBF?

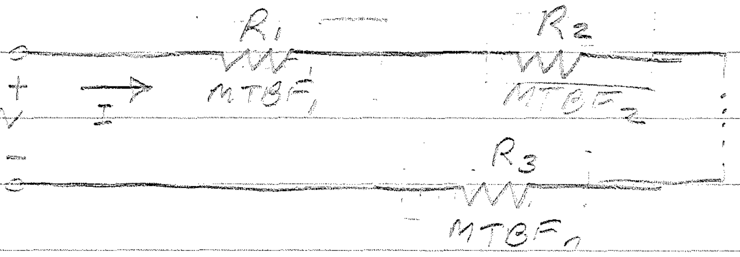


MTBF = 40 YEARS

SYSTEM VS UNIT RELIABILITY

[FOR A SYSTEM, WE MUST DEFINE WHAT WE MEAN BY "OPERABLE" TO COMPUTE MTBF]

1. SERIES CONNECTION:

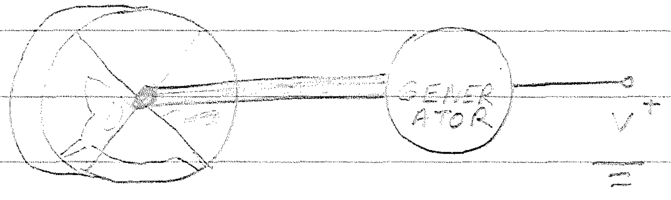


HERE, LET OPERABLE MEAN THAT A CURRENT IS FLOWING (THUS A FAILURE MEANS A RESISTOR HAS BLOWN) (OPEN CIRCUIT) [SHORT CIRCUIT FAILURE NOT CONSIDERED]

$$\frac{1}{MTBF_{SYSTEM}} = \sum_{K=1}^{n} \frac{1}{MTBF_n}$$

$\lambda = \frac{1}{MTBF}$ = FAILURE RATE : $\lambda_{SYS} = \sum_{K=1}^{n} \lambda_K$

EXAMPLE



$MTBF_{HAMSTER}$ = 2 YEARS
$MTBF_{CAGE}$ = 50 YEARS
$MTBF_{BAR}$ = 1000 YEARS
$MTBF_{GEN}$ = 3 YEARS

$$\lambda_{SYS} = \frac{1}{MTBF_{SYS}} = \frac{1}{2} + \frac{1}{50} + \frac{1}{1000} + \frac{1}{3} = 0.854/YR = \lambda_s$$

$$\Rightarrow MTBF_{SYS} = 1.17 \text{ YEARS}$$

$P_r$[LAST TWO YEARS] $= e^{-2/1.17} = 18\%$

NOTE: SERIES TYPE CONNECTIONS REDUCE RELIABILITY

MAINTAINABILITY - GIVEN THAT A UNIT IS DOWN @ $t=0$, THE UNIT'S MAINTAINABILITY IS THE PROBABILITY THAT IT WILL BE FIXED AT TIME $=t$.

MTTR = MEAN TIME TO REPAIR

$$= \frac{\text{TOTAL DOWN TIME}}{\text{\# FAILURES}}$$

EX

$$\text{MTBF} = \frac{\text{6 YEARS}}{\text{3 FAILURES}} = \text{2 YEARS}$$

$$\text{MTTR} = \frac{\text{3 DAYS}}{\text{3 FAILURES}} = \text{1 DAY}$$

AVAILABILITY - A MEASURE OF THE PERCENT OF TIME A UNIT IS OPERABLE

$$A = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

FOR ABOVE EXAMPLE

$$A = \frac{\text{2 YEARS}}{\text{2 YEARS} + \text{1 DAY}} = \frac{\text{730 DAYS}}{\text{731 DAYS}} = 99.863\%$$

TEST # 1 ON THURS.

[OPEN BOOK & NOTES, 1 HR
5 PROBLEMS, 100 PTS]

1. RECTIFIERS, DIODE AND/OR FET (PERFORMANCE, V-I CURV (15)
2. LINEAR SYSTEM REDUCTION
PROBLEM (15)
3. LAPLACE XFORM NETWORK SOLUTION AND/OR
FREQUENCY RESPONSE (25)
4. SYSTEM EFFECTIVENESS (RELIABILITY,
MAINTAINABILITY, ETC.) (25)
5. SAMPLING THEOREM AND/OR FOURIER SERIES (20)

CORRECT SOLUTION

$$\frac{\sin n\pi}{n\pi} = \begin{cases} 1 & ; n=0 \\ 0 & ; \text{OTHERWISE} \end{cases}$$

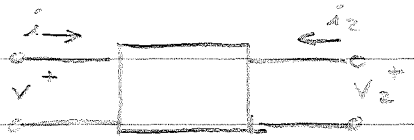
ALSO, MTTR IS REDUCED, NOT THE SAME

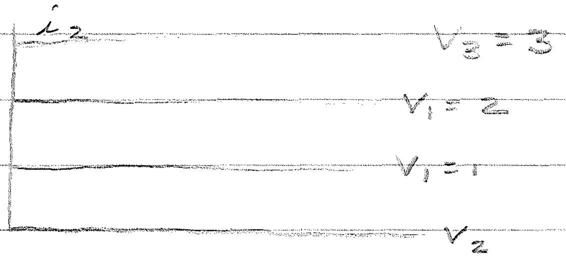
## II. TRANSISTOR BIASING CIRCUITS

PURPOSE: ESTABLISH AND MAINTAIN PROPER OPERATING POINTS

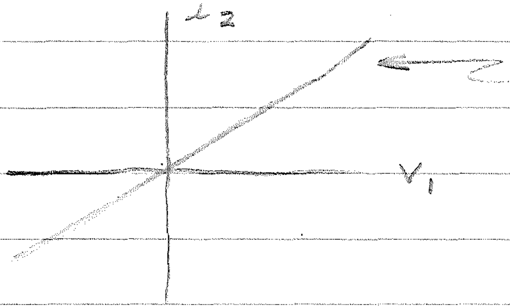
### A. FET BIASING

- AN IDEAL LINEAR AMPLIFIER (p. 274 SMITH)



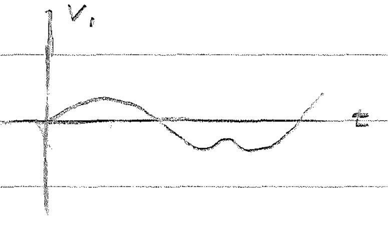


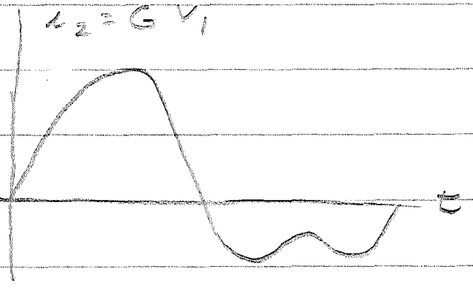
$i_2$ DEPENDS ONLY ON INPUT VOLTAGE



$i_2 = G V_1$

G = AMPLIFICATION (IN MHOS)



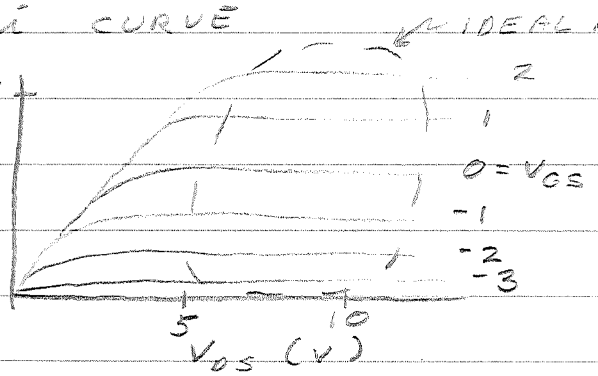


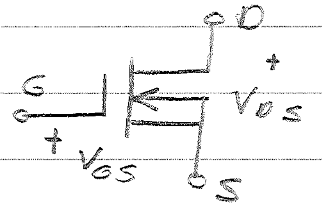
THIS TRANSDUCER TAKES AN INPUT VOLTAGE AND OUTPUTS A AMPLIFIED CURRENT.

## 1. DE MOSFET BIASING

(DEPLETION OR ENHANCEMENT MODE
METAL·OXIDE·SEMICONDUCTOR FET SMITH p.337)

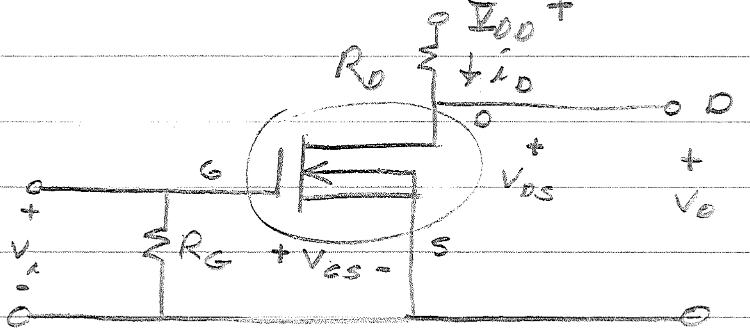
V-i CURVE (p.414 SMITH)





WE MUST ESTABLISH "QUIESCENT" OR "NO SIGNAL" CONDITION IN IDEAL AMP REGION.

A BIASING CIRCUIT:



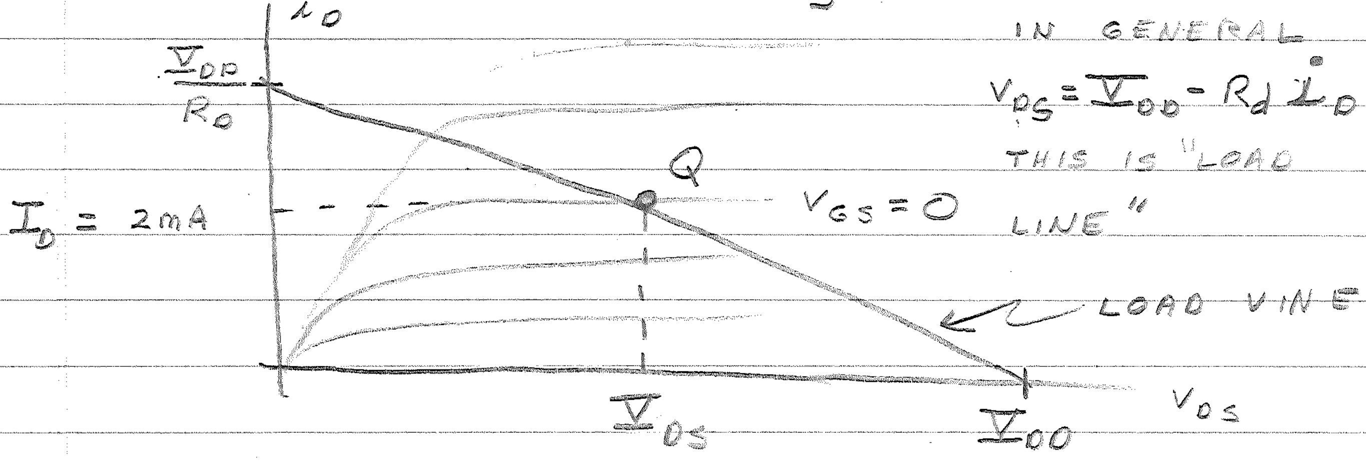
FOR DE MOSFET, WE MAY ALLOW $V_{GS} = 0$ AS QUIESCENT POINT. FROM CURVE, $I_D \approx 2mA$ FOR $V_{GS} = 0$ AND $V_{DS} > 4$ VOLTS CHOICE OF $R_D$ AT GIVES

QUIESCENT $V_{DS}$ AS $V_{DS} = V_{DD} - R_D I_D$.

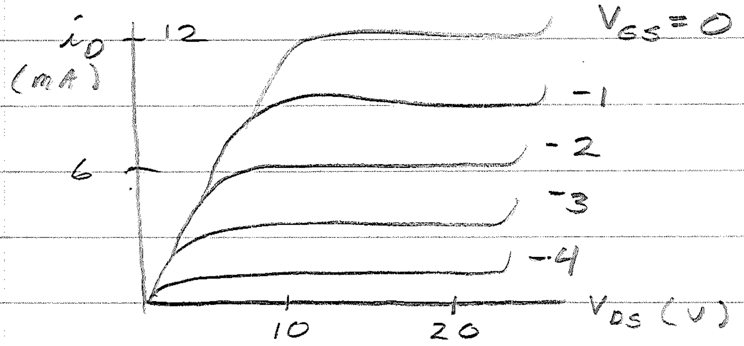
IN GENERAL

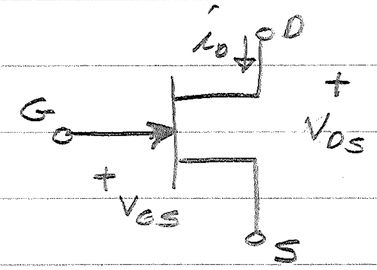
$v_{DS} = V_{DD} - R_d i_D$

THIS IS "LOAD LINE"

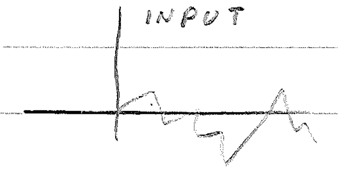


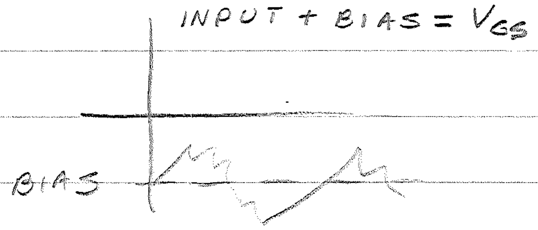
## 2. JFET BIASING (p. 415)



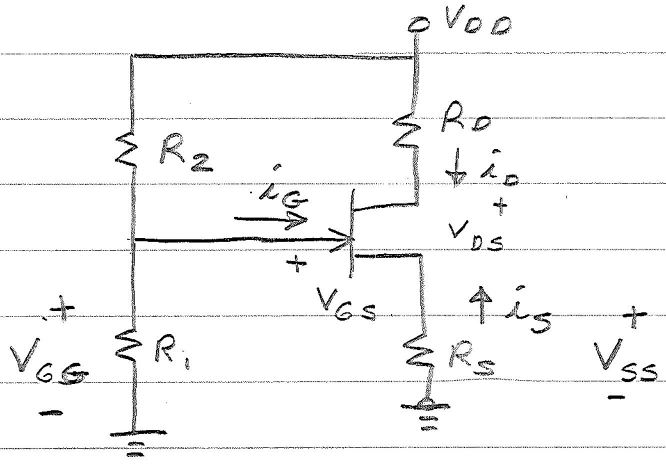


MORE COMPLICATED, SINCE $V_{GS} < 0$. MUST PUT $V_{GS}$ ON A "BIAS"





A BIASING CIRCUIT:



ANALYSIS

1. GATE CURRENT, ($i_G$) IS SMALL

(a) THUS, SINCE $i_G + i_S + i_D = 0 \Rightarrow i_S \cong -i_D$

AND $V_{SS} \cong R_S i_d$

(b) $R_1$ & $R_2$ FORM A VOLTAGE DIVIDER:

$$V_{GG} = \frac{R_1}{R_1 + R_2} V_{DD}$$

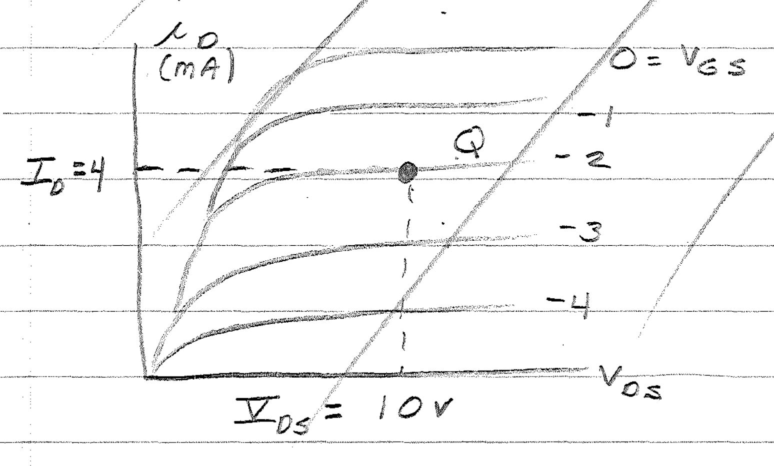
2. SUMMING VOLTAGES AROUND LOOP

$V_{GG} - V_{SS} - V_{GS} = 0$ $\Rightarrow V_{GG} - V_{SS} - V_{GS} = 0$ $\Rightarrow$

$\Rightarrow V_{GS} = \frac{R_1}{R_1 + R_2} V_{DD} - R_S i_D$

WE MAY ESTABLISH QUISCENCE WITH THIS RELATIONSHIP. USUALLY, $V_{GG} >>$

EX



WE WISH TO ESTABLISH Q AT $V_{GS} = -2$ v

$\Rightarrow I_D = 4$ mA

OR $I_D = \dfrac{V_{GG} - V_{GS}}{R_S}$

3. TO ESTABLISH QUISCENCE, CHOOSE $(I_D, V_{GS})$ ON CURVE. ALSO, SPECIFY A BIAS, $V_{GG}$. WE WISH TO KEEP THE INPUT RESISTANCE HI, SO CHOOSE $R_G = R_1 // R_2 = \dfrac{R_1 R_2}{R + R_2}$ TO BE "HI"

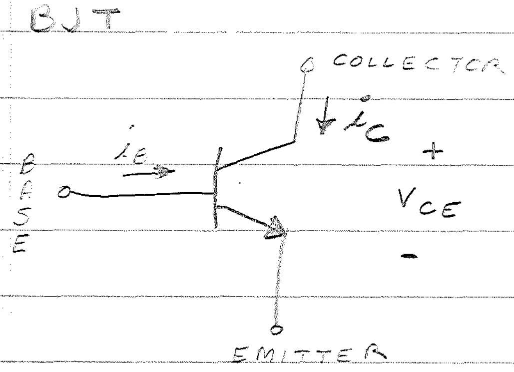
OUR EQUATIONS ARE THEN (H.W)

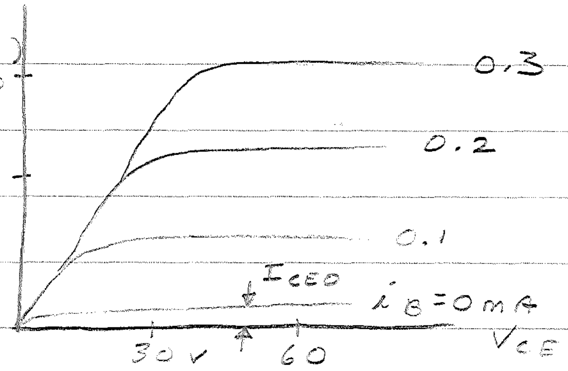
$$R_S = V_{GG} - V_{GS} / I_D$$

$$R_2 = R_G \, V_{DD} / V_{GG}$$

$$R_1 = R_G R_2 / (R_2 - R_G)$$

BJT





(P.345 OF SMITH)

$I_{CEO}$ = $i_C$ WHEN <u>COLLECTOR</u> <u>EMITTER</u> JUNCTION IS <u>OPEN</u>

$I_{CBO}$ = $i_E$ " ~~"~~ ~~BASE~~ " " "

$I_{CEO} = (1+\beta) I_{CEO}$

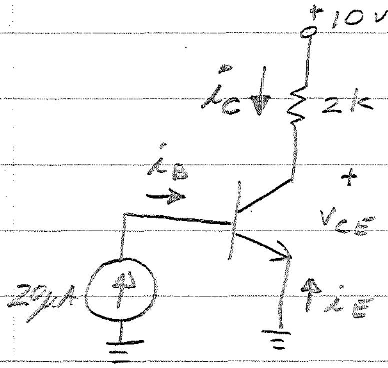
$\beta$ = "CURRENT TRANSFER RATIO"

$\alpha$ = "FORWARD CURRENT XFER RATIO"

$\beta = \frac{\alpha}{1-\alpha}$ $\quad 0 < \alpha < 1$

IN LINEAR PART OF XISTOR CURVE: $\overset{*}{i_C} = \beta i_B + I_{CEO}$

<u>EX</u> $\beta = 99$, $I_{CBO} = 10^{-11}$ AMPS (10 V PUTS US ON LIN PART)



$I_{CEO} = (1+\beta) I_{CBO} = 10^{-9}A$

$i_C = \beta i_B + I_{CEO}$

$= (99)(20 \times 10^{-6}) + 10^{-9} = 1.98mA$

FIND $i_E$:

FROM K'NODE LAW

$i_E = -(i_B + i_C)$

$= -(20 \times 10^{-6} + 1.98 \times 10^{-3}) = -2mA$

FIND $V_{CE}$

FROM K'S V LAW:

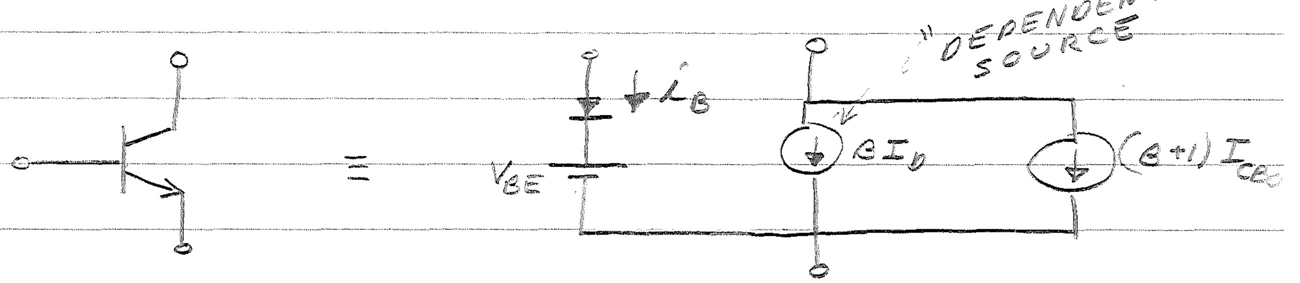
$V_{CE} = 10 - i_C R_C = 10 - (2mA) \times 2k\Omega = 6V$

NECECARY THAT

*COLLECTOR - BASE JUNCTION REVERSED BIASED

EMITTER " " FORWARD BIASED

IN LINEAR REGION, WE MAY REPLACE TRANSISTOR WITH "DC MODEL"

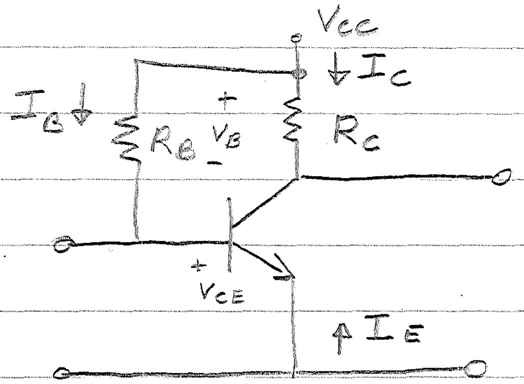


$V_{BE}$ = "DROP" ACROSS FORWARD BIASED P-N JUNCTION

≈ 0.7 V FOR Si

BJT BIASING (p. 417)

- FIXED CURRENT BIAS



EMITTER JUNCTION FORWARD BIASED $\Rightarrow V_{CE} \approx 0$

(ACTUALLY, $V_{CE} \cong 0.7V$ FOR SILICON)

$\Rightarrow V_B \approx V_{CC}$ AND $I_B = V_{CC}/R_B$

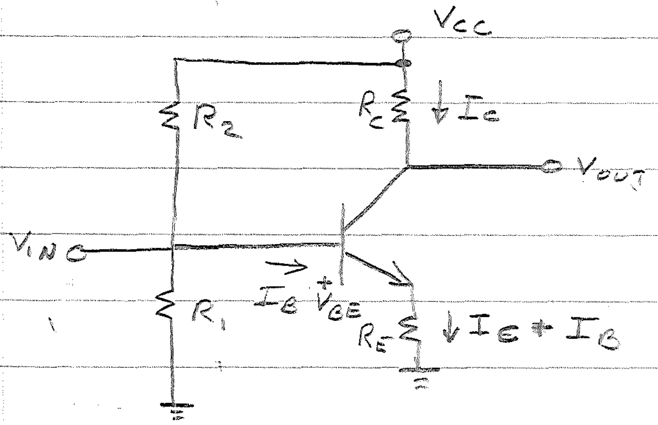
$I_C = \beta I_B + I_{CEO}$

PARAMETERS VARY WIDELY WITH TEMP / $\beta$ changes FROM UNIT TO UNIT

THERMAL RUNAWAY: $I_C$ INCREASES TEMP INCREASES

$I_C$ .... POW

- SELF BIAS (REDUCES EFFECTS OF $\beta$ AND TEMP ON QUIESCENT OPER. POINT)



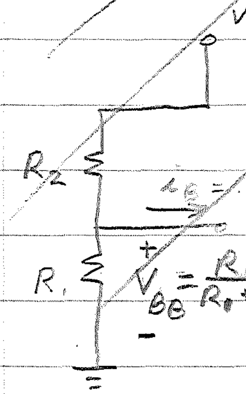
OPERATION (HEURISTIC)

$I_C$ TRIES TO INCREASE $\Rightarrow I_C + I_B$ INCREASES

$\Rightarrow$ VOLTAGE ACROSS $R_E$ INCREASES $\Rightarrow V_{BE}$ DECREASES

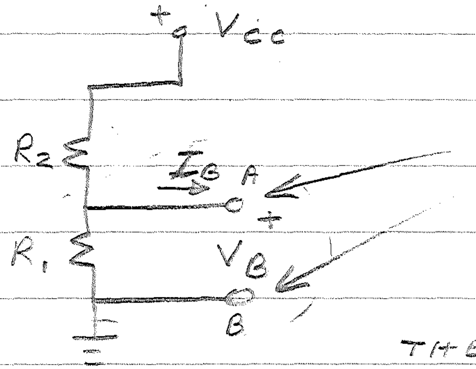
$\Rightarrow I_B$ REDUCED $\Rightarrow I_C = \beta I_B + I_{CEO}$ REDUCED

QUANTATATIVE:



$$V_{BB} = \frac{R_1}{R_1+R_2} V_{cc} = \cancel{\frac{1}{R_2}(R_1 \| R_2) V_{cc}} = \cancel{\frac{R_B}{R_2} V_{cc} =}$$

QUANTATATIVE:



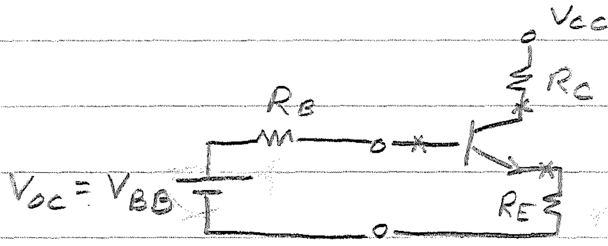
FIND THEVININ EQUIVALENT FOR THIS PORT

THEVININ:

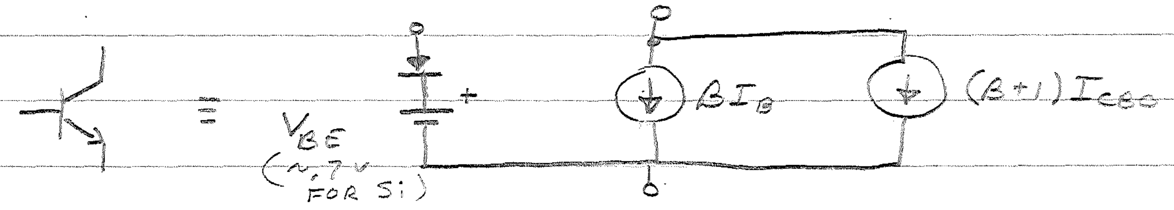
$V_{oc} = \frac{R_1}{R_1+R_2} V_{cc}$ (OPEN CIRCUIT VOLTAGE)

$I_{sc} = V_{cc}/R_2 \quad \Rightarrow R_B = V_{oc}/I_{sc} = \frac{R_1 R_2}{R_1+R_2} = R_1 \| R_2$

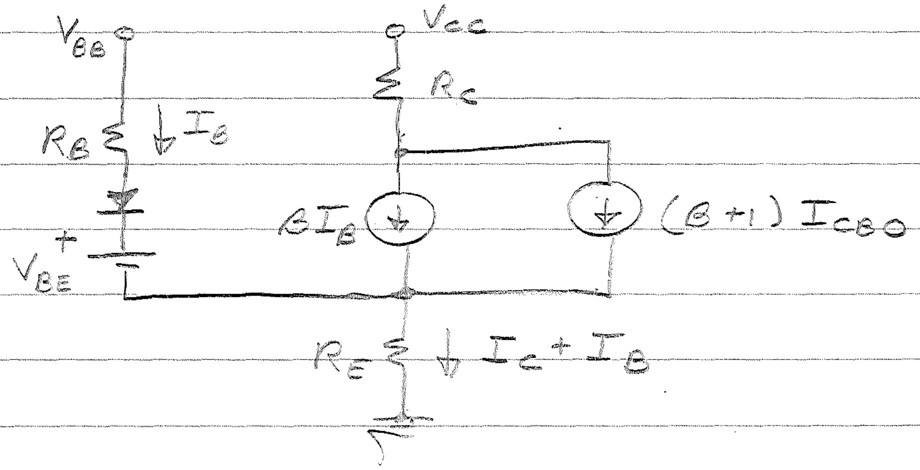
$\Rightarrow V_B = V_{oc} + R_B I_b$



REPLACE TRANSISTOR BY A "D.C MODEL"



OUR CIRCUIT IS



KIRCHOFF'S V LAW FROM $V_{BB}$ DOWN IS:

$$V_{BB} - I_B R_B - V_{BE} - (I_C + I_B) R_E = 0 \quad ①$$

SUMMING I @ NODE AT $R_E$:

$$\cancel{I_B} + \beta I_B + (1+\beta) I_{CBO} = I_C + \cancel{I_B}$$

$$\Rightarrow I_B = \frac{I_C}{\beta} - \frac{\beta+1}{\beta} I_{CBO} \quad ②$$

SUBSTITUTING INTO ① AND CRANKING:

$$I_C = \frac{V_{BB} - V_{BE} + \left(\frac{\beta+1}{\beta}\right) I_{CBO} (R_B + R_E)}{R_E + \frac{R_B + R_E}{\beta}}$$

NOTE: $V_{BE}$, $\beta$, AND $I_{CBO}$ ARE DEVICE PARAMETERS

$\frac{\beta+1}{\beta} \approx 1$ FOR LARGE $\beta$

$\frac{NUM}{MAKE}$ $V_{BB} - V_{BE} \gg \left(\frac{\beta+1}{\beta}\right) I_{CBO} (R_B + R_E)$ ← NU

$\simeq I_{CBO} (R_B + R_E)$

DEN/ MAKE $\frac{R_B + R_E}{\beta} << R_E$

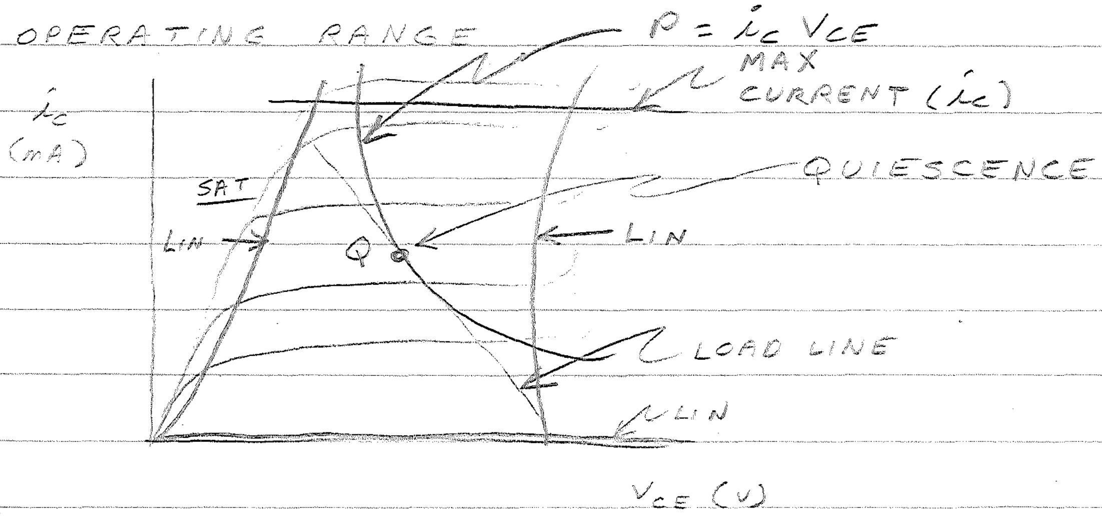
$R_B + R_E << \beta R_E$

$R_B << (\beta - 1) R_E \approx \beta R_E$

$R_B / R_E << \beta$

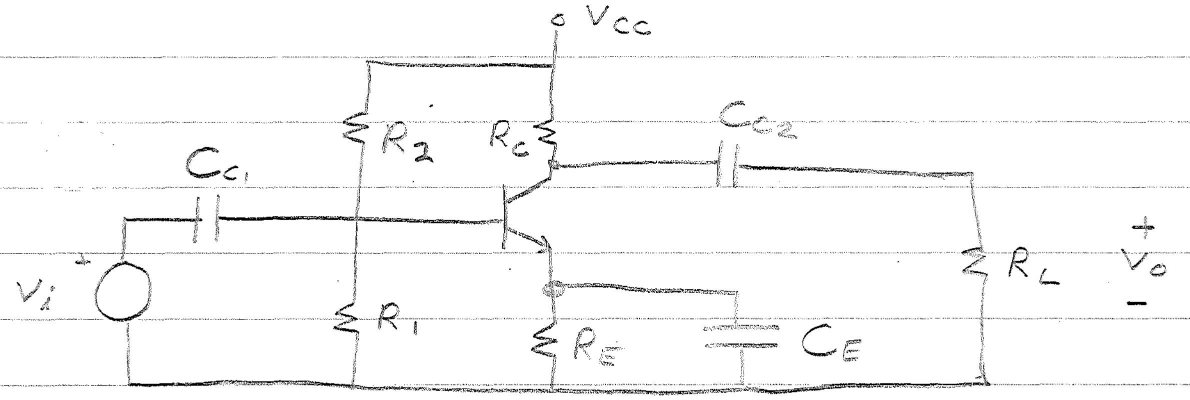
## POWER BJT AMPLIFIERS

OPERATING RANGE



IS BEST TO PLACE Q ON PWR HYPERBOLA AND HAVE LOAD LINE TANGENT

A LARGE SCALE AMP

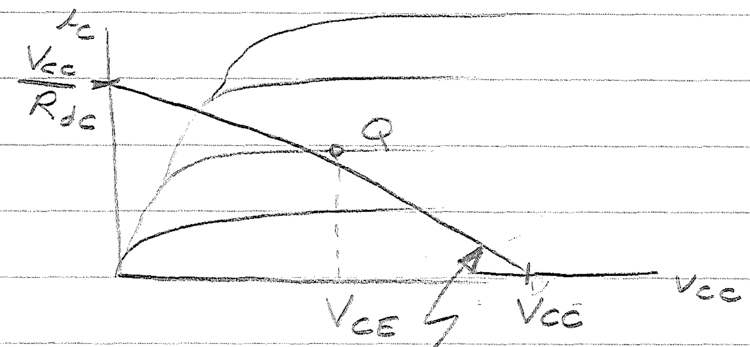


PURPOSE OF C'S IS TO ALLOW SIGNAL & BIAS VOLTAGES TO OPERATE INDEPENDENTLY

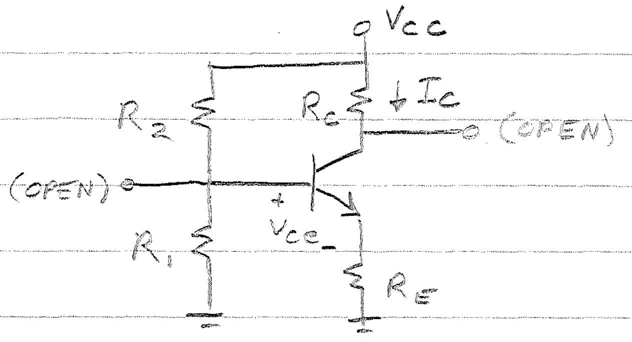
RULE OF THUMB: ASSUME C'S "LARGE"

DC $\Rightarrow$ C'S ARE "OPEN CIRCUITS"

AC (SIGNAL) $\Rightarrow$ C'S ARE SHORT



D.C. LOAD LINE:



(D-C CIRCUIT)

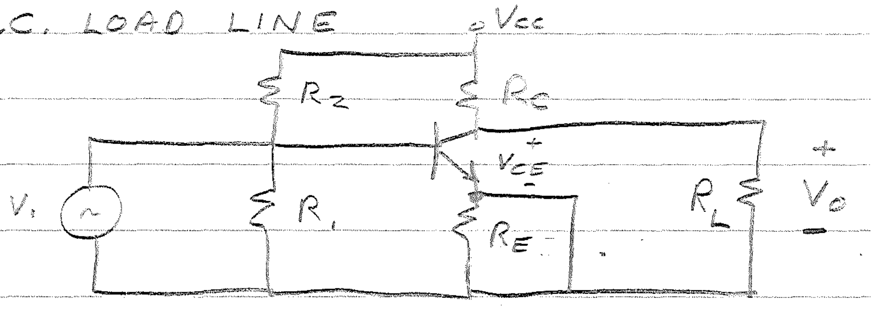
~~TYPICALLY ASSUME $R_1 \approx R_2$~~

~~$\Rightarrow V_{CC} \approx 2 V_{CE}$~~

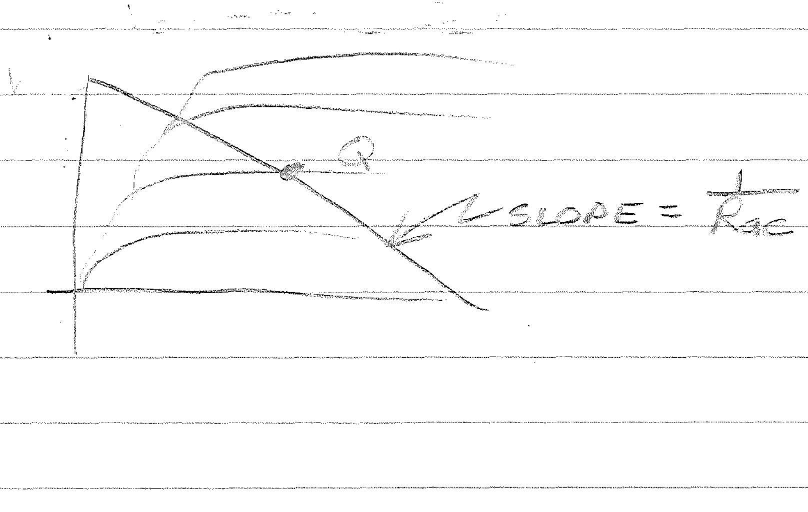
(KVL) $V_{CE} = V_{CC} - I_C(R_C + R_E)$

$= V_{CC} - I_C R_{dc}$

A.C. LOAD LINE



ANY a-c SIGNAL ON $R_C$ MUST ALSO APPEAR ACCROSS $R_L$ (OR, IN a.c. UPPER END OF $R_C$ IS GROUND) $\Rightarrow R_{ac} = R_C \,//\, R_L = \frac{R_C R_L}{R_C + R_L}$



TRANSDUCER: TRANSFORMS ONE TYPE OF INFORMATION
OR SIGNAL INTO ANOTHER TYPE

INSTRUMENTATION TRANSDUCERS (p. 722 SMITH)
(3.5, 3.15 VINES)

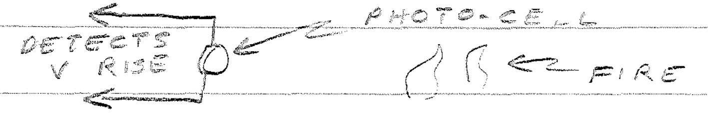
{ANALOG vs DIGITAL
ACTIVE vs PASSIVE}

EXAMPLES: (1) FIRE/HEAT DETECTORS (DIGITAL)

FIRE STAGES:

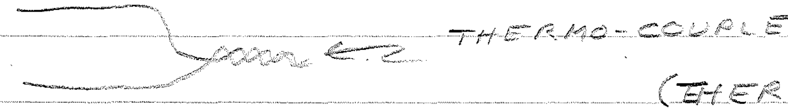
INCIPIENT, SMOKE, , FLAME, HEAT

FLAME



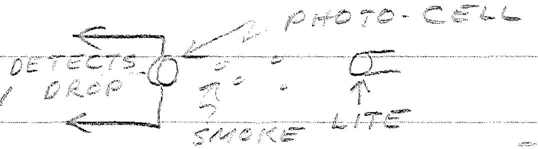
(ELECTRO-OPTIC)
OR
PHOTO-ELECTRIC

HEAT



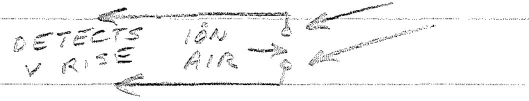
(THERMO ELECTRIC)

SMOKE



(ELECRO-OPTIC)

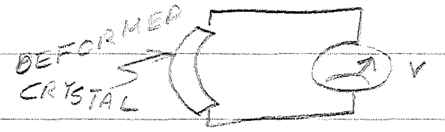
INCIPIENT



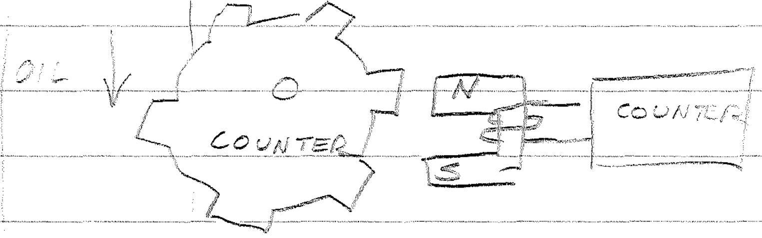
(ELECTRIC)

OTHER TRANSDUCER MEDIUMS

PIEZOELECTRIC

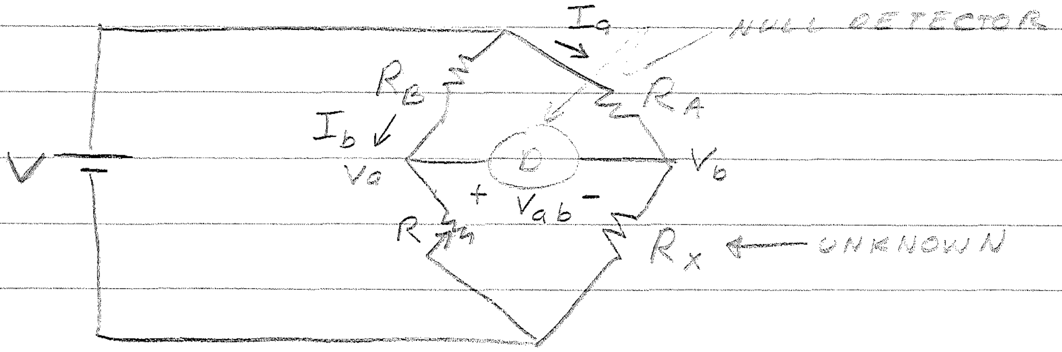


ELECROMAGNETIC



RESISTANCE DETECTION (STRAIN GAGES)

WHEATSTONE BRIDGE (MEASURES VERY ACCORATE R)



FOR BALANCE, $V_{ab} = 0$

$\Rightarrow V_a = V_b$

THUS $R_B I_B = I_A R_A$

$R I_B = I_A R_x$

DIVIDIDING $\Longrightarrow R_x = R \; {}^{R_A}/_{R_b}$ (NOTE: V IND)

EXAMPLE

$R_A = 500\,\Omega$
$R_B = 5000\,\Omega$ } 0.01% RESISTORS

R TUNED TO $270.4\,\Omega \pm 0.02\%$

$$R_X = R\,\frac{R_A}{R_B} = 270.4\,(1 \pm 0.0002)\,\frac{500\,(1 \pm 0.0001)}{5000\,(1 \pm 0.0001)}$$

FOR SMALL $X \overset{\sim}{\mp} Y$

$$\frac{1}{1 \pm X} \cong 1 \mp X$$

$$(1+X)(1+Y) = 1 + X + Y + XY \approx 1 + XY$$

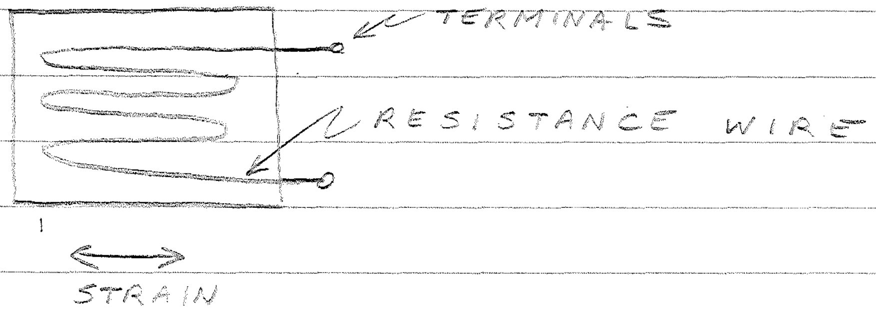
$\Rightarrow$ UPPER WORST CASE ERROR

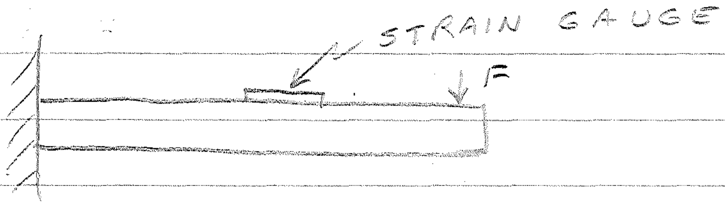
$$(1 \pm 0.0002)(1 \pm 0.0001)(1 \pm 0.0001)$$

$$\approx 1 + 0.0004$$

$$\Rightarrow R_x = 27.04\,(1 \pm 0.0004)\,\Omega$$

STRAIN GAUGE TRANSDUCER





$$\frac{\Delta R}{R} = K_G \epsilon = K_G \frac{\Delta l}{l} \quad ; K_G \approx \begin{cases} 2\text{-}4 \text{ (METALLIC} \\ \text{SEVERAL HUNDRED (SEMICOND)} \end{cases}$$

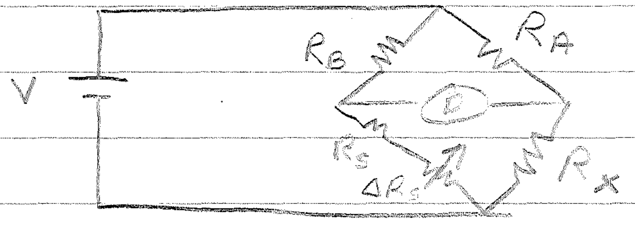
$K_G$ = GAUGE FACTOR

$\epsilon$ = STRAIN

$R, l$ = INITIAL RESISTANCE & LENGTH OF GAUGE

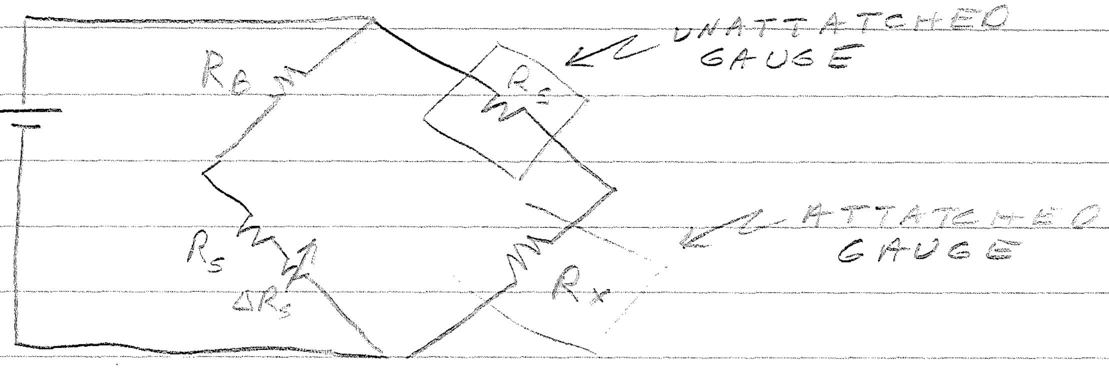
$R+\Delta R$, $l+\Delta l$ => $R$ & $l$ AFTER STRAIN

$\Delta R$ IS SMALL. MEASURE IT WITH WHEATSTONE BRIDGE.



PROBLEM: $R_x$ CHANGES WITH TEMP

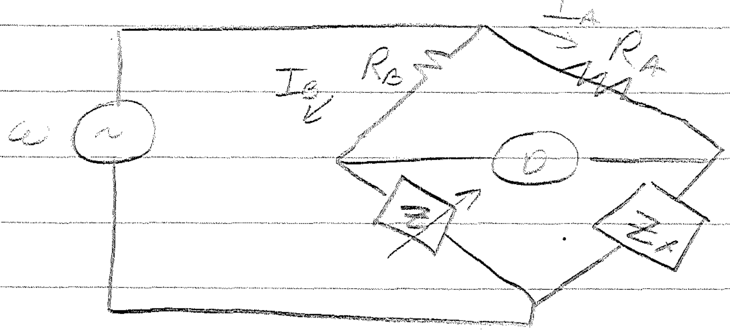
SOLN: USE AN IDENTICAL STRAIN GAUGE UNATTATCHED TO BEAM AT SAME TEMP FOR A REFERENCE



$$\Rightarrow R_x = (R_S + \Delta R_S)\frac{R_S}{R_B}$$

SINCE $R_x$ IS PROP TO $R_S$, CHANGES IN $R_x$ WILL BE COUNTERACTED BY CHANGES IN $R_S$.

## IMPEDANCE BRIDGE



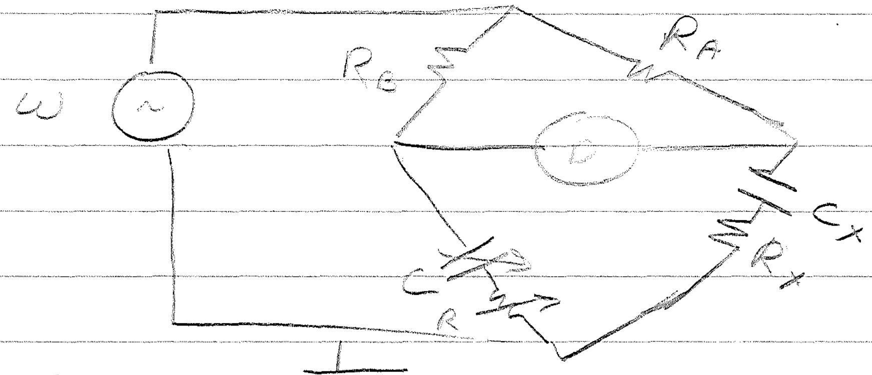
AT BALANCE: $R_B I_B = I_A R_A$

$$Z \; I_B = I_A Z_x$$

THUS

$$Z_x = Z \; {}^{R_A}/_{R_B}$$

EX:



$$Z_x = R_x + \frac{1}{j\omega C_x}$$

$$Z = R + \frac{1}{j\omega C}$$

$$\Rightarrow R_x - \frac{j}{\omega C_x} = \left(R - \frac{j}{\omega C}\right) {}^{R_A}/_{R_B}$$

$$= \frac{RR_A}{R_B} - j \; {}^{R_A}/_{R_B\omega C}$$

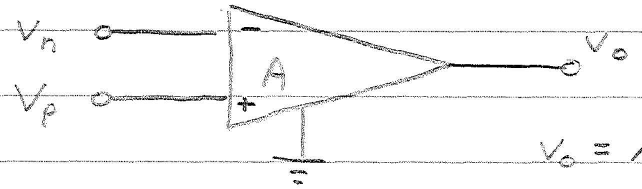
EQUATING REAL & IMAG. PARTS

$$R_x = {}^{RR_A}/_{R_B}$$

$$C_x = C \; {}^{R_B}/_{R_A}$$

OPERATIONAL (OP) AMPS

IDEAL:



$V_o = A(V_p - V_n)$

$A = \infty$ (ie, VERY LARGE)

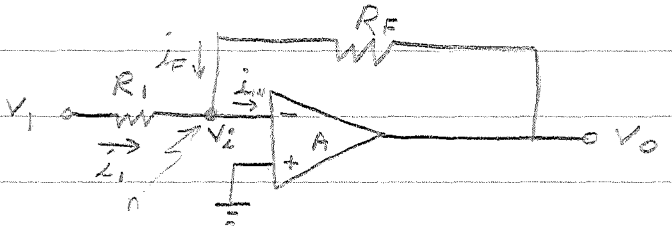
$V_n = V_p \Rightarrow V_o = 0$

BANDWIDTH $\rightarrow \infty$ (ie, DOES NOT DEPEND ON $\omega$)

INPUT $Z = \infty$

OUTPUT $Z = 0$

BASIC INVERTING CIRCUIT:



SINCE $Z_{IN} = \infty$, $i_{IN} = 0$

$$i_F = \frac{V_o - V_i}{R_F} \cancel{=} \cancel{\frac{V_o - V_o/A}{R_F}} = \cancel{\frac{V_o}{R_F}\left(1 - \frac{1}{A}\right)}$$

$$i_1 = \frac{V_1 - V_i}{R_1} \cancel{=} \cancel{\frac{1}{R_F}\left(V_1 - \frac{V_o}{A}\right)}$$

K'S NODE LAW

$$i_F + i_1 = 0 = \frac{V_1 - V_i}{R_1} + \frac{V_o - V_i}{R_F} \quad ①$$

$$V_i = V_o/A \quad ②$$

SUBSTITUTE ② INTO ① AND SOLVE FOR $V_o$:

$$V_o = \frac{-V_1\,(R_F/R_1)}{1 - (1/A)(1 + R_F/R_1)}$$

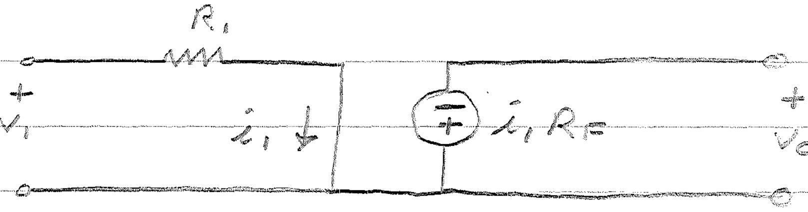
FOR $A = \infty$

$$V_o = -\frac{R_F}{R_1} V_1$$

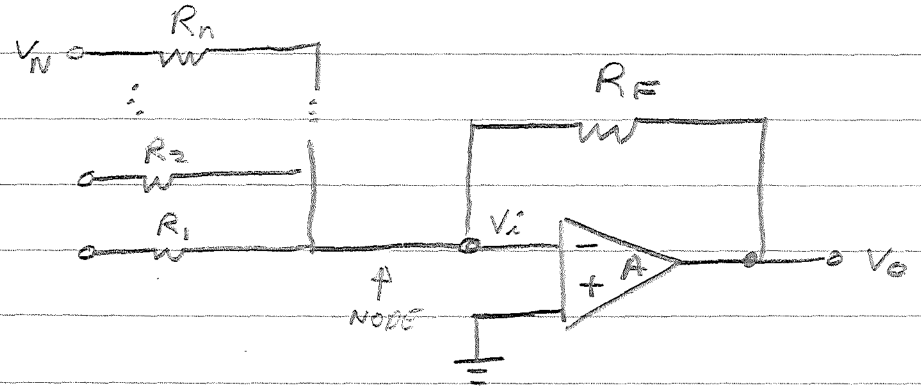
THIS IS AMPLIFIER WITH VOLTAGE GAIN $-\frac{R_F}{R_1}$.

- $i_1 \cong \frac{v_1}{R}$ (IND. OF OUTPUT) (SINCE $\frac{v_i}{A} \sim 0$)
- AMPLIFICATION, $A_F = {}^{-R_F}/R_1$ IS IND. OF OP AMP GAIN, A. (OPERATION NOT AFFECTED BY TEMP. CHANGE)

BASIC INVERTING CIRCUIT EQUIVALENT CIRCUIT



## SUMMING CIRCUIT



SUMMING CURRENTS AT NODE:

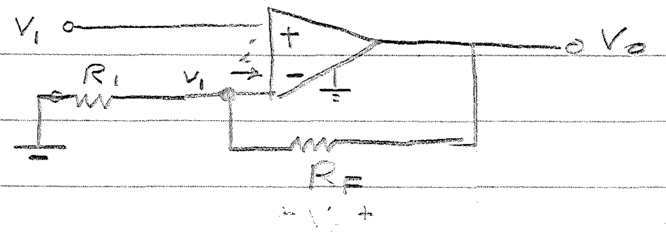
$$\frac{V_1 - V_i}{R_1} + \frac{V_2 - V_i}{R_2} + \dots + \frac{V_n - V_i}{R_1} = \frac{V_i - V_o}{R_F}$$

$$V_i = V_o/A \Rightarrow V_i << 1$$

$$\Rightarrow \frac{V_1}{R_1} + \frac{V_2}{R_2} + \dots + V_n/R_1 = {}^{-}V_o/R_F$$

OUTPUT IS "WEIGHTED" SUM OF INPUT VOLTAGES.

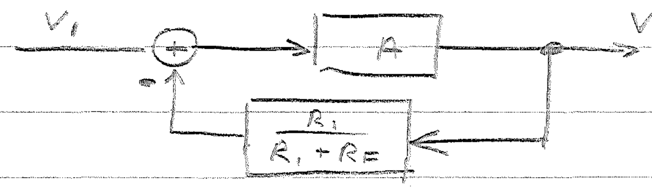
BASIC NON-INVERTING CIRCUIT



SINCE $i$ IS SMALL,

$R_F$ & $R_1$ FORM V DIVIDER WITH $V_o$

$$\Rightarrow V_1 = \frac{R_1}{R_1+R_F} V_o$$



(FEEDBACK) GAIN IS

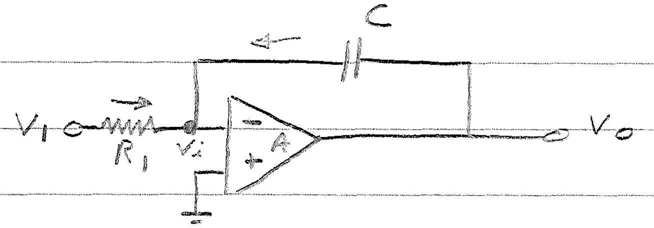
$$A_F = \frac{G}{1+GH} = \frac{A}{1 + AR_1/(R_1+R_F)}$$

$$= \frac{1}{1/A + R_1/R_1+R_F}$$

FOR LARGE A

$$A_F = \frac{R_1+R_F}{R_1}$$

## INTEGRATOR



SINCE $V_o = -A v_i$, $|V_i| << |V_o|$. $\Rightarrow V_i \approx 0$

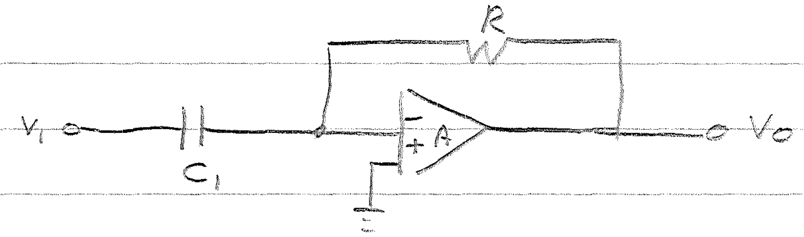
A CURRENTS AT $V_i$:

$$\frac{(V_1 - V_i)}{R_1} + C \frac{d(V_o - V_i)}{dt}$$

$$\approx \frac{V_1}{R_1} + C \frac{dV_o}{dt} = 0$$

$$\Rightarrow V_o = -\frac{1}{R_1 C} \int V_1(t)\, dt$$

## DIFFERENTIATOR



AGAIN, $V_i \approx 0$

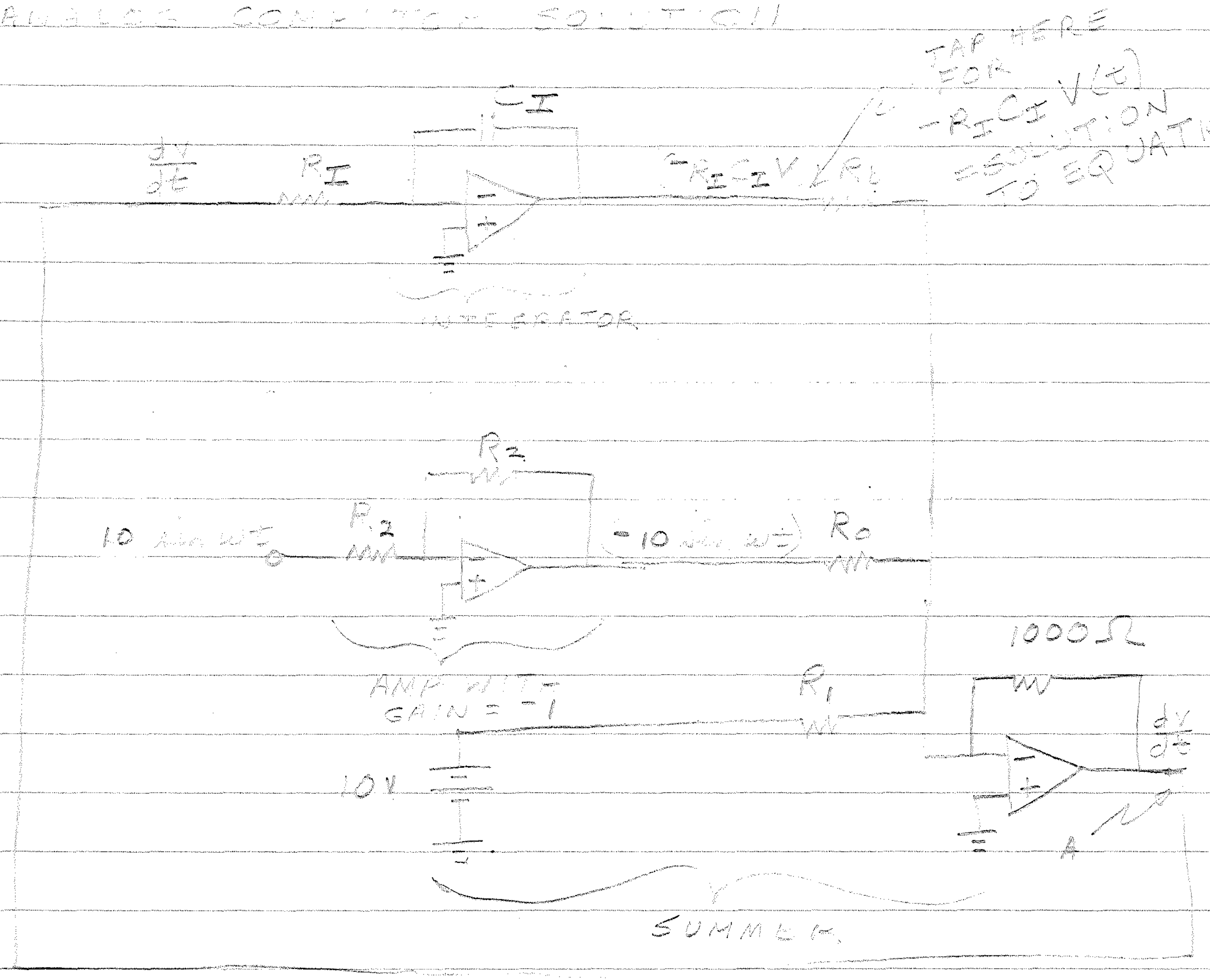
$$C_1 \frac{dV_1}{dt} + \frac{V_o}{R} = 0 \Rightarrow V_1 = -R_1 C_1 \frac{dV_1}{dt}$$

SOLUTION OF DIFFERENTIAL EQUATIONS

CONSIDER:

$$\frac{dv}{dt} = \quad bv(t) - V_1 + V_0 \sin \omega t$$

ANALOG COMPUTER SOLUTION



AT "A"

$$\frac{\frac{dv}{dt}}{1000} = \frac{+R_IC_I}{R_b} V(t) - \frac{10}{R_1} + \frac{10}{R_0} \sin \omega t$$

THUS, CHOOSE $b = (R_IC_I/R_b)1000$

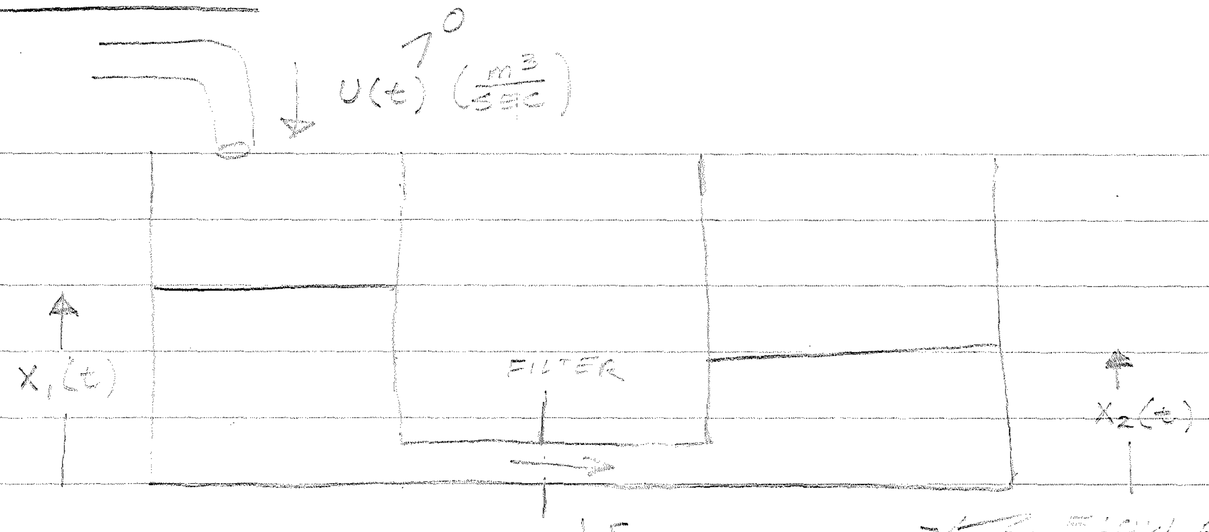
$V_1 = (\frac{10}{R_1})(1000)$

$V_0 = (10/R_0)1000$

NOTE: WE MUST

ASSUME $b$, $V_1$, & $V_0$ ARE POSITIVE

## MODELING



$$q = d\left[x_1(t) - x_2(t)\right] \lessgtr 0 \leftarrow \text{FLOW RATE} \left(\frac{m^3}{sec}\right)$$

ASSUME BOTH TANKS HAVE CROSS SECTIONAL AREAS $\alpha$. FLOW IS PROPORTIONAL TO HEAD DIFFERENCE

$$\underbrace{\alpha \dot{x}_1}_{\text{VOLUME RATE OF CHANGE}} = -q(t) + u(t)$$

$$= -d\left[x_1 - x_2\right] + u$$

OR

$$\dot{x}_1 = \frac{-d}{\alpha} x_1 + \frac{d}{\alpha} x_2 + \frac{1}{\alpha} u$$

ALSO

$$\alpha \dot{x}_2 = q = dx_1 - dx_2$$

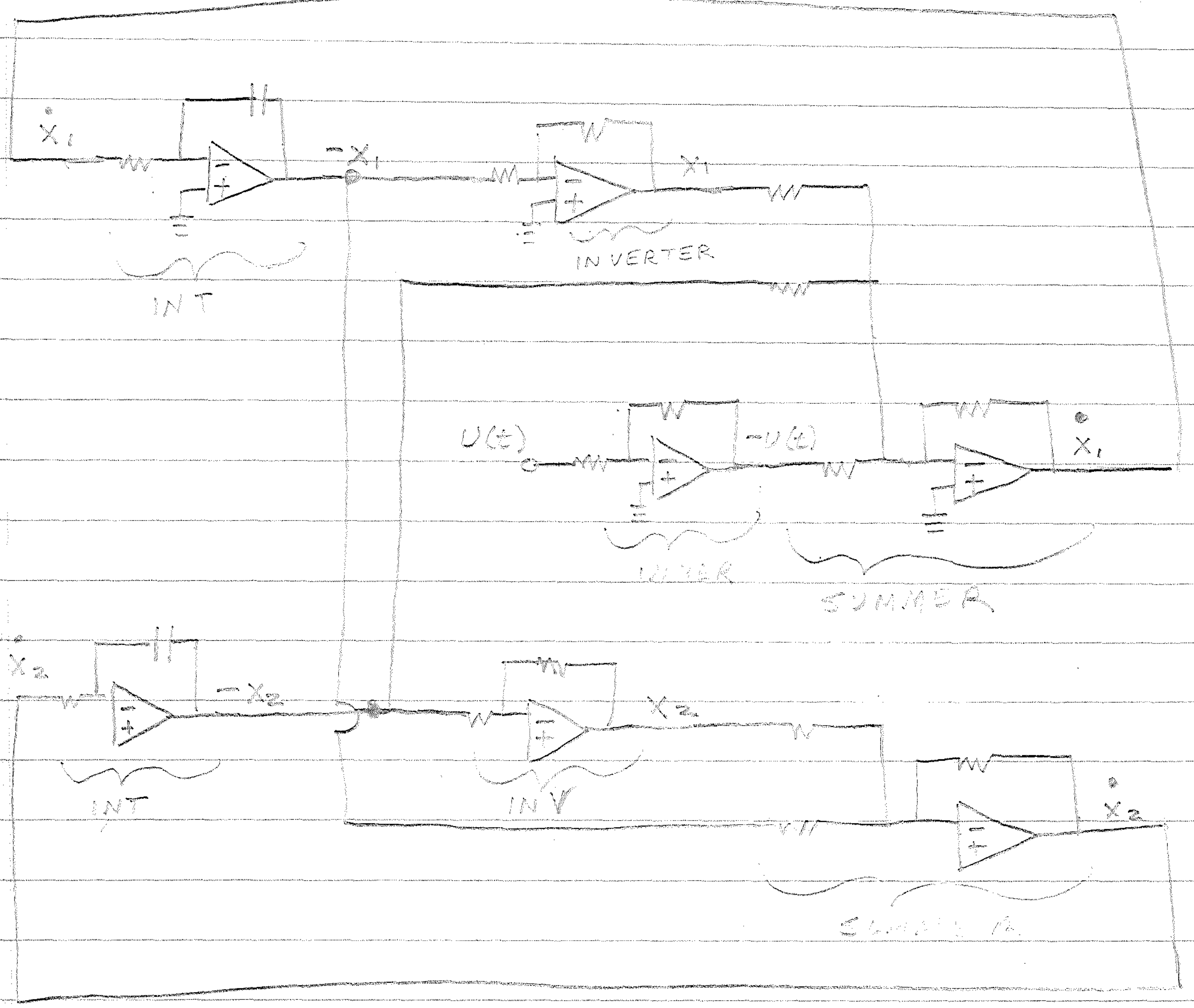
OR

$$\dot{x}_2 = \frac{d}{\alpha} x_1 - \frac{d}{\alpha} x_2$$

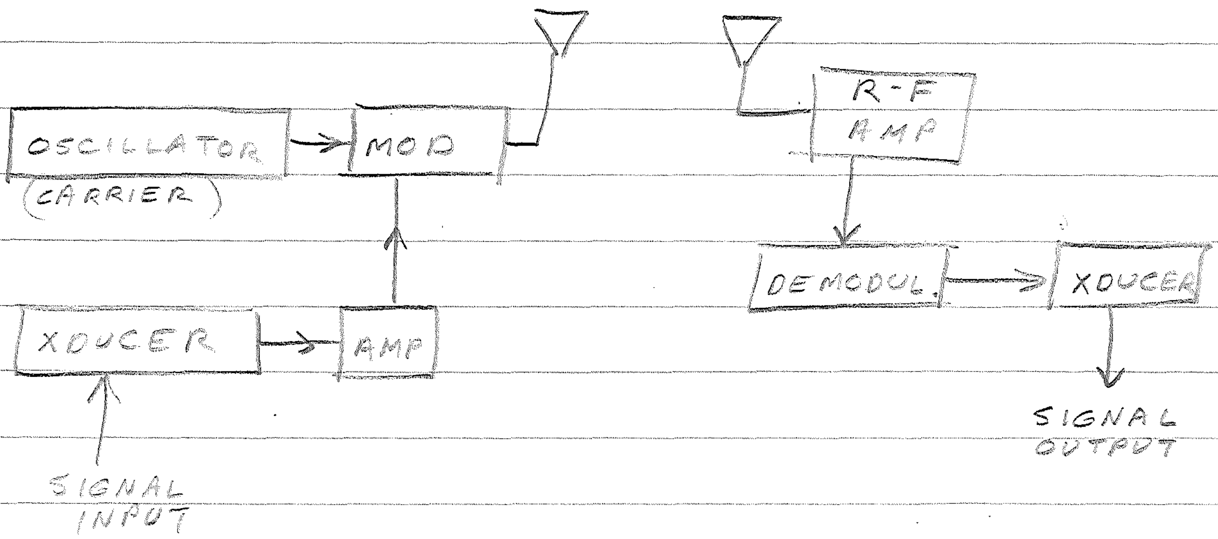
"STATE" EQUATIONS:

$$\dot{x}_1 = -\frac{d}{\alpha} x_1 + \frac{d}{\alpha} x_2 + \frac{1}{\alpha} u$$
$$\dot{x}_2 = \frac{d}{\alpha} x_1 - \frac{d}{\alpha} x_2$$

# ANALOG COMPUTOR SOLUTION

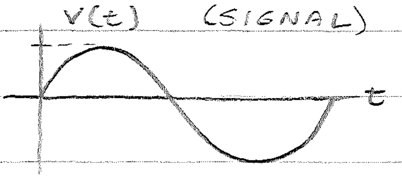


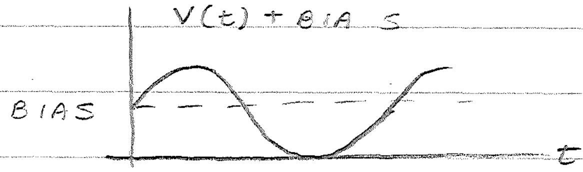
# BASIC COMMUNICATION SYSTEM

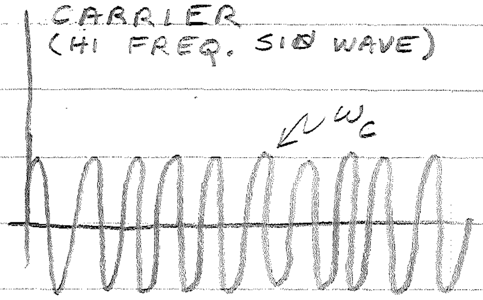


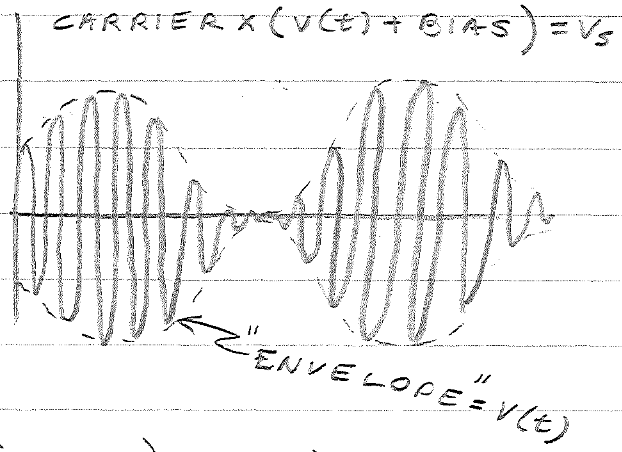
# MODULATION

## - AMPLITUDE MODULATION (p. 441)



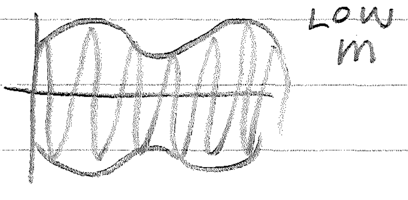


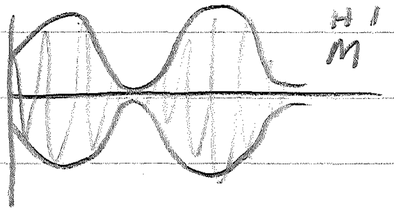




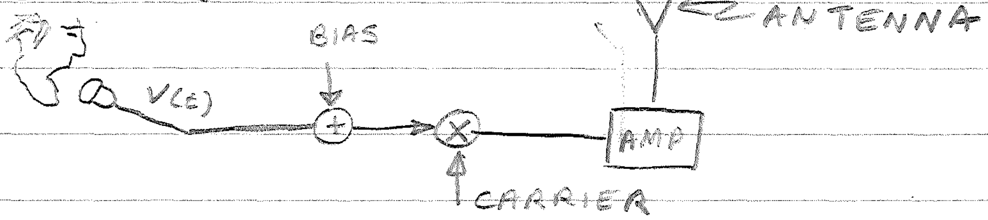
$$V_s(t) = (1 + m \sin \omega_M t)(V_c \underset{\substack{\uparrow \\ \text{CARRIER}}}{\sin} \omega_c t) \; ; \; \omega_c >> \omega_m$$

m = DEGREE OF MODULATION ; $0 < m < 1$





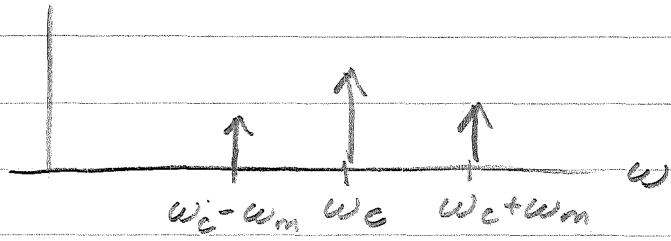
SENDING



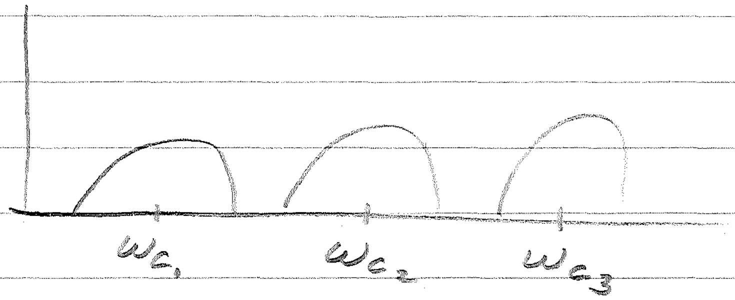
$$V_s(t) = V_c \sin \omega_c t + m V_c \sin \omega_m t \sin \omega_c t$$
$$= V_c \sin \omega_c t + \frac{m V_c}{2} \cos(\omega_m - \omega_c) t$$
$$- \frac{m V_c}{2} \cos(\omega_m + \omega_c)$$

FREQ. IN SIGNAL:

$\omega_c$ , $\omega_c - \omega_m$ , $\omega_c + \omega_m$

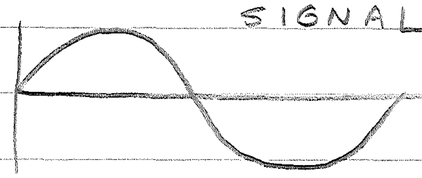


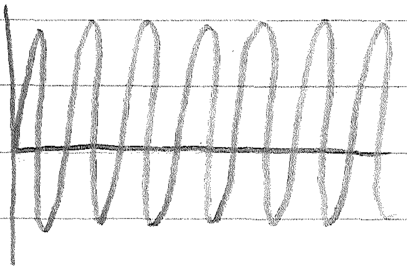
BY PLACING DIFFERENT SIGNALS ON DIFFERENT CARRIERS, WE CAN HAVE A NUMBER OF STATIONS:

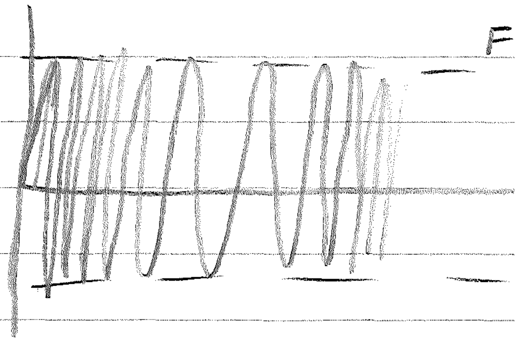


SPECTRUM CONTROLED BY FCC.

## FREQUENCY MODULATION:

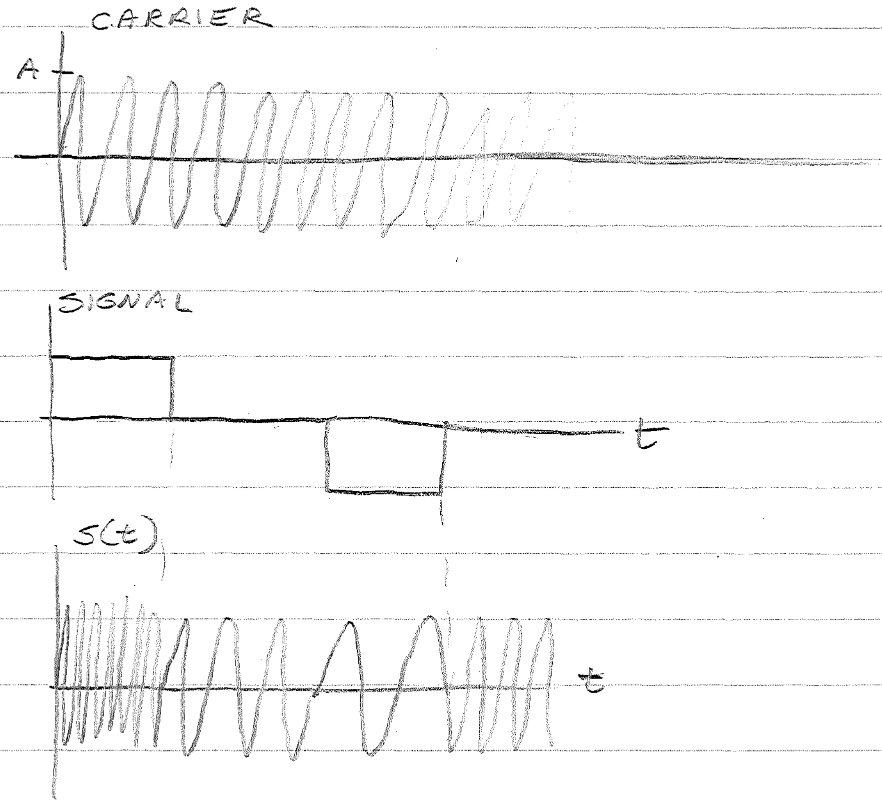

SIGNAL


CARRIER


FM SIGNAL

FM. ANALYTICALLY:

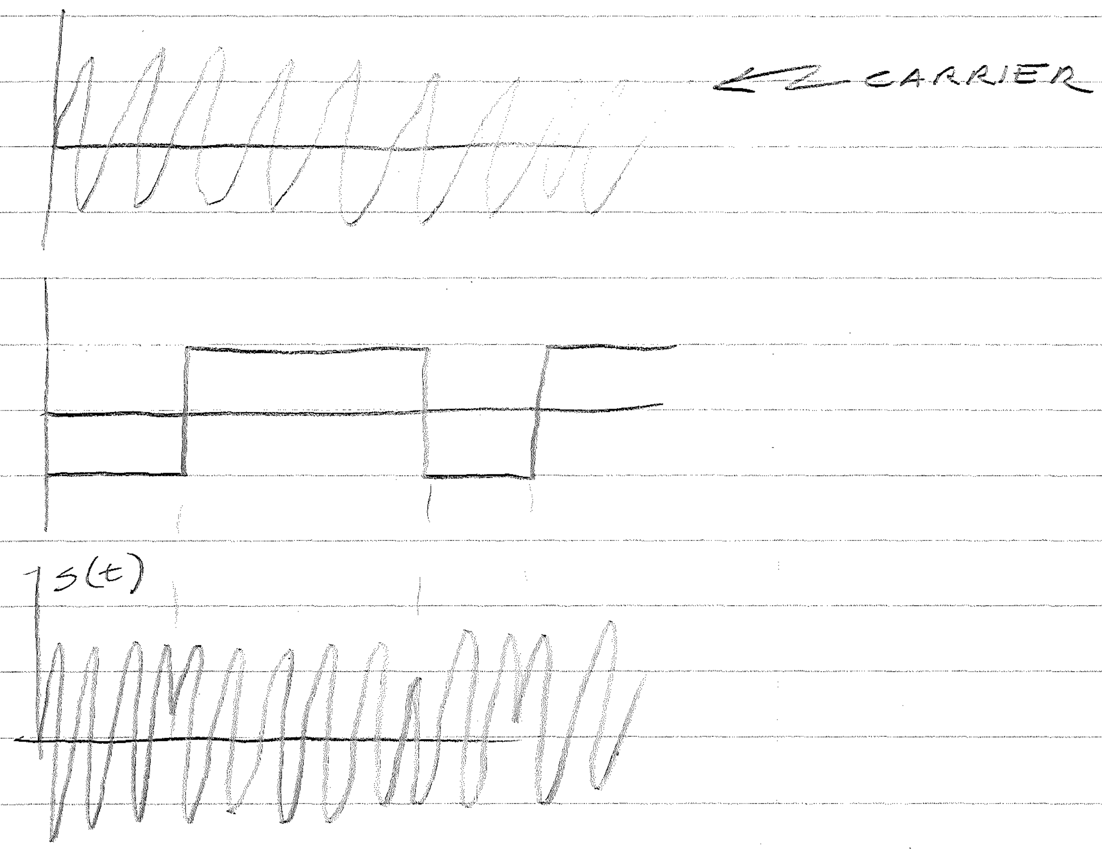
$$s(t) = A\cos\Big[\underset{\text{CARRIER}}{\omega_c}t + \underset{\substack{\text{MAX}\\\text{ANGULAR}\\\text{DEVIATION}}}{\Delta\omega}\int^{t}\underset{\text{SIGNAL}}{m(t)}\,dt\Big]$$



PHASE MODULATION:

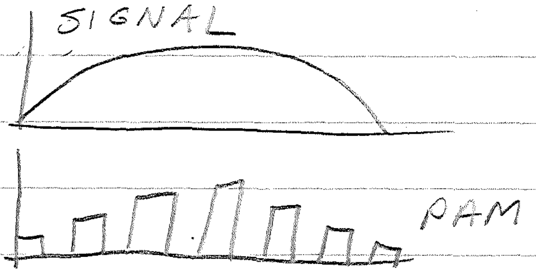
$$s(t) = A\cos(\underset{\substack{\uparrow\\ \text{CARRIER}}}{\omega_c t} + \underset{\substack{\uparrow\\ \text{MAX}\\ \text{PHASE}\\ \text{DEVIATION}}}{\phi_m}\ \underset{\substack{\uparrow\\ \text{SIGNAL}}}{m(t)})$$

FOR $m(t)$ BINARY, WE GET 180° SHIFT

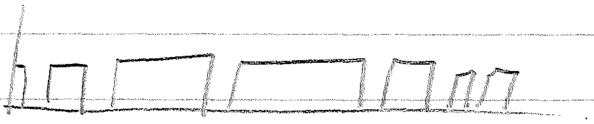


# PULSE MOD

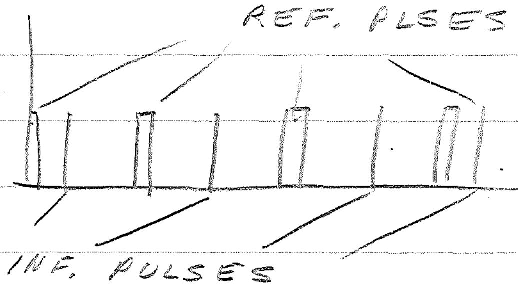
PULSE AMPLITUDE MODULATION: (PAM)



PULSE DURATION MODULATION: (PDM)



PULSE POSITION MOD (PPM)



SEP BETWEEN REF
PULSES $ INF
PULSES ~ AMPLITUDE

PULSE CODE MODULATION (~~A~~
(NEED BINARY #'S, LATER)

MULTIPLEXING: PLACING TWO OR MORE SIGNALS OVER THE SAME CHANNEL

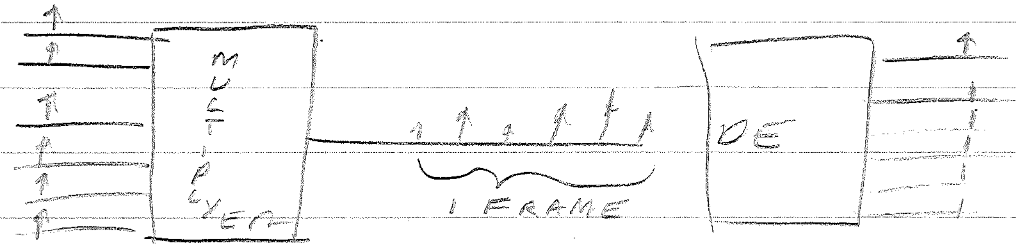
1. (PULSE) TIME DIVISION (TDM)

SAMPLING THM ⇒ SAMPLING RATE = 2× HI FREQ

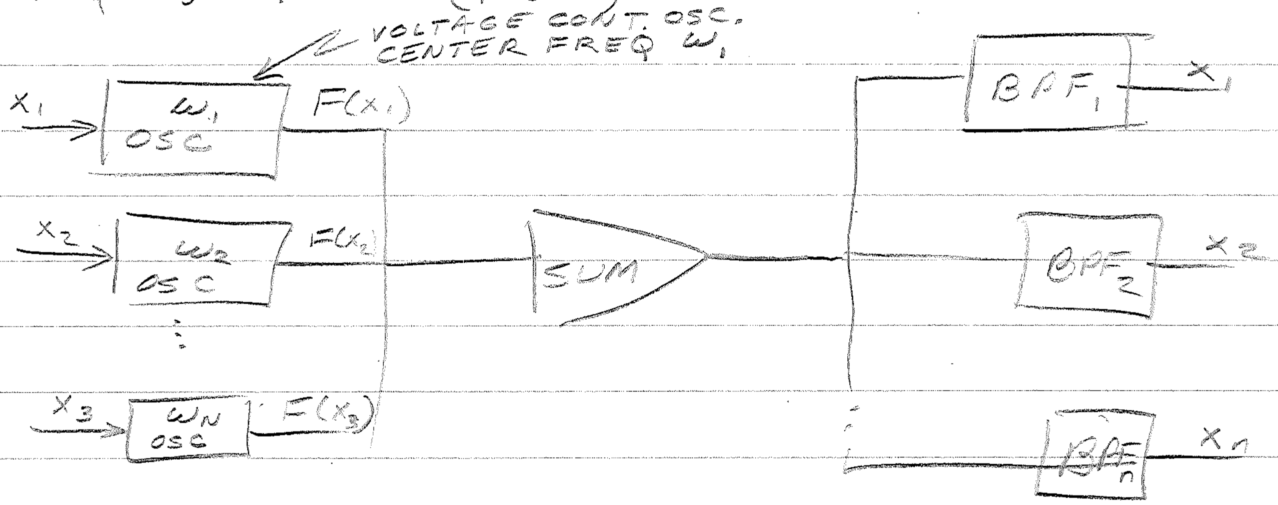
VOICE → 3000 HZ

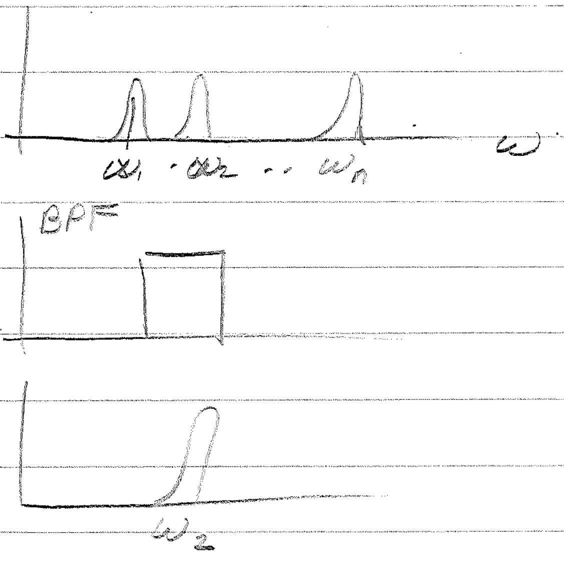
⇒ 6000 SAMP/SEC

CHANNEL CAP = 0 TO 36,000 HZ (SA/SEC)



2. FREQ DIV. M (FDM)





TEST #2

5 PROBLEMS, 20 PTS EACH

OPEN BOOK & OPEN NOTE

1. (20) 10 T-F QUESTIONS

(PENALTY FOR GUESSING)

-2 OR -3 OR +2

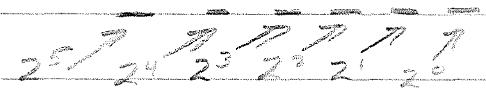
2. (20) MODULATION & MULTIPLEXING (SAMPLING THEM)

3. (20) TRANSISTOR CIRCUITRY & BIASING

4. (20) BRIDGES: WHEATSTONE, MAXWELL, BALANCING, TOLERENCES, STRAIN GAUGES, ETC.

5. (20) OP AMP

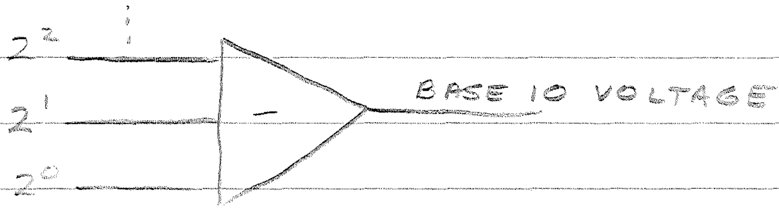
BINARY NUMBERS (VINES - CHAPT. 5)



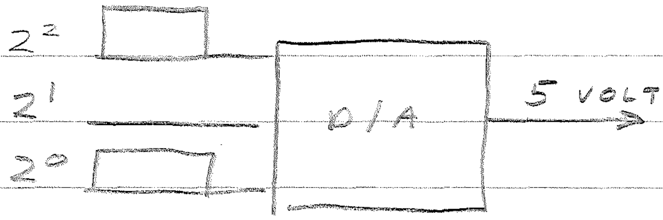
$(110)_2 = (1 \times 2^2 + 1 \times 2^1 + 0 \times 2^0) = 6$

$(1001)_2 = (1 \times 2^3 + 0 \times 2^2 + 0 \times 2 + 1 \times 2^0) = 9$

BINARY D/A CONVERTER



EXAMPLE:

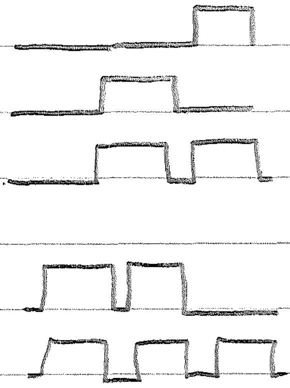


5 VOLTS = $(1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0)$ VOLTS

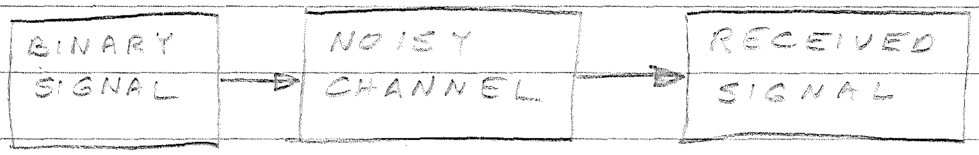
A/D CONVERTOR DOES OPPOSITE.

PULSE CODE EXAMPLE: 3 BITS LONG

| | |
|---|---|
| 1 | 001 |
| 2 | 010 |
| 3 | 011 |
| ⋮ | |
| 6 | 110 |
| 7 | 111 |



# CODING

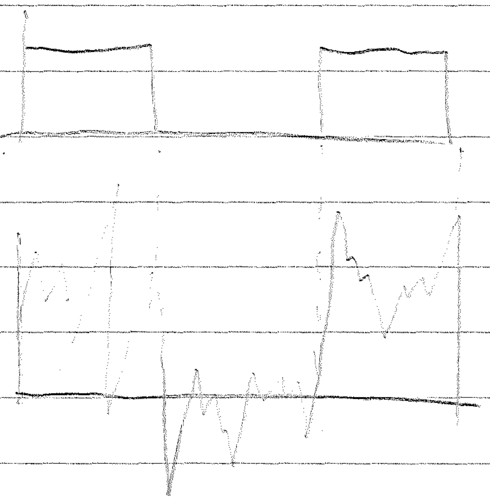


CODING CAN BE USED TO MINIMIZE EFFECTS OF ACCEPTING ERRONEOUS SIGNALS.

EX

SIGNAL SENT

RECEIVED:



6

## EXAMPLE

3 LETTERS IN A 3 BIT STRING. (a, b, c)

WHICH CODE IS BETTER?

#1: $a = 001$
$b = 010$
$c = 011$

#2: $a = 001$
$b = 010$
$c = 100$

CODE #2 IS BETTER FOR NOISE IMUNITY.

DISTANCE BETWEEN CODES

#1

$$\begin{array}{rccc} & S & D & D \\ a = & 0 & 0 & 1 \\ b = & 0 & 1 & 0 \\ \hline \end{array}$$

$\sqrt{0+1^2+1^2} = 2$ $\quad d(a,b) = \sqrt{2} = d(b,a)$

$b = 010$
$\underline{c = 011}$
$\sqrt{0+0+1^2} = 1$ $\quad d(b,c) = 1$

$a \ 001$
$c \ \underline{011}$
$\sqrt{0+1^2+0} \Rightarrow d(a,c) = 1$

#2 $\quad d(a,b) = d(a,c) = d(b,c) = \sqrt{2}$

IN GENERAL, THE GREATER THE DISTANCE, THE BETTER THE NOISE IMMUNITY.

~~CAN WE IMPROVE ON CODE~~?

~~YES: a = 1, 1, 1~~
~~b = 0, 0, 1~~

## ERROR CORRECTING CODES

1. ZERO ERROR CORRECTING: a, b, c

a = 01

b = 10

c = 11

WE RECEIVE, VIA NOISY CHANNEL, 11

(1) 11 = c SENT

(2) 01 = a SENT WITH SINGLE BIT ERROR

(3) 10 = b " " " " "

2. ~~SINGLE BIT~~ SINGLE BIT ERROR DETECTION CODE: a b c

a = 0101

b = 1010

c = 1111

CHANGING 1 BIT IN a, b, OR c DOES NOT RESULT IN ANOTHER LETTER.

EX. RECEIVE 0111 ⟸ MISTAKE!

MISTAKE ON a ⟹ 0101 ⟹ 0111

OR c ⟹ 1111 ⟹ 0111

~~OR b 2 BIT ERROR (LESS PROBABLE)~~

RECEIVE 0110 ⟹ 2 BIT ERROR ON EITHER a, b, OR c.

3. ERROR DETECTION & CORRECTION CODE

a = 000000

b = 000110

c = 111111

RECEIVE 111101 ⟹ c PROBABLY SENT

" 000100 ⟹ b PROBABLY SENT

THIS IS "SINGLE BIT" ERROR CORRECTING CODE. FOR EXAMPLE

RECEIVE 010111 = DOUBLE BIT ERROR IN BOTH b AND c. FOR DOUBLE BIT NOT CORRECTING CODE.

TO INCREASE GOODNESS OF XMISSION

1. SLOWER MORE ACCURATE TRANSMISSION
(ERROR DET. & CORR. CODES ARE
LONGER IN DURATION)

2. HIGHER CHANNEL CAPACITY
(ie, LARGER CHANNEL BANDWIDTH
⟹ MORE PULSES PER SECOND)

3. CLEVER (OPTIMAL) CODING SCHEMES
TO MAKE THE MOST FROM WHAT
WE HAVE.

A "CLEVER" CODING SCHEME (SINGLE BIT ERROR DETECTION)

FOUR BIT WORDS _ _ _ _

USE A FIFTH BIT FOR "PARITY CHECK"

EVEN PARITY CHECK:

$0 \Rightarrow$ # OF 1's IN WORD IS EVEN

$1 \Rightarrow$ # OF 0's IN WORD IS ODD

| i | WORD | PARITY |
|---|---|---|
| 0 | 0000 | 0 |
| 1 | 0001 | 1 |
| 2 | 0010 | 1 |
| 3 | 0011 | 0 |
| 4 | 0100 | 1 |
| 5 | 0101 | 0 |
| 6 | 0110 | 0 |
| 7 | 0111 | 1 |
| 8 | 1000 | 1 |
| ⋮ | | |

EX: RECEIVE

01111 ⇐ THIS IS PROB RIGHT

01011 ⇐ THIS IS **WRONG!**

EX: RECEIVE:

00001

MOST PROBABLE SENT: (DISTANCE = 1)

00000

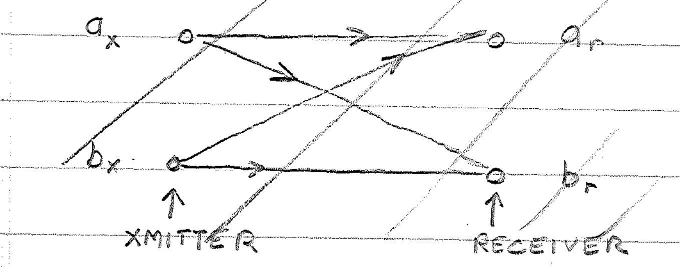
00011

00101

01001

10001

A SIMPLE BINARY CHANNEL



A LITTLE PROBABILITY

$P_r[E]$ = PROBABILITY OF THE OCCURANCE OF AN EVENT E OCCURING

JOINT PROB:

$P_r[E,F] = P_r$[EVENTS E <u>AND</u> F OCCUR]

CONDITIONAL PROB

$P_r[E/F] = P_r$[E OCCURS <u>GIVEN</u> F HAS OCCURED]

RELATION:

$P_r[E,F] = P_r[E/F]\,P_r[F]$

EX: ROLL OF TWO DIE: EVENT IS OUTCOME

$P_R[E=2] = 1/6$

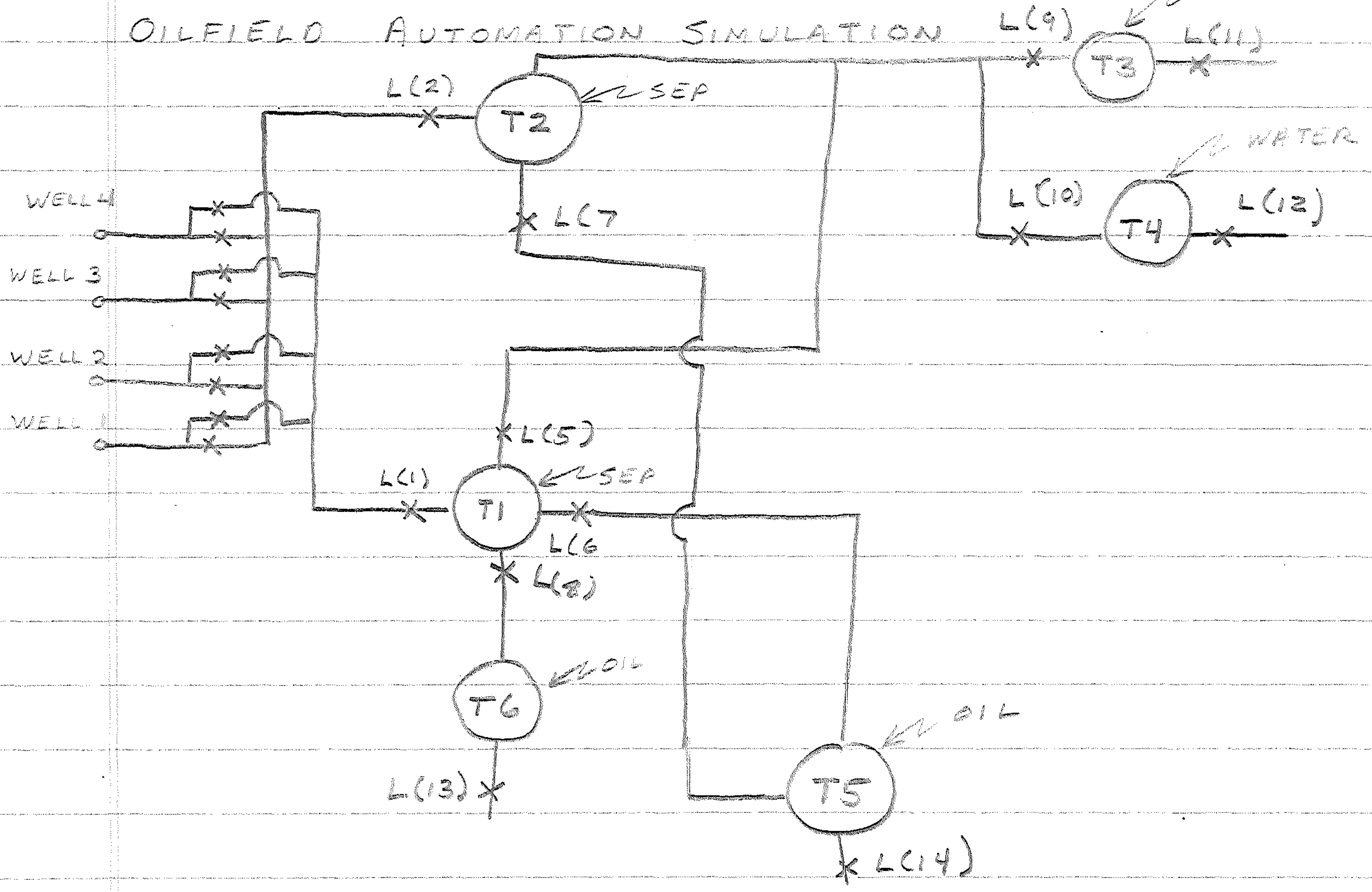
② $P_r$[E EVEN] = 1/2

$P_r$[E EVEN <u>AND</u> E = 3] = 0

① $P_r$[E EVEN <u>AND</u> E = 2] = $\frac{1}{6}$

$P_r$[E = 2 <u>GIVEN</u> E EVEN] = $\frac{①}{②} = \frac{1/6}{1/2} =$

# OILFIELD AUTOMATION SIMULATION



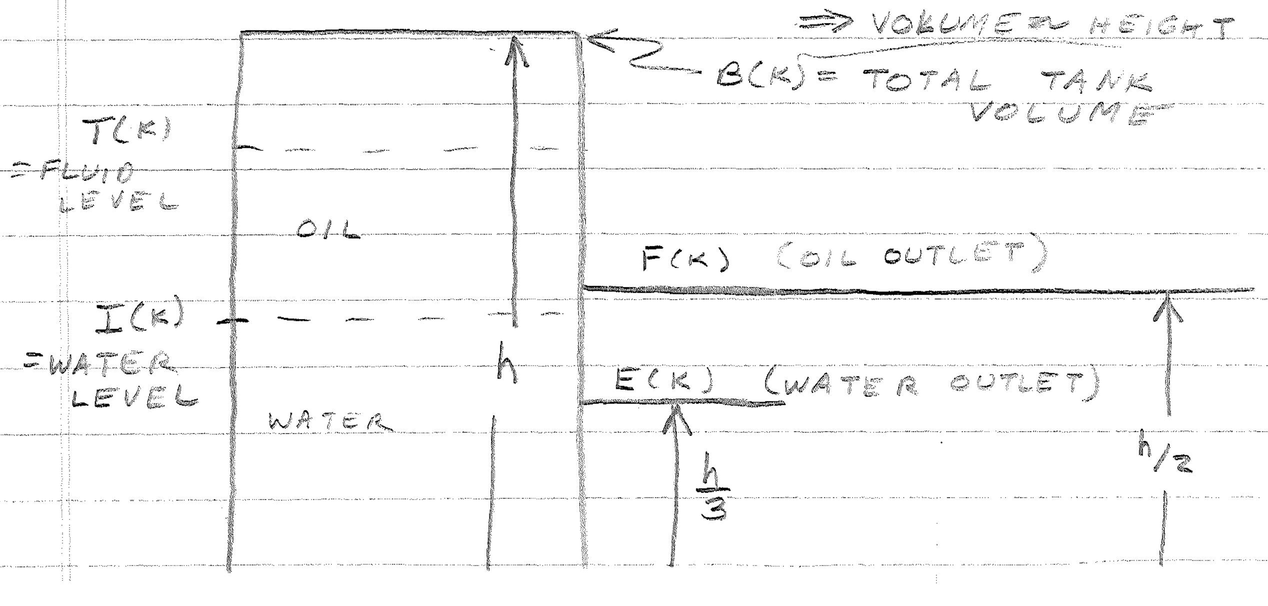
FOUR WELLS

TWO SEPARATORS: T(1) $ T(2)

TWO OIL HOLDING TANKS: T(5) $ T(6)

TWO WATER HOLDING TANKS: T(3) $ T(4)

CONTROL SYSTEM CENTERS AROUND SEPARATORS
(CYLYNDRICAL TANKS)
⇒ VOLUME ∝ HEIGHT

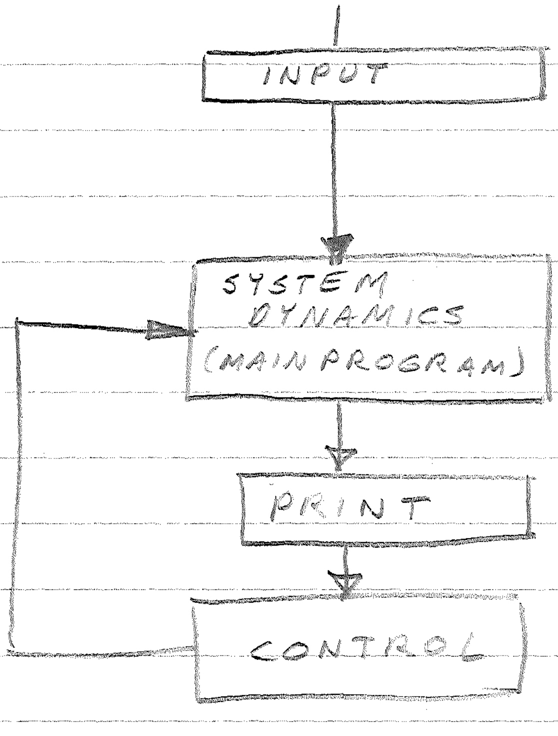


AUTOMATIC CONTROL

MAIN PROGRAM: WILL RECORD ACCUMULATIONS INTO THE TANKS ACCORDING TO WELLS AND VALUE SETTINGS

CONTROL PROGRAM PURPOSE: TO CONTROL THE FLOWS INTO AND OUT OF THE TANKS VIA THE VALVES.

FLOW:



INPUT (INITIALIZATION)

1. ARE WELLS (1-4) ON OR OFF?
2. WHICH WELL FEEDS WHICH
   SEPARATOR (T1 OR T2)
3. WHAT ARE PUMP CAPACITIES (GPM) ;
4. STATUS OF L(9) & L(10) (ON OR OFF)
5. SAMPLE TIME (MINUTES)
   (OR, HOW LONG DO YOU WANT THINGS TO
   RUN BEFORE CHECKING)

PROGRAM TERMINATIONS: (BAD)

1. OVERFLOW
2. WATER GETS INTO OIL
3. OIL GETS INTO WATER

REVIEW

$Pr[E]$

$Pr[E,F] = Pr[E \underline{\text{ AND }} F] = Pr[F,E]$

$Pr[E/F] = Pr[E \underline{\text{ GIVEN }} F]$

RELATION: $Pr[E,F] = Pr[E/F]\,Pr[F]$

ALSO $Pr[E \underline{\text{ OR }} F] = Pr[E] + Pr[F]$ IF E & F CAN'T ~~OCCUR~~ BOTH OCCUR AT SAME TIME

EX DRAW FROM A DECK OF CARDS

E = FIRST DRAW

F = SECOND DRAW

$Pr[E = \text{JACK}] = 4/52 \quad \left(\dfrac{4 \text{ JACKS}}{52 \text{ CARDS}}\right)$

$Pr[F = \text{JACK} / E = \text{JACK}] = \dfrac{3}{51} \quad \left(\dfrac{3 \text{ JACKS}}{51 \text{ CARDS}}\right)$

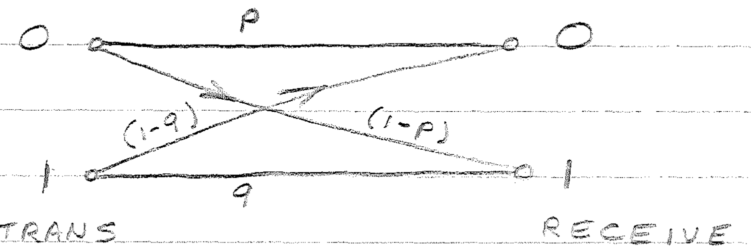
SINCE $Pr[F,E] = Pr[F/E]\,Pr[E]$

$Pr[F = \text{JACK} \underline{\text{ AND }} E = \text{JACK}]$

$$= Pr[F = \text{JACK} / E = \text{JACK}]\,Pr[E = \text{JACK}]$$

$$= \frac{3}{51} \times \frac{4}{52} = \frac{1}{17} \times \frac{1}{13} = \frac{1}{221}$$

BINARY CHANNEL



$p = P_r[0 \text{ RECEIVED} / 0 \text{ TRANSMITTED}] = P_r[0_R / 0_T]$

$1 - p = P_r[1_R / 0_T]$

NOTE: $P_r[0_R/0_T] + P_r[1_R/0_T] = 1$ SINCE, GIVEN 0 IS TRANSMITTED, SOMETHING MUST BE RECEIVED. (HARD DECISION)

$q = P_r[1_R | 1_T]$

$1 - q = P_r[0_R | 1_T]$

EX: GIVEN 1001 WAS XMITTED, WHAT IS PROB. 1001 IS RECEIVED?

$P_r[1001]$ RECEIVED $= qppq = q^2p^2$

-WHAT IS $P_r$ 1110 IS RECEIVED?

$$q(1-p)(1-p)p = pq(1-p)^2$$

FOR $p = 0.9$ & $q = 0.8$:

$p_r[(1001)_R/(1001)_T] = (0.9)^2(0.8)^2 = 51.84\%$

$p_r[(1110)_R/(1001)_T] = (0.8)(0.9)(0.1)^2 = 0.72\%$

"APRIORI" OR BEFOREHAND KNOWLEDGE

$p_0 = P_r[0_t]$

$= P_r[\text{A ZERO IS TRANSMITTED}]$

$p_1 = P_r[1_t]$

$= P_r[\text{A 1 IS TRANSMITTED}]$

EX: WHAT IS $P_r[0_R]$?

$P_r[0_R] = P_r[(1_t \text{ AND } 0_R) \text{ OR } (0_t \text{ AND } 0_R)]$

$= P_r[1_t, 0_R] + P_r[0_t, 0_R)$

$= P_r[0_R / I_t] P[1_t] + P_r[0_R / 0_t] P[0_t]$

$= (1-q) p_1 + p p_0$

FOR $p_1 = P_r[1_t] = p_0 = P_r[0_t] = \frac{1}{2}$

$p = 0.9 \qquad q = 0.8$

$P_r[0_R] = [(0.2) + (0.9)]\frac{1}{2} = 55\%$

EX: WHAT IS $P_r[\text{ERROR}]$?

$P_r[E] = P_R[(0_t, 1_R] \text{ OR } (1_t, 0_R)]$

$= P_r(0_t, 1_R) + P_r[1_t, 0_R)$

$= P_r[1_R / 0_t] P_r[0_t] + P_r[0_R / 1_t] P_r[1_t]$

$= (1-p) p_0 + (1-q) p_1$

FOR $p_0 = p_1 = \frac{1}{2}$

$p = 0.9 \qquad q = 0.8$

$P_r[E] = \frac{1}{2}(0.2 + 0.1) = 15\%$

$P[\text{NO ERROR}] + P[E] = 1$

$\Rightarrow P[\text{NO ERROR}] = 1 - [(1-p)p_0 + (1-q)p_1]$

CONSIDER "BINARY SYMMETRIC CHANNEL"

$p = q$

ASSUME $p_0 = q_0 = \frac{1}{2}$

~~WHA~~

FOR A SINGLE BIT, WHAT IS $P_r[\text{ERROR}]$

$$P_r[\text{ERROR}] = P_r[0_t, 1_r] + P_r[1_t, 0_R)$$

$$= P_r[1_r / 0_t] P(0_t) + P_r[0_R / 1_t] P_r[1_t]$$

$$= \frac{1}{2}[(1-p) + \frac{1}{2}(1-q)]$$

$$= (1-p)$$

WHAT IS $P_r[\text{NO ERROR}]$

$$P[\text{NO ERROR}] = 1 - P[\text{ERROR}] = p$$

CONSIDER $n$ BIT WORD

$$P_r[\text{NO ERROR}] = p^n$$

WHAT IS $P_r[1 \text{ BIT ERROR}]$?

$$= (1-p) p \cdots p$$

$$+ p(1-p) \cdots p$$

OR

$$+ \ldots + p \cdot p \cdots (1-p)$$

$$= n (1-p) p^{n-1}$$

IN GENERAL, $p_r(k \text{ ERRORS})$ $(0 \leq k \leq n)$

$$= \binom{n}{k} (1-p)^k p^{n-k}$$

$$\binom{n}{k} = \frac{n!}{k!(n-k)!}$$

NOTE:

$$\sum_{k=0}^{n} P_r[k \text{ ERRORS}] = \sum_{k=1}^{n} \binom{n}{k} (1-p)^k p^{n-k}$$

$$= [(1-p) + p]^n = 1$$

BOOLEAN OPERATIONS (READ CHAPT. 4 IN VINES)

"AND" FUNCTION

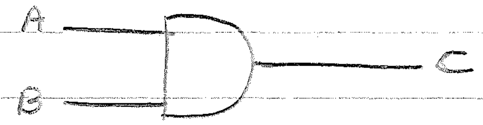
0 - "FALSE"
1 - "TRUE"

| A | · | B | = | C |
|---|---|---|---|---|
| 0 |  | 0 |  | 0 |
| 0 |  | 1 |  | 0 |
| 1 |  | 0 |  | 0 |
| 1 |  | 1 |  | 1 |

⇐ TRUTH TABLE

BOTH A & B MUST BE TRUE FOR C TO BE TRUE.

AND GATE:

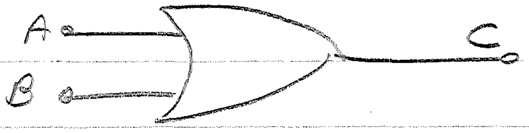


"OR" FUNCTION (INCLUSIVE)

| A | + | B | = | C |
|---|---|---|---|---|
| 0 |  | 0 |  | 0 |
| 0 |  | 1 |  | 1 |
| 1 |  | 0 |  | 1 |
| 1 |  | 1 |  | 1 |

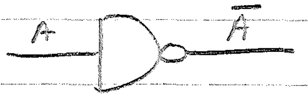
EITHER A OR B MUST BE TRUE FOR C TO BE TRUE

OR GATE



"NOT" FUNCTION

| A | $\overline{A}$ |
|---|---|
| 0 | 1 |
| 1 | 0 |



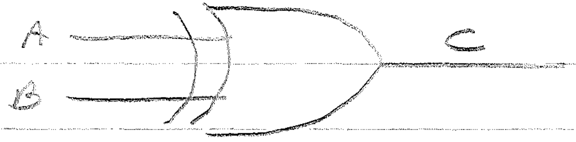
"NOT" GATE

EXCLUSIVE OR

INCLUSIVE: BAD HEALTH MAY RESULT FROM INFECTION OR POOR DIET
(ONE OR THE OTHER IS POSSIBLE)

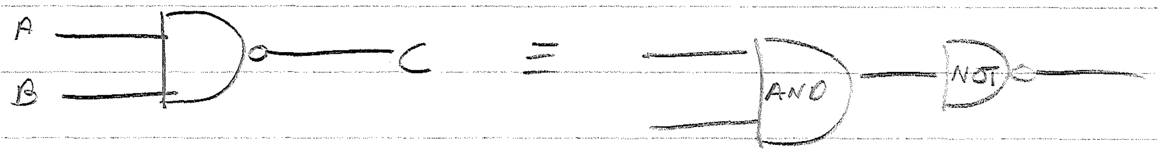
EXCLUSIVE: I WILL GRADUATE EITHER IN MAY OR IN DEC.
(ONLY ONE IS POSSIBLE)

| A $\oplus$ | B = | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

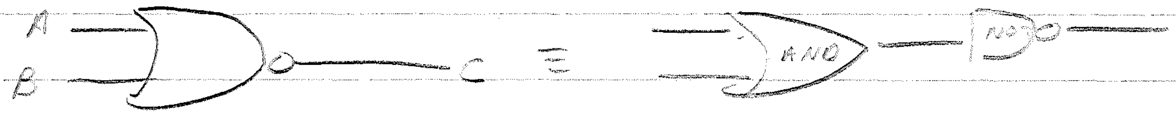


← EX. OR GATE

"NAND" GATE



"NOR" GATE



DE MORGAN'S THEM:

$\overline{AB} = \overline{A} + \overline{B}$

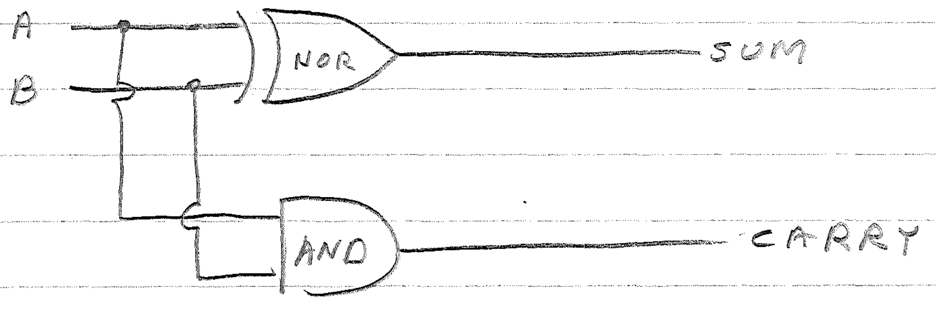
$\overline{A+B} = \overline{A}\ \overline{B}$

<u>Ex:</u> HALF ADDER

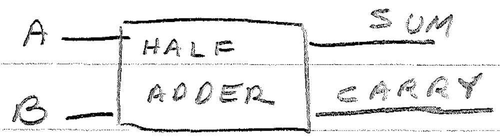
| A | B | SUM =A⊕B | CARRY |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 1 |

A⊕B IS EXCLUSIVE OR ~~AND~~ GATE

CARRY IS "AND" GATE



OR

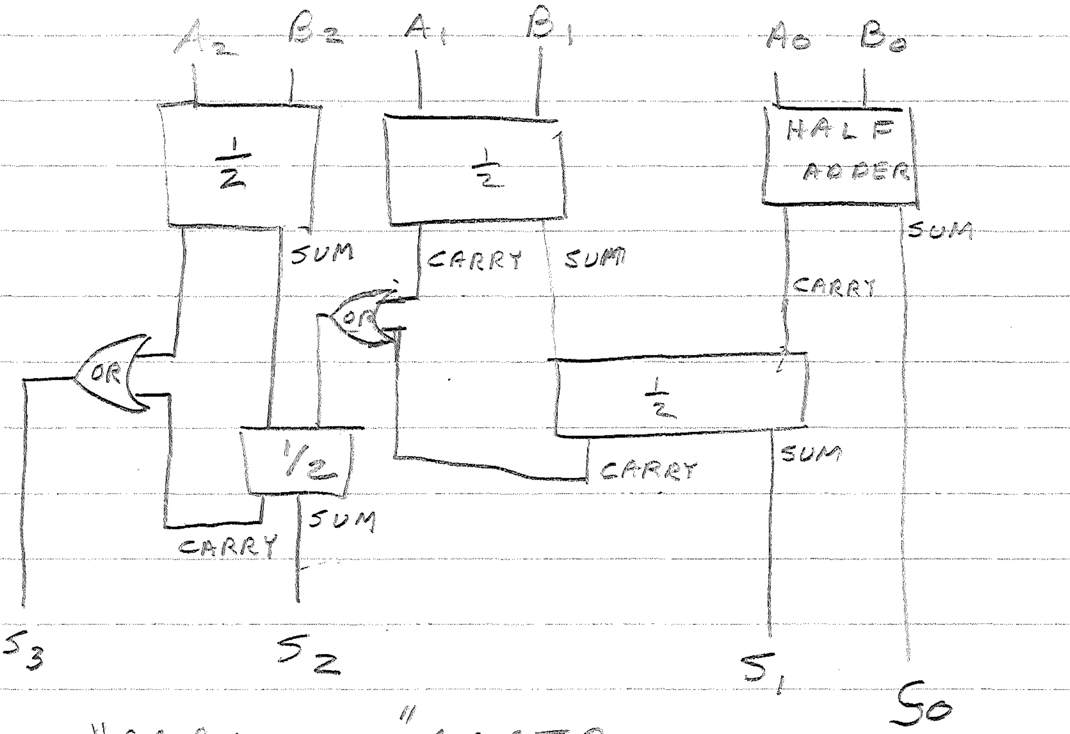


CAN COMBINE HALF ADDERS TO FULL ADDER. EX:

$$\begin{array}{r} \overset{\cdot}{0}\,1\,0 \\ 1\,0\,1 \\ \hline 1\,0\,0\,1 \end{array}$$

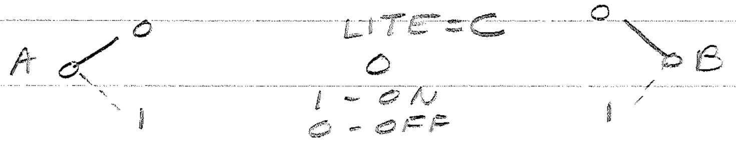
$010 = A_2 A_1 A_0$

$111 = B_2 B_1 B_0$ $\quad 1001 = S_3 S_2 S_1 S_0$



"PARALLEL" ADDER

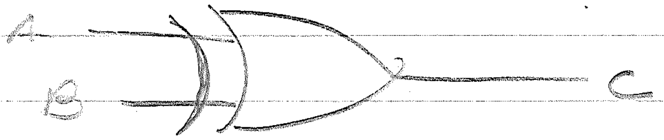
EX: TWO WAY LIGHT SWITCH



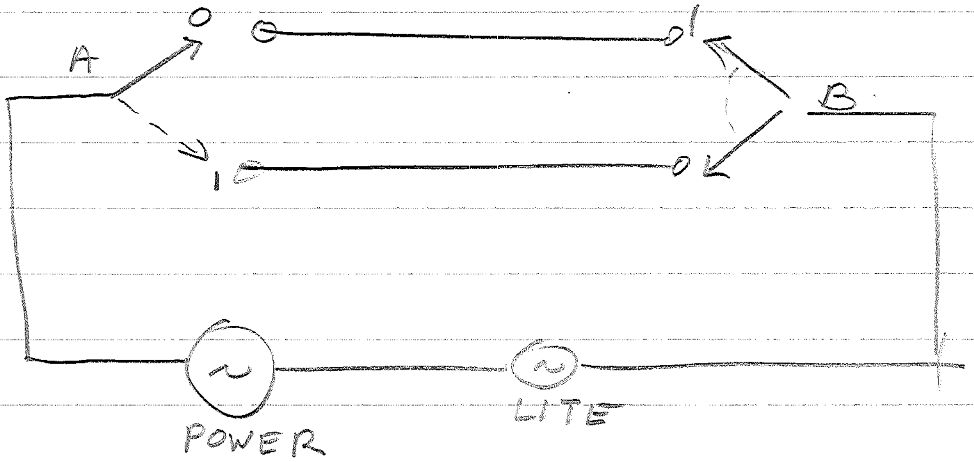
ASSUME A = B = 0 ⇒ LITE OFF

| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

THIS IS "EXCLUSIVE" OR

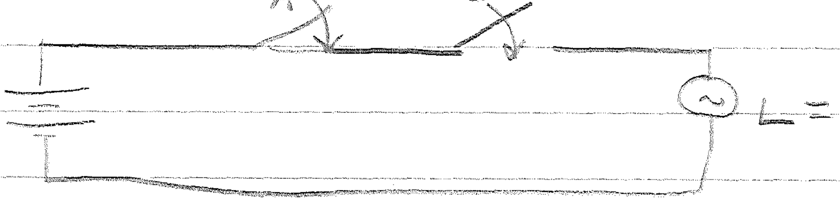


WITH SWITCHES:



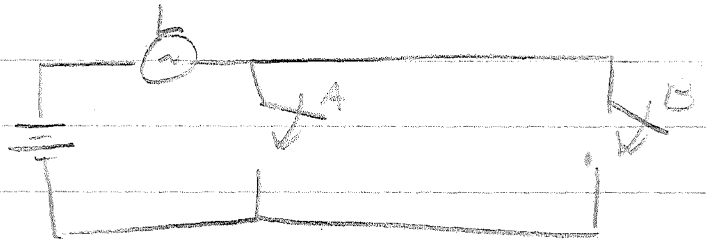
SWITCHES:

"AND"



$L = AB$

"OR"

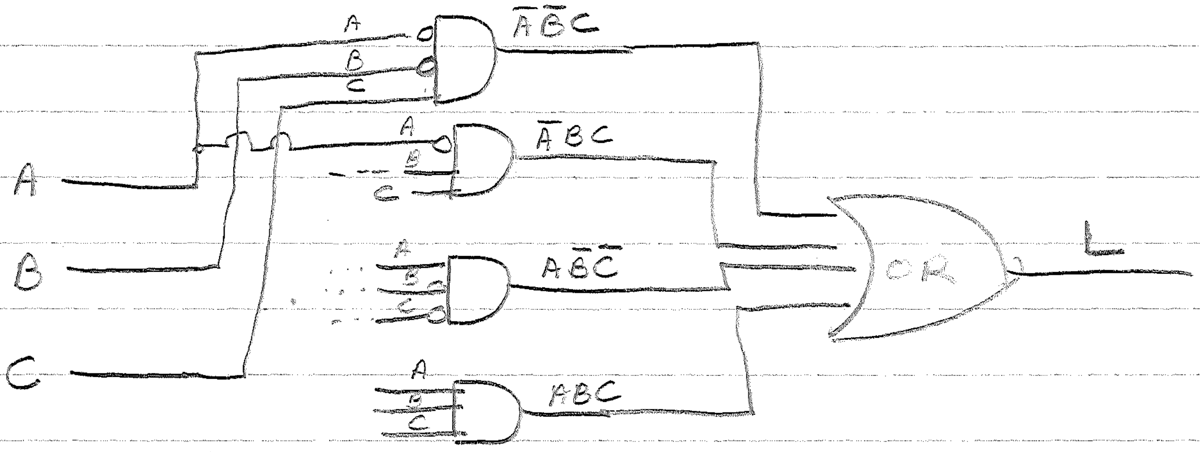


$L = A + B$

**EX:** THREE WAY LITE

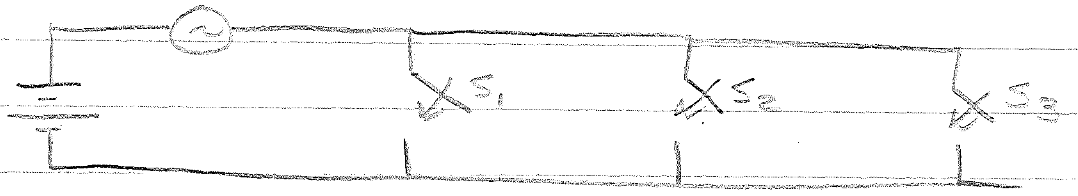
| A | B | C | L | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | ← STARTING POINT |
| 0 | 0 | 1 | 1 | ⇐ ONE BIT |
| 0 | 1 | 0 | 1 | ⇐ 1 BIT |
| 0 | 1 | 1 | 0 | ⇐ 2 BIT |
| 1 | 0 | 0 | 1 | ⇐ 1 BIT |
| 1 | 0 | 1 | 0 | ⇐ 2 |
| 1 | 1 | 0 | 0 | ⇐ 2 |
| 1 | 1 | 1 | 1 | ⇐ 3 BIT |

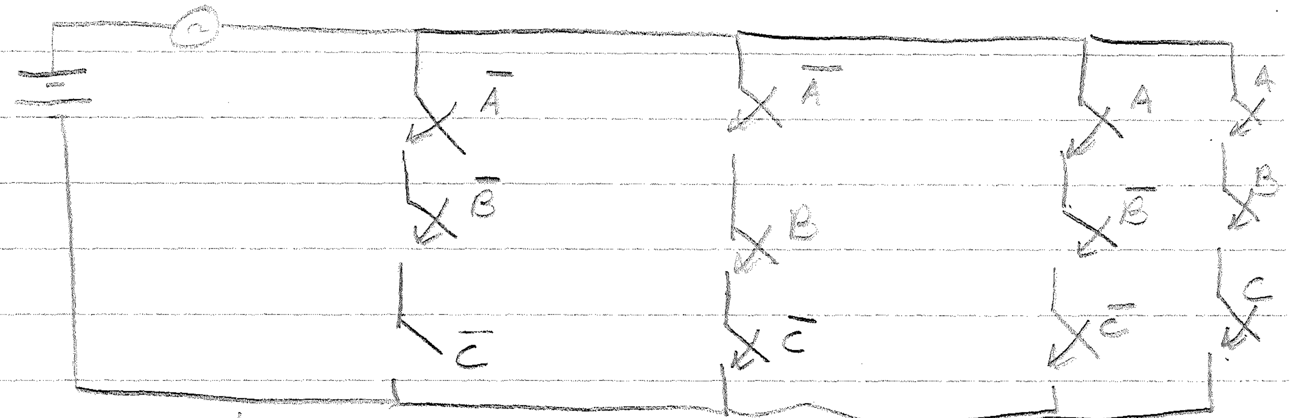
$$L = \bar{A}\bar{B}C \underset{\overset{\uparrow}{OR}}{+} \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$$



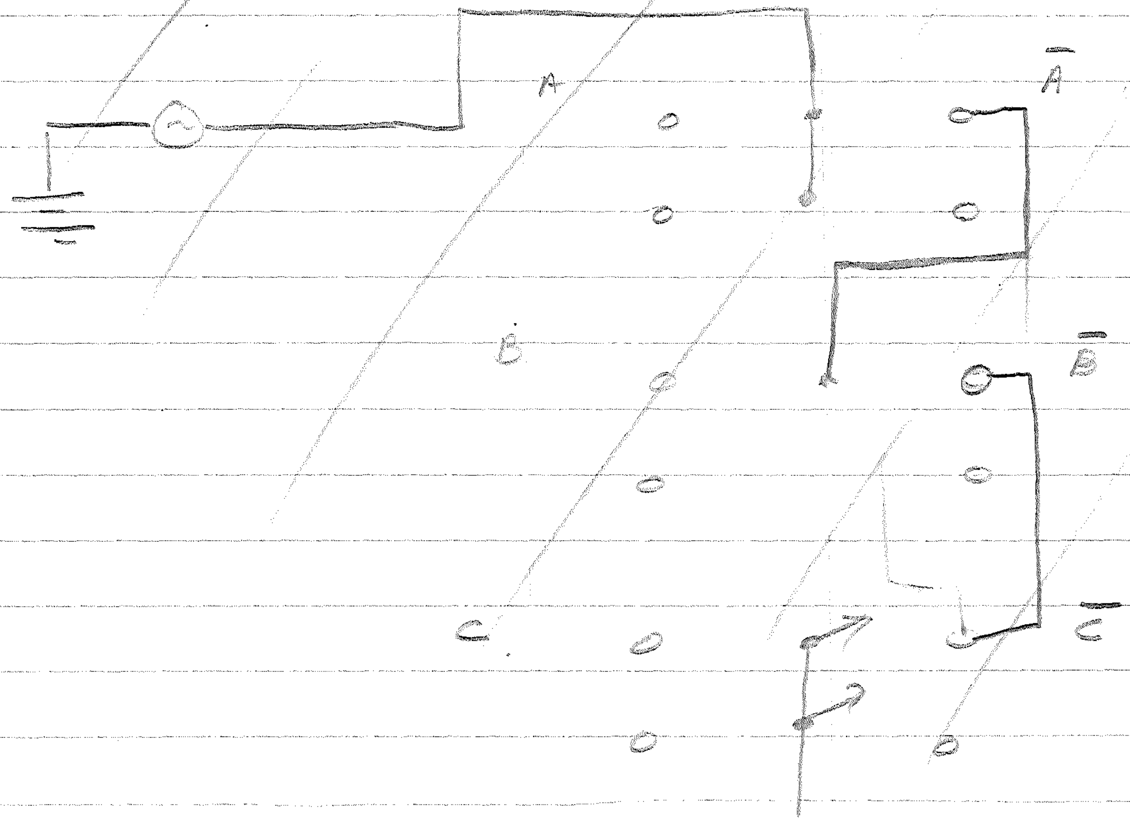
USING SWITHES

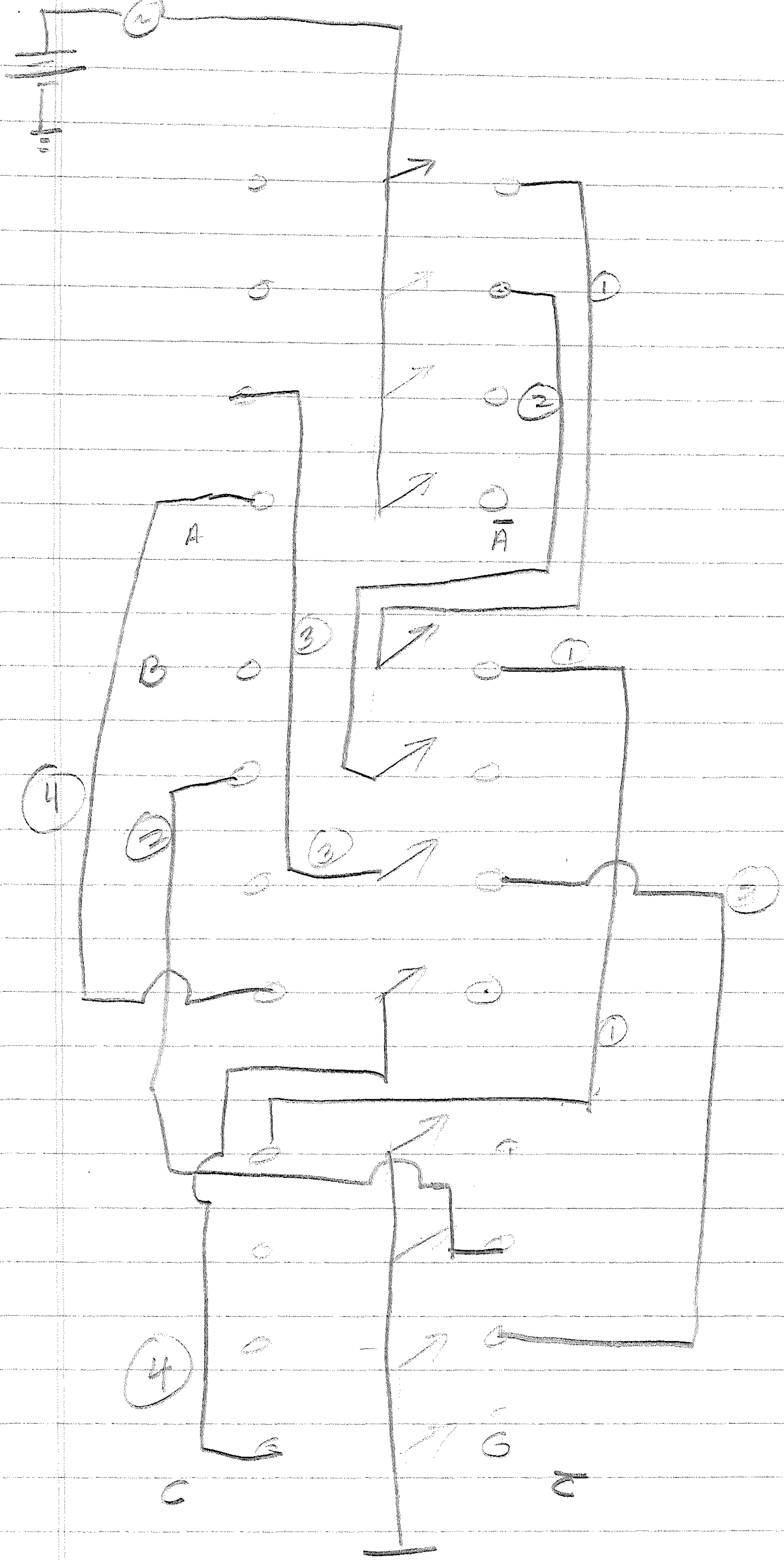
$$L = \underbrace{\bar{A}\bar{B}C}_{S_1} + \underbrace{\bar{A}B\bar{C}}_{S_2} + \underbrace{A\bar{B}\bar{C}}_{S_3} + \underbrace{ABC}_{S_4}$$





USE DOUBLE POLE - DOUBLE THROW SWITHES

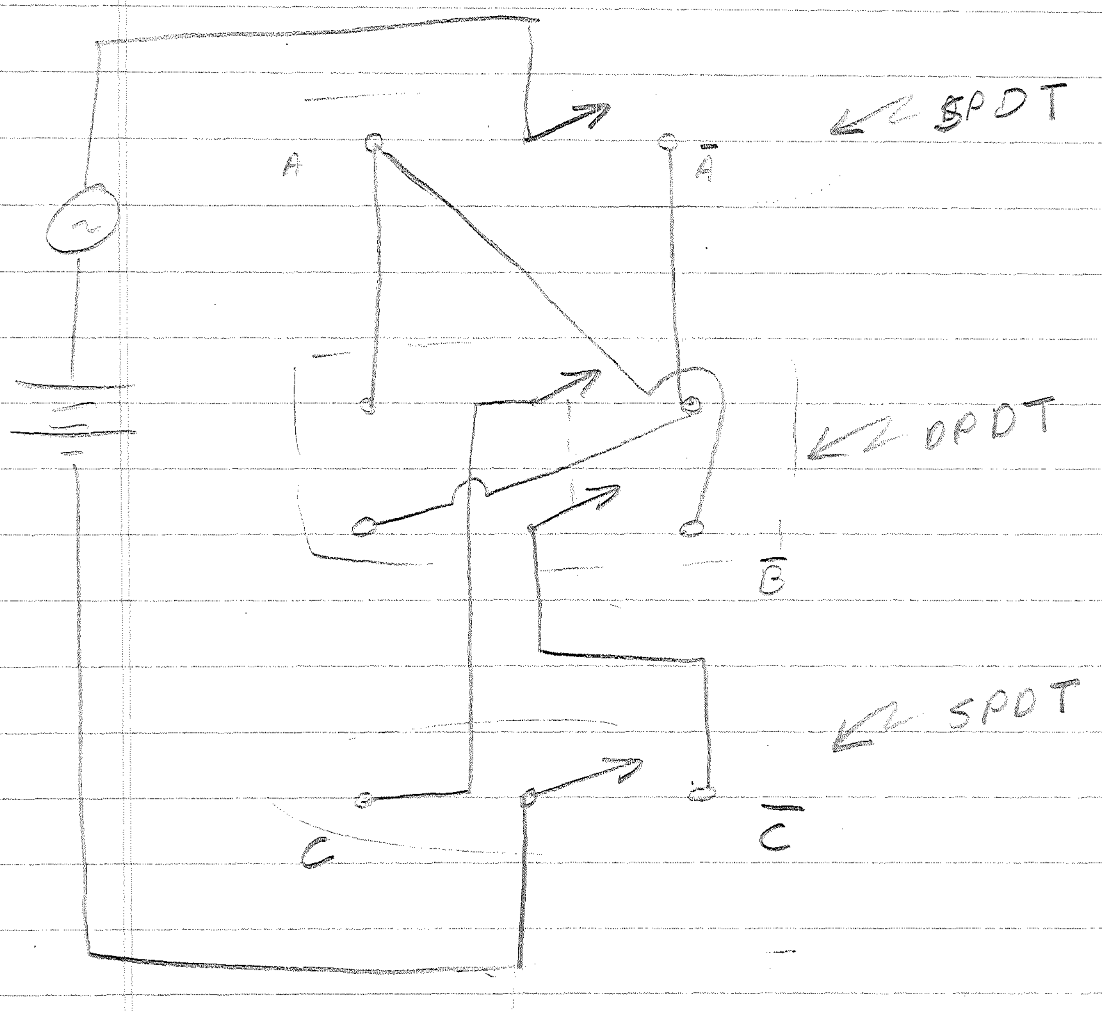



2
1
2
A
Ā
3
1
B
4
2
3
4
1
4
C
G
C̄

SIMPLIFYING (SWITCHING THEORY)

$$L = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$$

$$= \bar{A}(\bar{B}C + B\bar{C}) + A(\bar{B}\bar{C} + BC)$$



TEST # 3

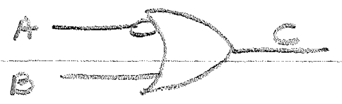
5 PROBLEMS, 20 PTS PER PROBLEM

1. TRUTH TABLE FABRICATION, LOGIC CIRCUIT DESIGN

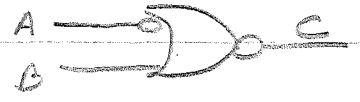
2. PARITY BIT ERROR CODING, BINARY SYMMETRIC CHANNEL

3. SWITCHING, BOOLEAN FUNCTIONS FROM TRUTH TABLES.

4. LOGIC GATES



$C = \overline{A} + C$



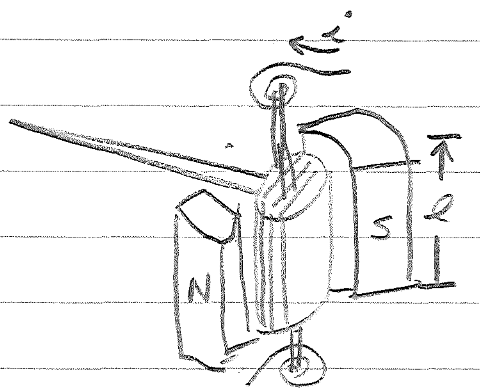
$C = \overline{\overline{A} + C}$

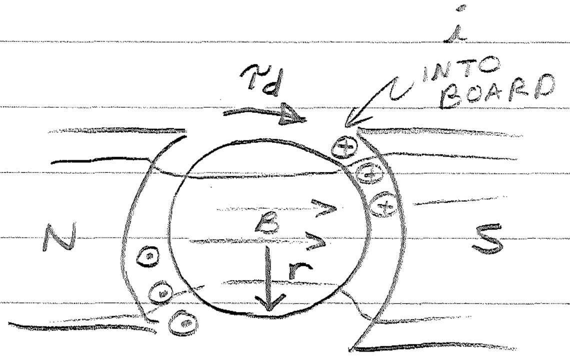
5. BINARY SYMMETRIC CHANNEL, HAMMING CODE,

IMPORTANT:

BRING COPY ON VINE'S BOOK
AND CALCULATOR THAT CAN
COMPUTE $Y^x$.

EX: d'ARSONVAL MECHANISM





$\tau_d = f_d \bullet r$

$f_d = B \hat{\ell} i$

N WINDINGS EACH WITH TWO SIDES

$\hat{\ell} = 2N\ell$

$\Rightarrow f_d = B\, 2N\ell i \Rightarrow \tau_d = 2NB\ell r i$

$= k_M i$

FROM THE SPRINGS:

$\tau_s = \theta / K_R$

$K_R$ = ROTATIONAL COMPLIANCE

$\tau_s = \tau_d$

$\Rightarrow \theta = (2NB\ell r K_r) i = k_\theta i$

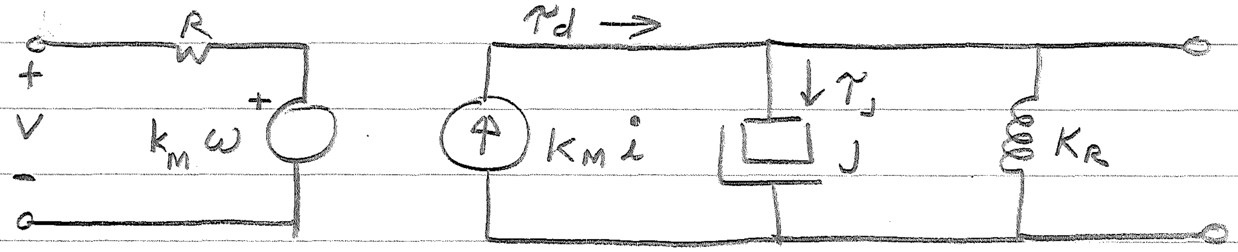
$\therefore$ ROTATION IS PROP. TO CURRENT

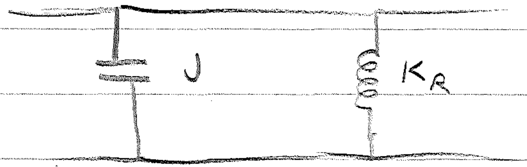
CIRCUIT:

$J$ = ROTATIONAL INERTIA

$\omega = \frac{d\theta}{dt}$ = ANGULAR VELOCITY

$K_r$ = COMBINED SPRING COMPLIANCE





$$\tau\left(= \frac{L}{R}\right) = \frac{K_R}{J}$$

FINAL: OPEN BOOK & NOTE

100 T-F ⇒ 200 pts

4 PROBLEMS ⇒ 50 PTS/PROB ⇒ 200 PTS

MAJOR TOPICS COVERED:

1. DIODES AND RECTIFIERS
2. FET AND BJT CIRCUITS
   - BIASING
   - EQUIV. CIRCUITS
3. LINEAR SYSTEM THEORY
   - LAPLACE
   - XFER FUNCTIONS & FREQ RESPONSE
   - FEEDBACK
4. SAMPLING THEOREM & FOURIER SERIES
5. RELIABILITY (SYSTEM EFFECTIVENESS
6. IMPEDANCE BRIDGES
7. OP AMPS
8. MODULATION & MULTIPLEXING
9. CODING & BINARY CHANELS
10. BOOLEAN LOGIC AND GATES
11. ELECTRO-MECHANICS
    - MECHANICAL CIRCUITS
    - MOTORS & GENERATORS

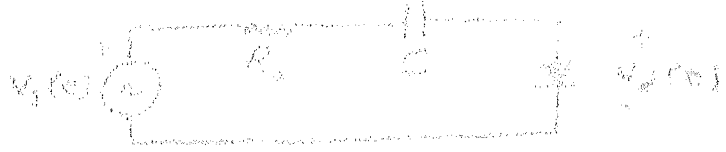
FINAL GRADE

$$G = (0.1)(\underset{\substack{\uparrow \\ 300\,PTS}}{HW\%}) + (0.4)(\underset{\substack{\uparrow \\ 300\,PTS}}{T\%})$$

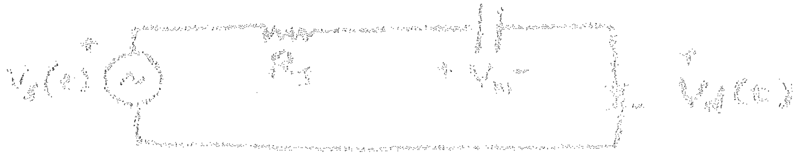
$$+(0.2)(L\%) + (0.3)(\underset{\substack{\uparrow \\ 400\,PTS}}{F\%})$$

$$0 < G < \underline{1}00\%$$

[illegible] $v_d(t)$ GIVEN THAT $V_s(t) = V_m \sin\omega t$, [illegible] RESULT AND [illegible] YOUR [illegible] (b) WHAT IS [illegible] AVERAGE [illegible] OF $V_d(t)$ [illegible] EXPLAIN WHY THE CIRCUIT [illegible] CALLED A "DIODE CLAMPER."



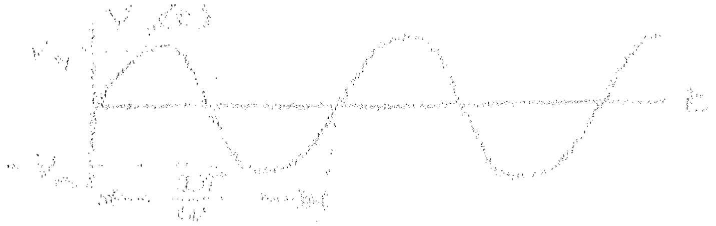
(a) AS $V_s(t)$ FIRST STARTS TO RISE, THE DIODE IS FORWARD BIASED AND THE CAPACITOR CHARGES TO (APPROXIMATELY) THE PEAK VALUE OF $V_s(t)$ WHICH IS $V_m$. IT FURTHERMORE RETAINS THIS CHARGE IN THE STEADY STATE. AS SUCH, WE HAVE THE CIRCUIT:



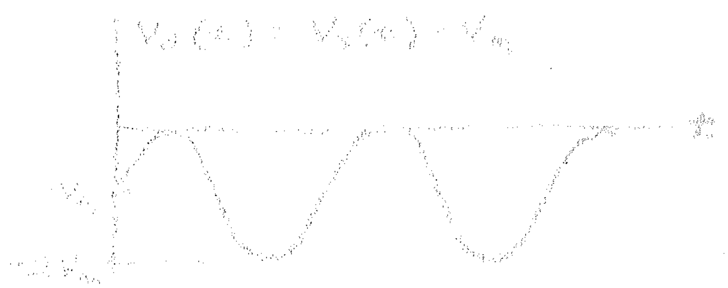
ASSUMING NEGLIGIBLE VOLTAGE DROP ACROSS $R_s$, WE FIND, FROM KIRCHHOFF'S VOLTAGE LAW, THAT

$$V_d(t) = V_s(t) - V_m$$
$$= V_m\left[\sin\omega t - 1\right].$$

OUR SOURCE VOLTAGE LOOKS LIKE



THUS OUR DIODE VOLTAGE IS



(b) WE CALL THIS CIRCUIT A "DIODE CLAMPER" SINCE IT "CLAMPS" THE SINUSOIDAL INPUT TO THE $V_d = 0$ AXIS.

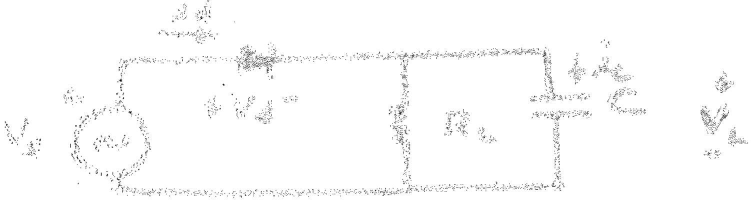
(b) $r^2 = \frac{V_{rms}^2}{V_{dc}^2} - 1$

$$V_{dc} = \frac{1}{T}\int_T v_L(t)\,dt = \frac{\omega V_m}{2\pi}\int_0^{2\pi/\omega}(1 - \sin\omega t)\,dt$$
$$= \frac{\omega V_m}{2\pi}\left[\frac{2\pi}{\omega} - 0\right] = V_m$$

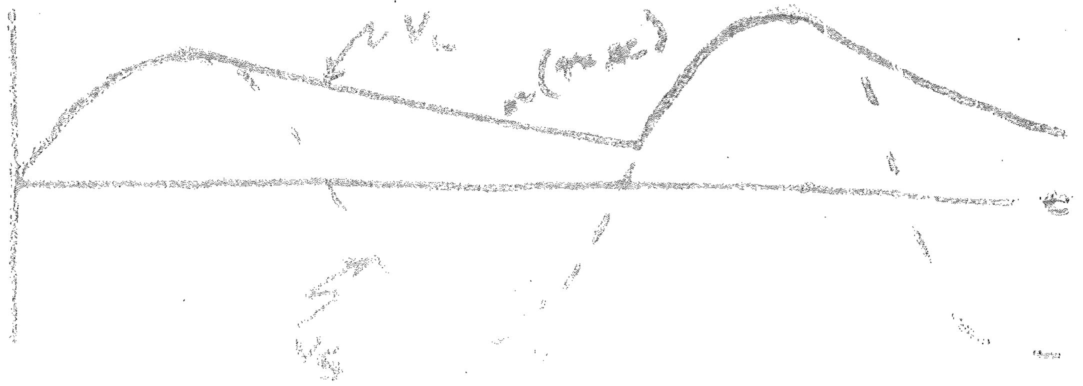
$$V_{rms}^2 = \frac{1}{T}\int_T v_L^2(t)\,dt$$
$$= \frac{\omega V_m^2}{2\pi}\int_0^{2\pi/\omega}(1 - \sin\omega t)^2\,dt$$
$$= \frac{1}{2\pi}\omega V_m^2\left[\int_0^{2\pi/\omega}dt - 2\int_0^{2\pi/\omega}\sin\omega t\,dt + \int_0^{2\pi/\omega}\sin^2\omega t\,dt\right]$$
$$= \frac{1}{2\pi}\omega V_m^2\left[\frac{2\pi}{\omega} - 2(0) + \frac{1}{2}\int_0^{2\pi/\omega}[1 - \cos 2\omega t]\,dt\right]$$
$$= \frac{1}{2\pi}\omega V_m^2\left[\frac{2\pi}{\omega} + 0 + \frac{1}{2}\left(\frac{2\pi}{\omega} - 0\right)\right]$$
$$= \frac{1}{2\pi}\omega V_m^2\left(\frac{3\pi}{\omega}\right)$$
$$= \frac{3}{2}V_m^2$$

$$\Rightarrow r^2 = \frac{\frac{3}{2}V_m^2}{V_m^2} - 1 = \frac{3}{2} - 1 = \frac{1}{2} \Rightarrow r = \frac{1}{\sqrt{2}}$$
$$\approx 0.707$$

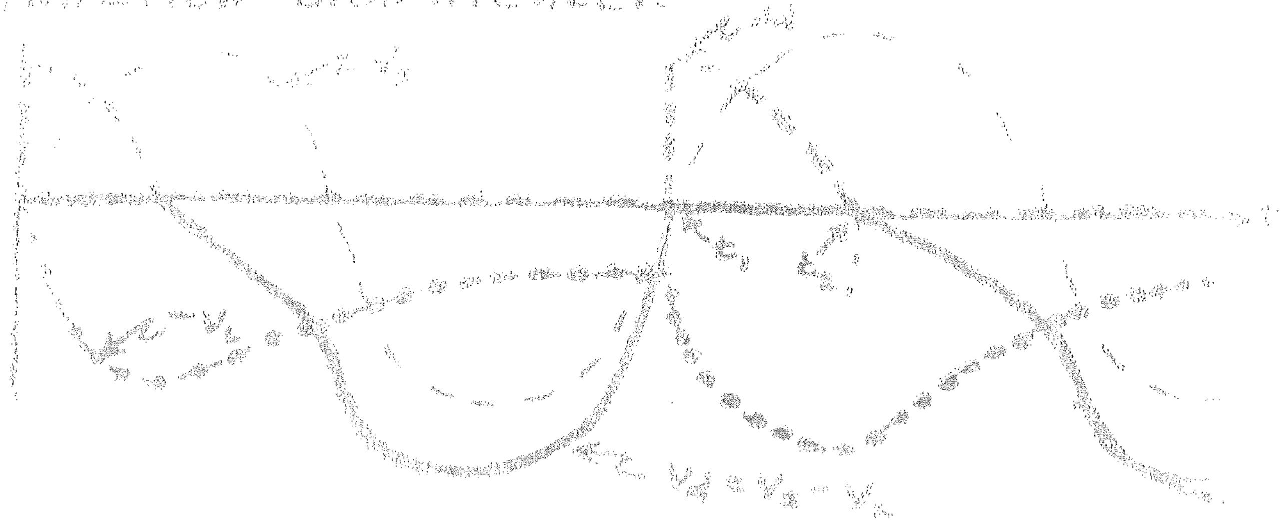
2. FOR THE HALF-WAVE RECTIFIER WITH CAPACITIVE FILTER, SKETCH THE SOURCE VOLTAGE, DIODE VOLTAGE, AND DIODE CURRENT ON THE SAME GRAPH. DOCUMENT YOUR RESULTS.



THE GRAPH OF SOURCE VOLTAGE VS. $V_L$ WAS GIVEN IN CLASS:



FROM KIRCHHOFF'S VOLTAGE LAW: $V_d = V_s - V_L$. FROM THE PREVIOUS SKETCH, WE MAKE THIS SUBTRACTION GRAPHICALLY:



THE DIODE WILL BE CONDUCTING IN THAT REGION DURING THE TIME WHEN $V_d = 0$, AT $t_1$, THE SUPPLY VOLTAGE, $V_s$, SLIGHTLY EXCEEDS $V_L$ AND THE DIODE CONDUCTS. THE DIODE CURRENT RISES ABRUPTLY TO SATISFY THE RELATION $i_c = C\,{}^{dV}/_{dt}$ AND THEN GOES BACK DOWN TO ZERO.

"WHATEVER THE MIND OF MAN CAN CONCEIVE AND BELIEVE, IT CAN ACHIEVE"

NAPOLEON HILL.

HOMEWORK #2 DUE 2/10/77

IN CLASS

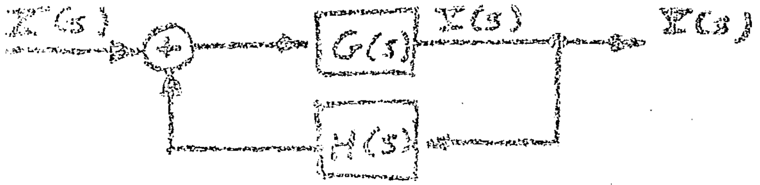
1. (a) SHOW THAT, IF $X(s) = \mathcal{L}[x(t)]$ AND $x(t) = 0$ FOR $t<0$, THEN $\mathcal{L}[x(t-\tau)] = X(s)e^{-s\tau}$

(b) THE INPUT-OUTPUT RELATION OF A LINEAR, TIME-INVARIANT SYSTEM CAN BE EXPRESSED BY THE "CONVOLUTION INTEGRAL"

$$y(t) = \int_0^\infty x(\tau)\, T(t-\tau)\, d\tau$$

WHERE $T(t) = \mathcal{L}^{-1}[T(s)]$. USING THE RESULTS OF (a), SHOW THAT IT FOLLOWS THAT $Y(s) = X(s)\,T(s)$.

2. CONSIDER TWO SYSTEMS CONNECTED IN A "FEEDBACK" CONFIGURATION:



DERIVE THE TRANSFER FUNCTION $T(s) = Y(s)/X(s)$ (HINT: SEE p. 233 OF SMITH)

3. CLASSIFY THE FOLLOWING SYSTEMS ACCORDING TO LINEARITY, TIME INVARIANCE, AND CAUSALITY.

(a) $y(t) = \frac{d^n}{dt^n} x(t)$ (d) $y(t) = [x(t) - d]^n$

(b) $y(t) = a\,x(t) + b$ (e) $y(t) = t\,x(t)$

(c) $y(t) = \int_0^t x(t)\,dt$ (f) $y(t) = x(t-4)$

WHICH SYSTEMS CAN WE USE LAPLACE TRANSFORMS ON?

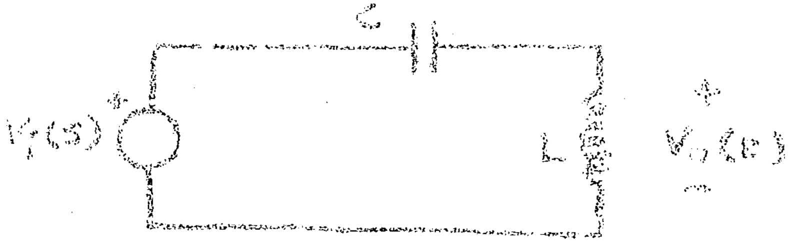
4. FOR THE FOLLOWING CIRCUIT

(a) FIND THE TRANSFER FUNCTION $T(s) = V_o(s)/V_i(s)$

(b) FIND THE OUTPUT FOR $V(t) = V_o\,u(t)$

(c) DISCUSS YOUR RESULT IN (b)

(d) COMPUTE AND SKETCH THE FREQUENCY RESPONSE $|T(j\omega)|$.



HOMEWORK # I SOLUTIONS

1. (a) $Y(s) = \mathcal{L}[x(t-\tau)] = \int_0^\infty x(t-\tau)\, e^{-st} dt$

LET $t' = t - \tau \Rightarrow dt' = dt$

$\Rightarrow Y(s) = \int_{-\tau}^{\infty} x(t')\, e^{-s(t'+\tau)} dt'$, BUT $x(t) = 0$ FOR $t < 0$

$\Rightarrow Y(s) = \int_0^\infty x(t')\, e^{-s(t'+\tau)} dt = \int_0^\infty x(t')\, e^{-st'} dt'\, e^{-s\tau}$

$= \int_0^\infty x(t)\, e^{-st} dt\, e^{-s\tau} = X(s)\, e^{-s\tau}$

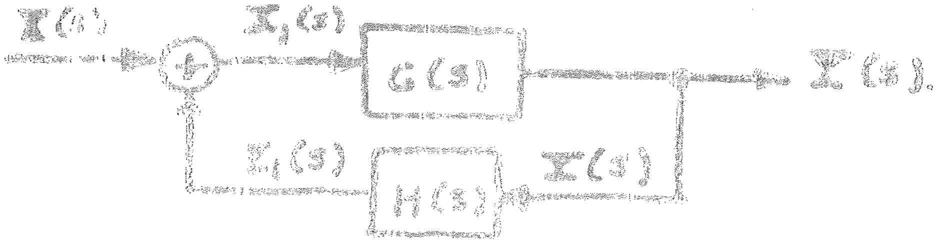
(b) $y(t) = \int_0^\infty x(\tau)\, T(t-\tau)\, d\tau$

$\mathcal{L}[y(t)] = \int_0^\infty x(\tau)\, \mathcal{L}[T(t-\tau)]\, d\tau = \int_0^\infty x(\tau)\, \mathcal{L}[T(t)]\, e^{-s\tau} d\tau$

$= \int_0^\infty x(\tau)\, e^{-s\tau} d\tau\, \mathcal{L}[T(t)] = \mathcal{L}[x(t)]\, \mathcal{L}[T(t)]$

THUS $Y(s) = X(s)\, T(s)$

2.



$X_1(s) = X(s) + X_2(s) = X(s) + Y(s)H(s)$ ①

ALSO $Y(s) = X_1(s)G(s) \Rightarrow X_1(s) = Y(s)/G(s)$ ②

EQUATING ① AND ②:

$X(s) + Y(s)H(s) = Y(s)/G(s)$

SOLVING FOR $Y(s)$ GIVES $\Longrightarrow Y(s) = \dfrac{G(s)X(s)}{1 - G(s)H(s)}$

THUS $T(s) = Y(s)/X(s) = \dfrac{G(s)}{1 - G(s)H(s)}$

3. (a) $y(t) = \frac{d^2}{dt^2} x(t)$

- $\frac{d^2}{dt^2}[a x_1(t) + b x_2(t)] = a\frac{d^2}{dt^2} x_1(t) + b\frac{d^2}{dt^2} x_2(t) \Leftarrow$ LINEAR
- $y(t-\tau) = \frac{d^2}{dt^2} x(t-\tau) \Leftarrow$ TIME INVARIANT
- $y(t)$ DEPENDS ONLY ON $x(t)$ TO $t \Leftarrow$ CAUSAL

(b) $y(t) = a\,x(t) + b$

- $[a x_1(t) + b] + [a x_2(t) + b] \neq a[x_1(t) + x_2(t)] + b \Leftarrow$ NOT LINEAR
- $y(t-\tau) = a\,x(t-\tau) + b \Leftarrow$ TIME INVARIANT
- CAUSAL

(c) $y(t) = \int_0^t x(t)\,dt$

- $a\int_0^t x_1(t)\,dt + b\int_0^t x_2(t)\,dt = \int_0^t [a x_1(t) + b x_2(t)]\,dt \Leftarrow$ LINEAR
- $y(t-\tau) = \int_0^{t-\tau} x(t)\,dt \Leftarrow$ TIME INVARIANT
- CAUSAL

(d) $y(t) = [x(t) - d]^2$

- $[a x_1(t) + b x_2(t) - d]^2 \neq a[x_1(t) - d]^2 + b[x_2(t) - d]^2 \Rightarrow$ NONLINEAR
- $y(t-T) = [x(t-T) - d]^2 \Rightarrow$ TIME-INVARIANT
- CAUSAL

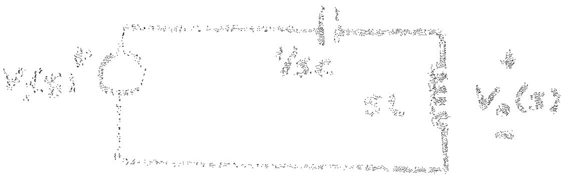
(e) $y(t) = t\,x(t)$

- $t[a x_1(t) + b x_2(t)] = a t x_1(t) + b t x_2(t) \Rightarrow$ LINEAR
- $y(t-T) \neq t\,x(t-T) \Rightarrow$ TIME-VARIANT (it has time variable [illegible])
- CAUSAL

(f) $y(t) = x(t$ [illegible]$)$

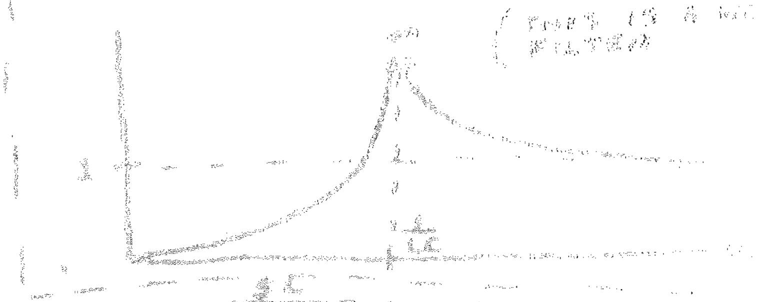
- LINEAR
- TIME INVARIANT
- ~~NON~~ CAUSAL

4 a



(d) $|T(j\omega)| = \left|\frac{\omega^2 LC}{1-\omega^2 LC}\right|$

(THIS IS A HIGH PASS FILTER)



(a) BY VOLTAGE DIVIDER: $V_o(s) = \frac{sL}{sL + \frac{1}{sC}} V_i(s)$

$\Rightarrow T(s) = \frac{V_o(s)}{V_i(s)} = \frac{sL}{sL + \frac{1}{sC}} = \frac{s^2 LC}{1 + s^2 LC}$

(b) $v_i(t) = V_0\, u(t) \Rightarrow V_i(s) = \frac{V_0}{s}$

$V_o(s) = T(s)\, V_i(s) = \frac{V_0\, s LC}{1 + s^2 LC} = \frac{V_0 s}{\left(\frac{1}{\sqrt{LC}}\right)^2 + s^2}$

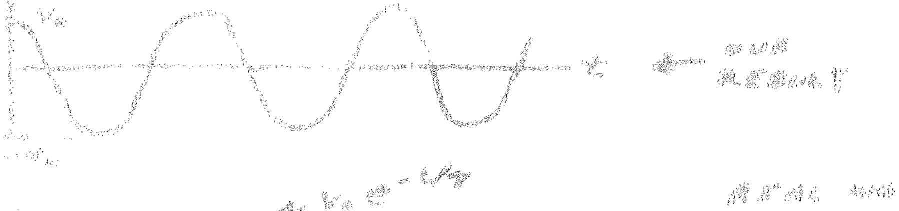
FROM LAPLACE TRANSFORM TABLE:

$v_o(t) = V_0 \cos \frac{1}{\sqrt{LC}} t$

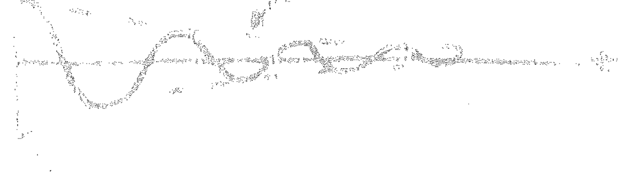
(c) THIS CIRCUIT IS AN OSCILLATOR. IN PRACTICE, THE COSINE WILL BE "DAMPED" SINCE SOME RESISTANCE IN THE CIRCUIT WILL ABSORB POWER IN ACTUAL PHYSICAL WORLD

$v_o(t) \cong V_0 \cos \omega t \; e^{-t/\tau}$

WHERE τ IS DETERMINED BY CIRCUIT PARAMETER.



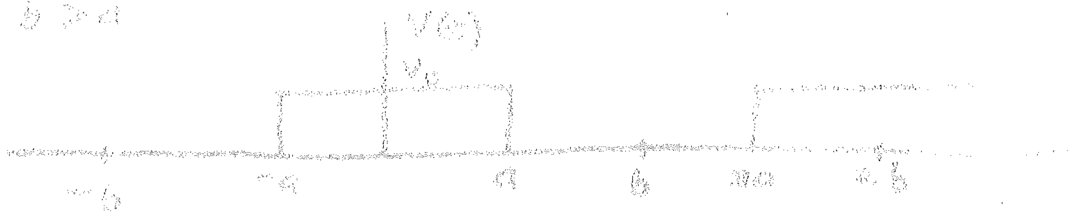
← OUR RESULT



← REAL WORLD RESULT (DUE TO RESISTANCE)

[illegible] ) 2.

(1) (a) FOR THE FOLLOWING PERIODIC WAVEFORM(a) FI[illegible] THE FOURIER SERIES COEFFICIENTS, $\alpha_n$. ASS[illegible] THAT $b > a$



[HINT: $\frac{1}{j2}(e^{j\theta} - e^{-j\theta}) = \sin\theta$]

(b) ASSUME THAT $b = 2a$. WHAT IS $\alpha_n$ FO[illegible]

$n = 0$ [HINT: $\lim_{x \to 0} \frac{\sin \pi x}{\pi x} = 1$]

$n$ EVEN

$n = 1, 5, 9, 13, 17, \ldots$

$n = 3, 7, 11, 15, 19, \ldots$

(c) PLOT $\pi|\alpha_n|/V_0$ FOR $n$ UP TO 7.

(2) FOR $x(t) = \sum_{n=-\infty}^{\infty} \alpha_n e^{j2\pi nt/T}$

(a) SHOW THAT $\int_{2T} x(t)\,dt = \sum_{n=-\infty}^{\infty}$ [illegible]

[HINT: $\int_{2T} e^{j2\pi nt/T}\,dt = \frac{1}{2T}$]

(b) PROVE "PARCEVAL'S THEOREM":

$$\int_{2T} |x(t)|^2 dt = \sum_{n=-\infty}^{\infty} \frac{|\alpha_n|^2}{2T}$$

[HINTS: $|\sum_n B_n|^2 = \sum_n \sum_m B_n B_m^*$

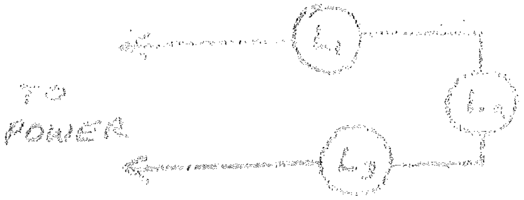
$$\int_{2T} e^{j2\pi t(n-m)/T}\,dt = \frac{1}{2W}\,\delta_{nm}$$

$$\delta_{nm} = \left\{ \begin{array}{ll} 1 & ; n = m \\ 0 & ; n \neq m \end{array} \right\} \Leftarrow \text{KRONECKER D.}$$

(3) JOHNNY CASH AND TINY TIM (LO & HI VOIC[illegible] RE[illegible] A 3 MINUTE 55 SECOND RECORDING. IF NEI[illegible]ER VOICE EXCEEDED 20 kHz ($= 20{,}000$ CYCL[illegible]ES) WE WISHED TO STORE THE RECORD IN S[illegible]LE FORM, HOW MANY SAMPLES WOULD WE [illegible] TO STORE? IF WE LOST EVERY OTHER SA[illegible]LE, WHOSE VOICE WOULD BE DISTORTED [illegible] ST [illegible]?

NO

(4) CONSIDER A SYSTEM CONSISTING OF THREE LIGHTBULBS HOOKED IN SERIES:



WE CONSIDER THE SYSTEM "OP[illegible] TWO OR MORE OF THE LIGHTS [illegible]

(a) ASSUMING THAT THE MTBF O[illegible] BULB IS TWO MONTHS. AND [illegible] ARE ON THE RANDOM FAILURE [illegible] PORTION OF THE BATHTUB CU[illegible] THE SYSTEM MTBF AND THE [illegible] THAT THE SYSTEM WILL BE [illegible] TWO MONTHS OF USE.

(b) IF IT TAKES 30 MINUTES (ON [illegible] TO REPLACE A BULB, COMPUTE [illegible] AVAILABILITY. (ASSUME 1 MONTH [illegible]

(c) CONSIDERING OUR DEFINITION [illegible] SUGGEST A BETTER WAY OF [illegible] THE LIGHTS SO THAT THE O[illegible] RELIABILITY IS INCREASED. [illegible] THIS EFFECT THE SYSTEM [illegible] [CAN YOU COMPUTE THE MT[illegible] NEW SYSTEM?]

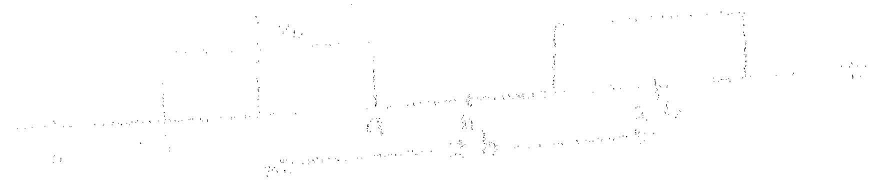
(d) IN THE IMPROVED SYSTEM OF [illegible] EXPLAIN HOW THE AVAILAB[illegible] RELIABILITY OF THE SYSTEM CA[illegible] IMPROVED BY INTRODUCING [illegible] OF *"PREVENTATIVE MAITAN[illegible] [illegible] WILL THIS EFFECT THE MTBF [illegible]

* ie, REPLACING A BURNT OUT BULB BEFORE THE SYSTEM IS "INOPERABLE"

"HE THAT REFUSETH INSTRUCTION DESPISETH HIS OWN SOUL."

PROV. 15:32

[illegible]



(a) $\alpha_n = \frac{1}{T}\int x(t) e^{-j2\pi n t/T} dt$

$\alpha_n = \frac{1}{b}\left[\int (0)dt + \int_{-a}^{a} e^{-j2\pi n t/b} V_0 dt\right]$

$= \frac{V_0}{b}\int_{-a}^{a} e^{-j2\pi n t/b} dt$

$= \frac{V_0}{b}\left[\frac{b}{-j2\pi n} e^{-j2\pi n t/b}\right]_{-a}^{a}$

$= \frac{V_0}{-j2\pi n}\left[e^{-j2\pi n a/b} - e^{j2\pi n a/b}\right]$

$= \frac{V_0}{\pi n} \sin 2\pi\left(\frac{a}{b}\right) n$

(b) $b = 2a \Rightarrow \alpha_n = \frac{V_0}{\pi n}\sin \pi n$

$= \begin{cases} V_0 & ; n = 0 \\ 0 & ; \text{OTHERWISE} \\ ~~\frac{V_0}{\pi n}~~ & \end{cases}$

(2) (a) $x(t) = \sum_{n=-\infty}^{\infty} \alpha_n e^{j2\pi n t/T}$

$\int_T x(t)\,dt = \sum_{n=-\infty}^{\infty} \alpha_n \int_T e^{j2\pi n t/T} dt = \ldots \sum_{n=-\infty}^{\infty} \alpha_n$

(b) $|x(t)|^2 = \sum_{n=-\infty}^{\infty}\sum_{m=-\infty}^{\infty} \alpha_n \alpha_m^* e^{j2\pi(n-m)t/T}$

$\int_T |x(t)|^2 dt = \sum_{n=-\infty}^{\infty}\sum_{m=-\infty}^{\infty} \alpha_n \alpha_m^* \int_T e^{j2\pi(n-m)t/T} dt =$

$= \sum_n \sum_m \alpha_n \alpha_m^* \left(T\,\delta_{nm}\right)$

$= \sum_n |\alpha_n|^2$

(3) S = TOTAL SAMPLES

( ) = (3 MIN 55 SEC)(2 × 20 KHZ)

= (235 SEC)(40,000/SEC) = 9.4 MILLION [illegible]

UNDER-SAMPLING DISTORTS THE HIGHER FREQUENCIES. THUS, TINY TIM, [illegible] HIGHER VOICE, WOULD BE DISTORTED [illegible]

NO (4)(a) SINCE ONE LIGHT BULB FAILING WILL [illegible] IN SYSTEM FAILURE, THE SYSTEM MTBF IS

$$MTBF_S = \frac{MTBF_L}{3} = \frac{2}{3} \text{ MONTH}$$

$$R_S(t) = e^{-t/MTBF_S} \Rightarrow R_S(2 \text{ MONTH}) = e^{[illegible]}$$

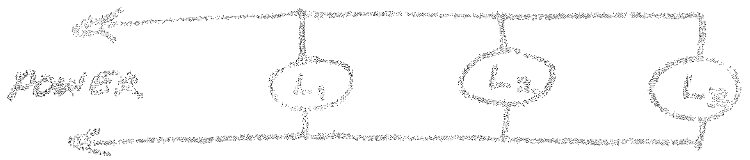
$$= e^{-3} \cong 0.05$$ ⇒ THERE IS ABOUT A 5% CHANCE THE SYSTEM WILL OPERATE FOR TWO STRAIGHT MONTHS.

(b) MTTR = 30 MIN

$$A = \frac{MTBF}{MTBF + MTTR} = \frac{\frac{2}{3} \times 30 \times 24 \times 60}{\frac{2}{3} \times 30 \times 24 \times 60 + 30}$$

$$= \frac{28800}{28830} = 99.896\%$$

(c) IT WOULD BE BETTER TO CONNECT [illegible] IN PARALLEL



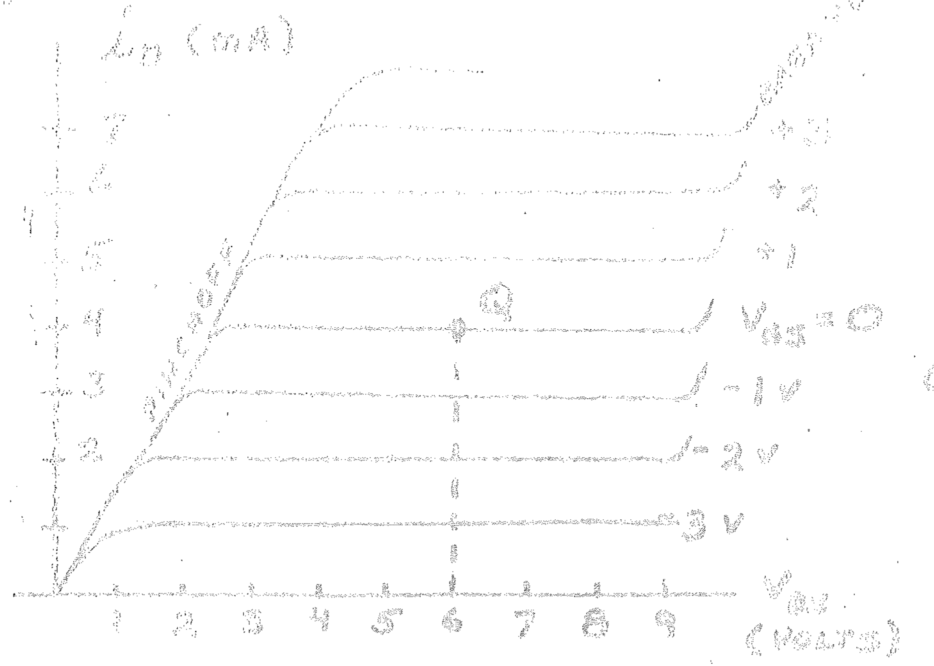
HERE, IF ONLY ONE LIGHT FAILS, THE SYSTEM IS STILL "OPERABLE"

(d) BY REPLACING A LIGHT WHICH HAS BURNT OUT WHILE THE SYSTEM IS "OPERABLE" WE ARE PERFORMING "PREVENTIVE MAINTENANCE" THE MTTR IS REDUCED ~~STILL THE SAME~~, BUT THE MTBF (AND THUS THE AVAILABILITY) IS INCREASED.

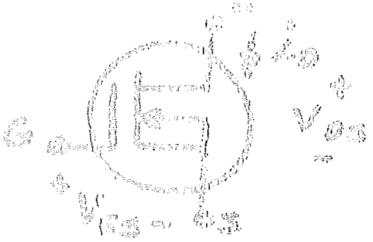
"HE THAT HANDLETH A MATTER WISELY SHALL FIND GOOD: A-

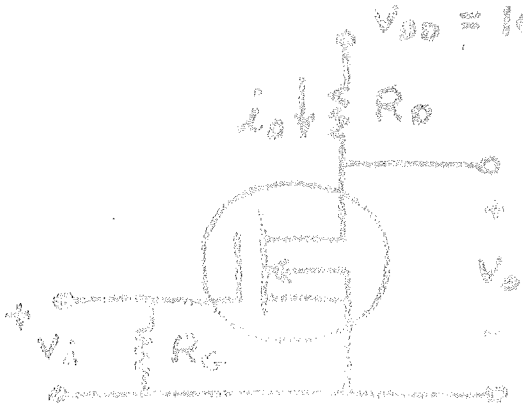
WHOSO) TRUSTETH IN THE LORD, HAPPY IS HE" [illegible] #7 ([illegible] 201) [illegible]

DUE MARCH 4



DE MOSFET





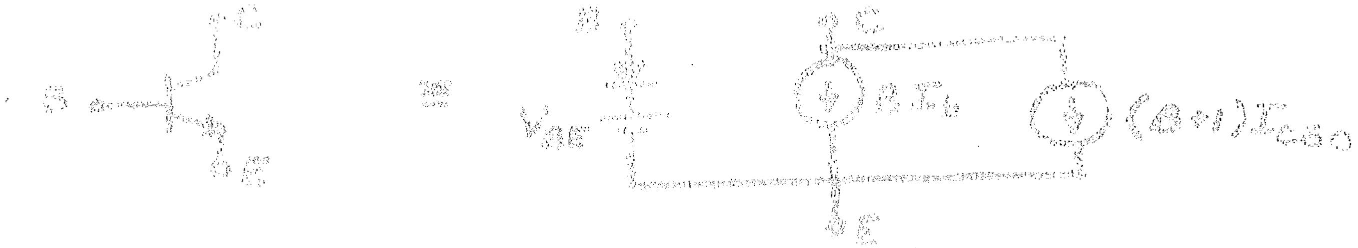
(a) DETERMINE $R_D$ TO ESTABLISH QUIESCENCE AT THE POINT INDICATED. $V_{DD} = 10V$

(b) DETERMINE THE EQUATION FOR THE LOAD LINE AND SKETCH IT ON THE ABOVE DE-MOSFET V-$i$ CURVE.

(c) FROM (b), MAKE A PLOT OF SOME POINTS FOR THE CURVE $i_D$ vs. $V_{GS}$. ASSUMING $V_{GS}$ IS THE INPUT AND $i_D$ THE OUTPUT, WHAT IS THE "GAIN" OF THIS TRANSDUCER IN MHO'S?

(d) GIVE AN ESTIMATE OF THE INTERVAL $V_{GS}$ MUST BE LIMITED TO TO AVOID GROSS OUTPUT "DISTORTION"

(2) OUR TRANSISTOR D.C. MODEL WAS



(a) FOR $I_{CBO} = 5\,nA$, SKETCH $i_C$ (VERTICAL AXIS) vs. $V_{CE}$ ON THE SAME GRAPH FOR $I_B = 0.1, 0.2, 0.3, 0.4\ mA$. ASSUME $\beta = 100$

(b) REPEAT (a) FOR $\beta = 200$. HOW HAS THE CURVE CHANGED?

(c) COMPARE YOUR SKETCH IN (a) TO THE CORRESPONDING TRANSISTOR CURVE.

(d) EXPLAIN WHY WE WOULD REQUIRE $I_B > 0$ (IN THE MODEL AND PHYSICALLY)

(3) IN A CERTAIN TRANSISTOR, THE PARAMETERS CHANGE WITH TEMPERATURE BUT ARE KNOWN TO FALL WITHIN THE BOUNDS:

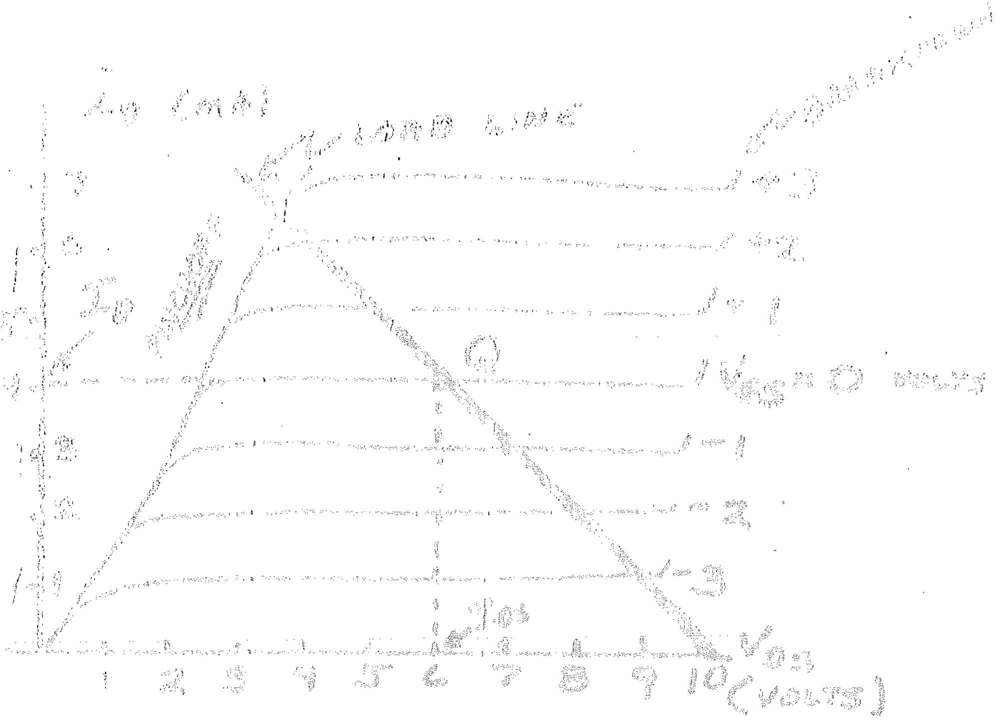
$$30 < \beta < 180$$
$$0.5 < V_{BE} < 0.9 \text{ VOLTS}$$
$$1 < I_{CBO} < 10\,nA.$$

BY ASSUMING WORST CASE CONDITIONS, FIND THE BOUNDS ON THE VARIATION OF $I_C$ IN A SELF-BIASING CIRCUIT. THAT IS, FIND $I_{MINIMUM}$ AND $I_{MAXIMUM}$ SUCH THAT

$$I_{MINIMUM} \le I_C \le I_{MAXIMUM}$$

ASSUME THAT THE CIRCUIT VALUES ARE $R = 10\ k\Omega$, $R_2 = 100\ k\Omega$, $R_E = 1\ k\Omega$ $R_C = 5\ k\Omega$ AND $V_{CC} = 22$ VOLTS.

( (a)



(a) $V_{DS} = V_{DD} - R_D I_D$

$\Rightarrow R_D = (V_{DD} - V_{DS})/I_D = \frac{10 \text{ volts} - 6 \text{ volts}}{4 \text{ mA}} = 1 k\Omega$

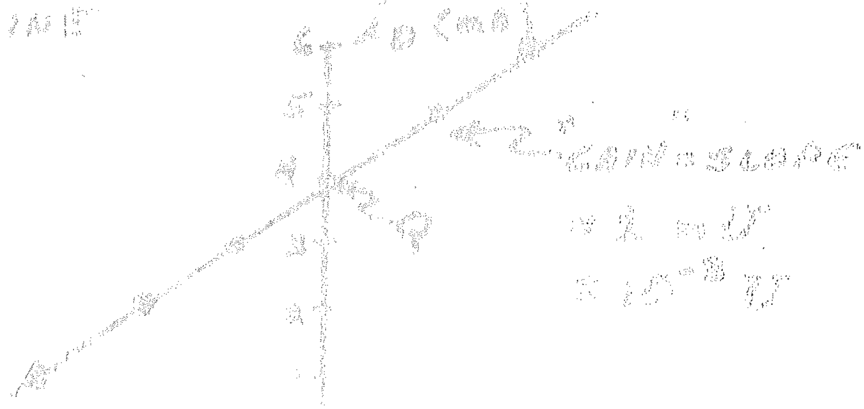
( (b) LOAD LINE: $V_{DS} = V_{DD} - R_D i_D$

$\Rightarrow V_{DS} = 10 - 10^3 i_D$

$\Rightarrow i_D = 10^{-3}(V_{DS} - 10)$

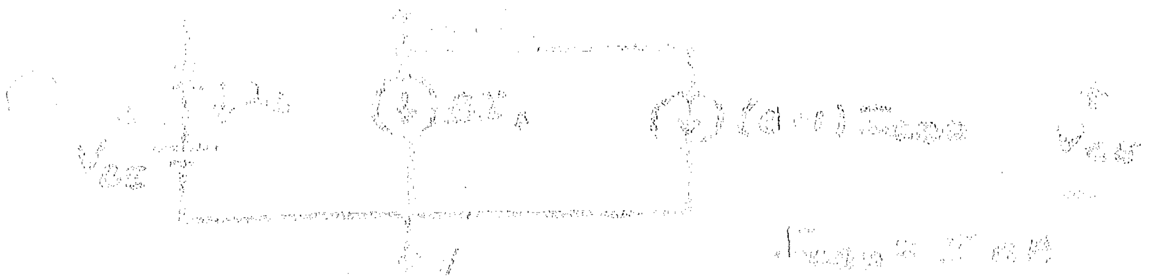
(c) FROM LOAD LINE

| $V_{GS}$ (V) | $i_D$ (mA) |
|---|---|
| 2 | 6 |
| 1 | 5 |
| 0 | 4 |
| -1 | 3 |
| -2 | 2 |
| -3 | 1 |



(d) FOR $V_{GS} > -3$ V, WE GET "PINCHOFF"; FOR $V_{GS} < -3$, WE GET BREAKDOWN. THUS, A REGION LIMIT IS

( $-3$ V $< V_{GS} < 1$ V



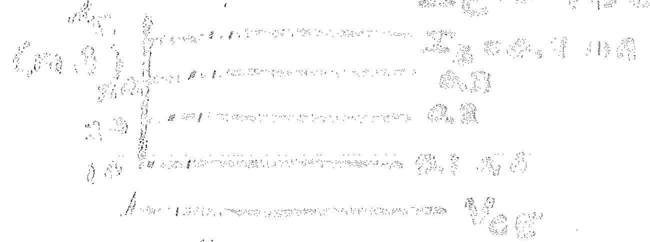
$I_{CBO} = 1$ nA

(a) SUMMING CURRENT AT COLLECTOR: $I_C = \beta I_B + (\beta+1) I_{CBO}$

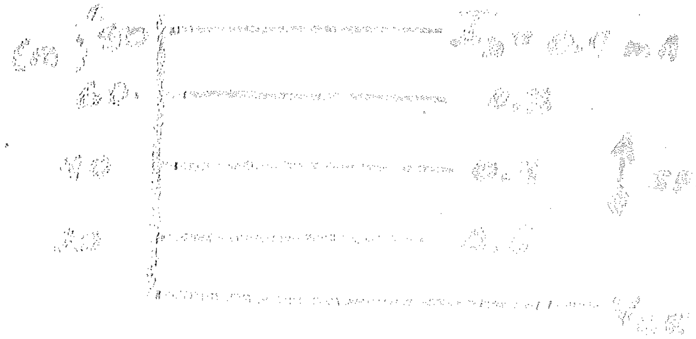
$\beta = 100$ : $I_C = 100 I_B + 101 I_{CBO}$

FOR $I_B = 0.1, 0.2, 0.3, 0.4$ mA

$I_C \approx 100 I_B = 10, 20, 30, 40$ mA



(b) FOR $\beta = 200$, CURVE IS SIMPLY "SPREAD OUT"

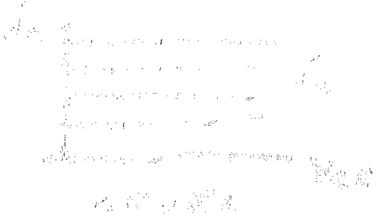


$I_C \approx 200 I_B$

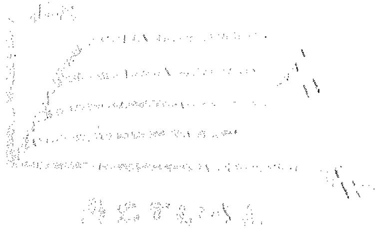
$= 20, 40, 60, 80$ mA

SPREAD OUT BY HIGHER $\beta$

(c)



MODEL



ACTUAL

(d) $I_B > 0$ SIMPLY SO THAT "I" CAN FLOW THROUGH THE DIODE IN OUR MODEL (OR THE BASE-EMITTER P-N JUNCTION IN OUR ACTUAL TRANSISTOR).

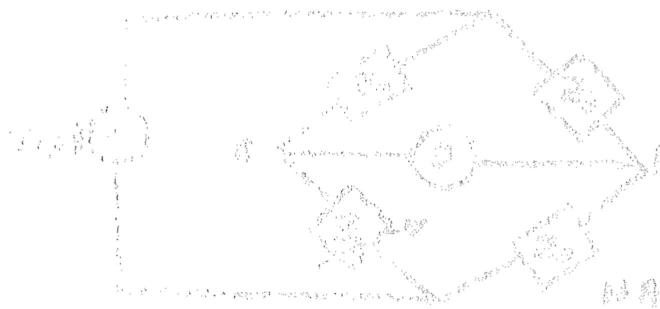
(e) THIS PROBLEM IS WORKED IN EXAMPLE ( 2, PAGE 42) OF SMITH, 3RD ED.

[illegible]

(1.)

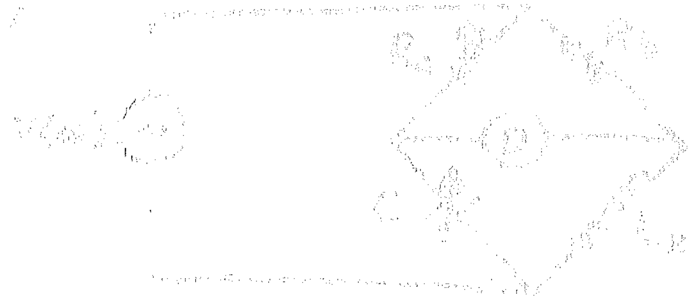
[illegible] BRIDGE, WE FIND THE UNKNOWNS, $L_x$ AND $R_x$ BY ADJUSTING $R_B$ AND R UNTIL THE NULL DETECTOR D, DETECTS NO VOLTAGE. (a) SHOW THAT, WHEN THIS BRIDGE IS BALANCED, THAT $R_x = RR_A/R_B$ AND $L_x = C_B R R_A$. (b) IF THE VARIABLE RESISTORS HAVE ACCURACY ±1% [illegible] IS ±1%, AND $C_B$ IS ±5%, FIND THE ACCURACY OF OUR MEASUREMENTS OF $L_x$ AND $R_x$. (c) WHAT DEPENDENCY DOES OUR MEASUREMENT HAVE ON THE AMPLITUDE AND FREQUENCY OF OUR SOURCE, IF ANY? WHY [illegible] WE SET THE AMPLITUDE AND/OR FREQUENCY TO ZERO?

(2.)



IN THIS BRIDGE, $Z_1$ AND $Z_2$ ARE FIXED, $Z_3$ IS ADJUSTABLE, AND $Z_x$ IS UNKNOWN. IF THIS BRIDGE IS BALANCED, FIND $Z_x$ [illegible] $Z_1$, $Z_2$, AND $Z_3$. [illegible] HAPPEN IF [illegible] TERMINALS [illegible] BRIDGE IS BALANCED?

(3.)



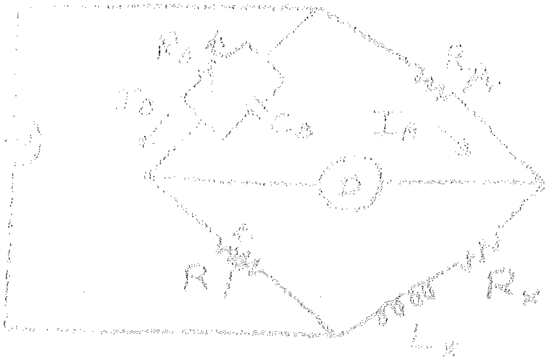
HERE, $C_A$ [illegible] $R_A$ AND C [illegible] AND THE [illegible] BALANCED? IF [illegible], FIND [illegible] OF $R_A$, $R_B$, [illegible]

(HINT: USE [illegible])

[illegible] CIRCUIT [illegible] CREATION [illegible]

HOMEWORK #5 SOLUTIONS (by Marcus F.

1)



(a) UNDER BALANCED CONDITIONS

1° $I_B Z_B = I_A R_A$

WHERE $Z_B = \frac{R_B/j\omega C_B}{R_B + \frac{1}{j\omega C_B}} = \frac{R_B}{1 + j\omega C_B R_B}$

AND 2° $I_B R = I_A Z_x$

WHERE $Z_x = R_x + j\omega L_x$

DIVIDING 1° BY 2° AND SOLVING FOR $Z_x$ GIVES:

$$Z_x = R_A R / Z_B = R_A R \left(j\omega C_B R_B + 1\right)/R_B$$

$$\Rightarrow R_x + j\omega L_x = \frac{R_A R}{R_B} + j\omega\left[C_B R R_A\right]$$

EQUATING REAL & IMAGINARY COMPONENTS:

$R_x = R_A R/R_B$ $\quad$ $L_x = C_B R R_A$

(b) $\epsilon[R_x] = [1 \pm 0.0001][1 \pm 0.0002][1 \pm 0.0002]$

$= 1 \pm 0.0005 \Rightarrow \pm 5\%$

$\epsilon[L_x] = [1 \pm 0.0005][1 \pm 0.0002][1 \pm 0.0001]$

$= 1 \pm 0.0008 \Rightarrow \pm 8\%$

(c) THERE IS NO DEPENDENCE ON $\omega$ OR $V_{in}$. IF WE SET EITHER TO ZERO, THEN ALL OUR EQUATIONS BECOME DEGENERATE, IN THE SENSE OF GOING TO ZERO, INFINITY, OR BEING UNDEFINED.

(a) WHEN THE VOLTAGE BETWEEN a & b IS ZERO, WE HAVE

$$\left.\begin{aligned} I_1 Z_a &= I_2 Z_b \\ I_1 Z &= I_2 Z_x \end{aligned}\right\} \Rightarrow \frac{Z_a}{Z} = \frac{Z_b}{Z_x} \Rightarrow Z_x = \frac{Z_b Z}{Z_a}$$

(b) NOTHING, THE POTENTIAL AT a & b IS THE SAME

(3)

USING RESULTS OF ②: IF BRIDGE IS BALANCED

$$Z_x = \frac{Z_b}{Z_a} Z$$

$$j\omega L_x = \frac{R_b}{R_a}\frac{1}{j\omega C}$$

$$-\omega L_x = \frac{R_a}{R_b}\frac{1}{\omega C} \Rightarrow L_x = -\frac{R_a}{R_b}\frac{1}{\omega^2 C}$$

BUT, ALL INDUCTANCE MUST BE POSITIVE THUS, WE CONCLUDE THAT THE BRIDGE CANNOT BE BALANCED.

[illegible] MARK[illegible]

(1) [illegible] VOLTAGE GAIN IS MANY TIMES EXPRESSED IN "DECIBELS" AS "db". THE DB GAIN, $A_{DB}$, IS RELATED TO THE GAIN $A_V = \left|V_{out}/V_{in}\right|$ BY THE RELATION

$$A_{DB} = 20 \log_{10} A_V$$

(a) DESIGN AN OP AMP BASIC INVERTING CIRCUIT WITH A GAIN OF $A_{DB} = 20$ db AND AN INPUT IMPEDANCE (RESISTANCE) OF $100\Omega$

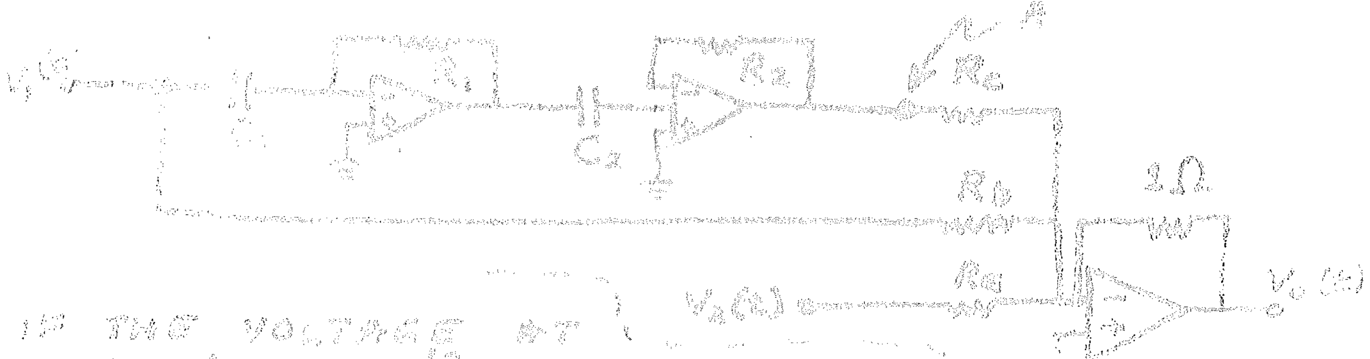
(b) SAME AS (a), BUT $A_{DB} = 40$ db

(c) IN GENERAL, IF WE DOUBLE THE db GAIN, $A_{DB}$, WHAT MUST WE DO TO THE GAIN, $A_V$?

(2) WE WISH TO COMBINE TWO VOLTAGES, $V_1(t)$ AN[illegible] $V_2(t)$ INTO $V_0(t)$ WHERE

$$V_0(t) = a V_2(t) + b V_1(t) + c \frac{d^2 V_1(t)}{dt^2}$$

WHERE a, b, AND c ARE KNOWN NEGATIVE CONSTANTS. THE FOLLOWING ANALOG COMPUTER WILL DO THE TRICK:



IF THE VOLTAGE AT POINT A IS $\frac{d^2}{dt^2} V_1(t)$, FIND THE REQUIRED RELATIONSHIP BETWEEN THE PARAMETERS $R_1$, $C_1$, $R_2$, $C_2$, $R_a$, $R_b$, AND $R_c$ WITH THE NEGATIVE CONSTANTS, a, b, AND c. [HINT: IF $V_A(t) = d^2 V_1/dt^2$, THEN $R_1 C_1 R_2 C_2$ = CONSTANT. FINDING THIS CONSTANT WILL BE THE SOLUTION TO HALF THIS PROBLEM. CONSTANT IS INDEPENDENT OF a, b, AND c]

( (a) OP AMPS AND ANALOG COMPUTERS CAN BE USED TO SOLVE DIFFERENTIAL EQUATIONS. CONSIDER:

$$\frac{d^2 v_1(t)}{dt^2} = -a_2 \frac{dv_1(t)}{dt} + a_1 v_1(t) - b\,u(t)$$

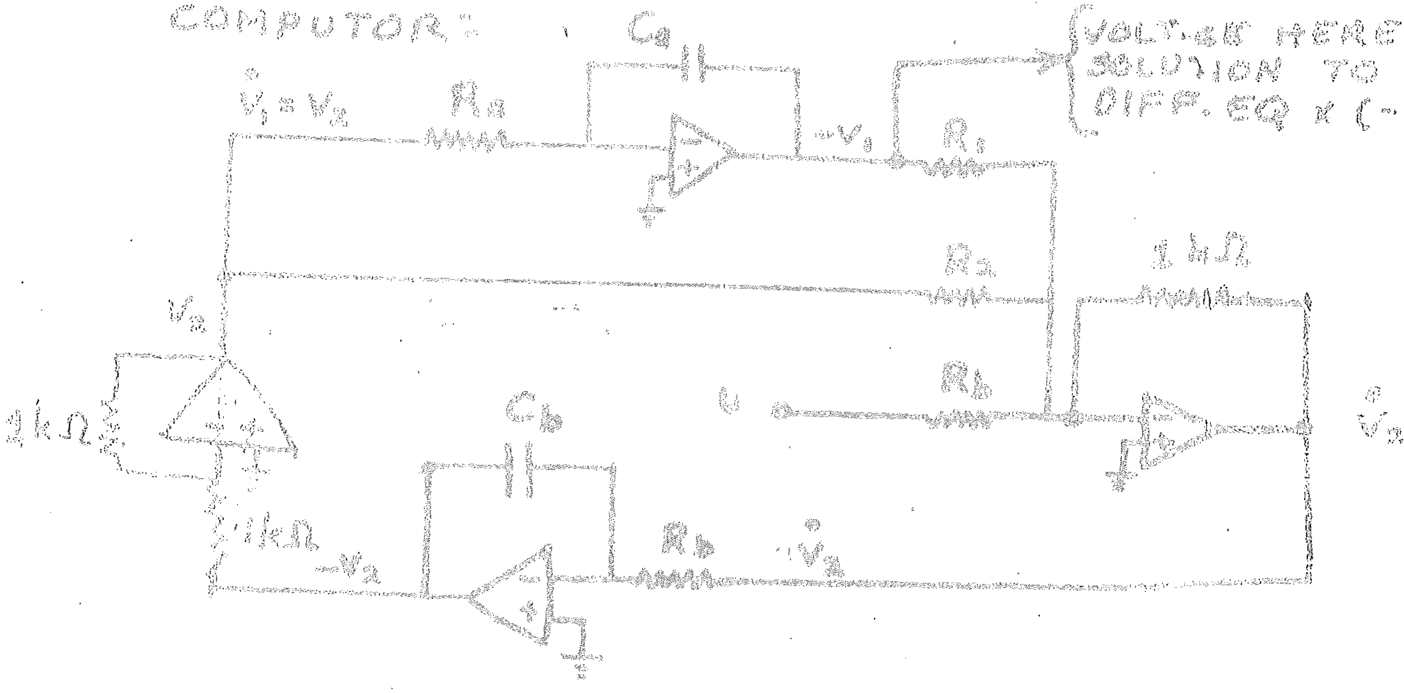
WE WISH TO FIND $V_1(t)$ FOR A GIVEN INPUT, (OR "FORCING FUNCTION") $V(t)$. LET

$V_2(t' = {}^{dv_1(t)}/_{dt}$ (a) SHOW THAT WE CAN COMBINE THESE ABOVE TWO RELATIONS INTO "STATE EQUATIONS":

$$\dot{V}_1 = a_1 V_1 - a_2 V_2 - bU$$

$$\dot{v}_1 = V_2 \qquad \left[ \dot{v} = {}^{dv}/_{dt} \right]$$

(b) ASSUMING ZERO INITIAL CONDITIONS, FIND THE RELATIONSHIPS BETWEEN THE CONSTANTS $a_1$, $a_2$, AND b AND THE R'S AND C'S IN THE FOLLOWING COMPUTOR:



VOLTAGE HERE IS SOLUTION TO DIFF. EQ × (-1)

( ASSUME THAT CONSTANTS $a_1$, b, AND $a_2$ ARE POSITIVE (HINT: AS AN EXAMPLE, $R_a C_a = 1$ AND $R_1 = (1/a_1)\,k\Omega$. USE VOLTAGES SHOWN ON CIRCUIT).

[illegible] (Ch 2.3) J. Mark.

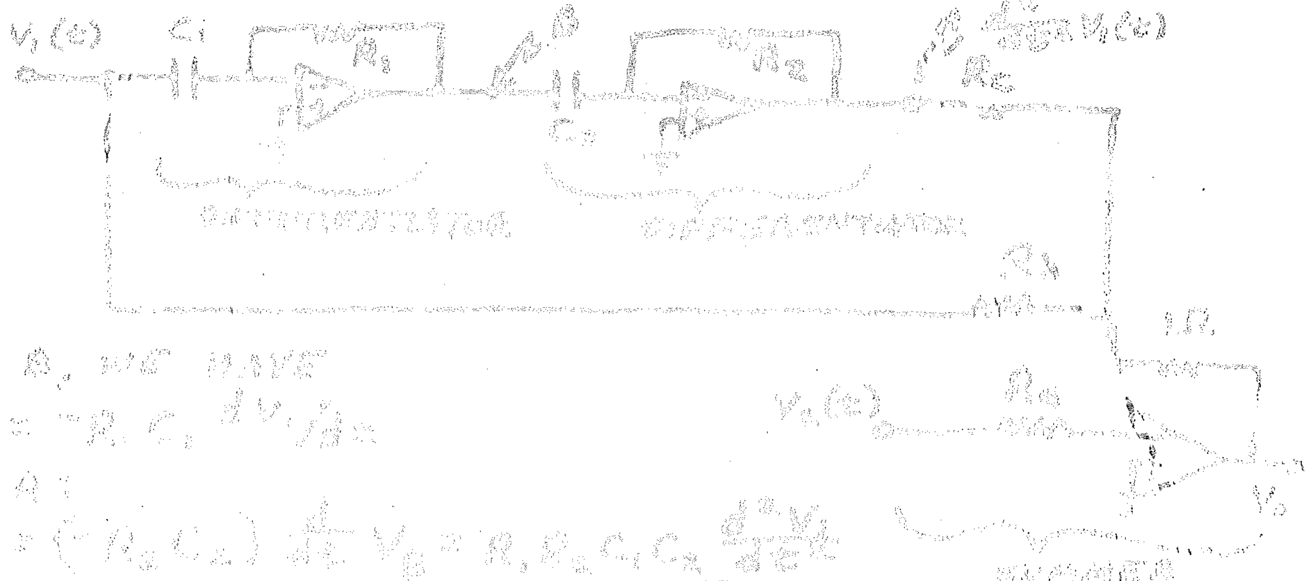
(1) 

IS STANDARD INVERTING CIRCUIT WITH GAIN $A_v = -R_2/R_1$ AND INPUT IMPEDANCE $R_1 = 1$ kΩ

(a) $A_{dB} = 20$dB ⇒ $|A_v| = 10$, SINCE $20 \log_{10} 10 = 20$
$|A_v| = R_2/R_1 = R_2/1000 = 10$, ⇒ $R_2 = 10^4\,\Omega = 10$ kΩ

(b) $A_{dB} = 40$dB ⇒ $|A_v| = 100$ SINCE $20 \log_{10} 10^2 = 40$
$|A_v| = R_2/100 = 100 \Rightarrow R_2 = 10^4 = 10$kΩ

(c) LET $|A_v|$ CORRESPOND TO $A_{dB} = 20 \log_{10} A_v$.
THUS $A_v = 10^{A_{dB}/20}$. LET $\hat{A}_{dB} = 2A_{dB}$. THEN
$\hat{A}_v = 10^{\hat{A}_{dB}/20} = 10^{2A_{dB}/20} = (10^{A_{dB}/20})^2 = A_v^2$.
THUS, IF WE DOUBLE $A_{dB}$, WE SQUARE $A_v$.

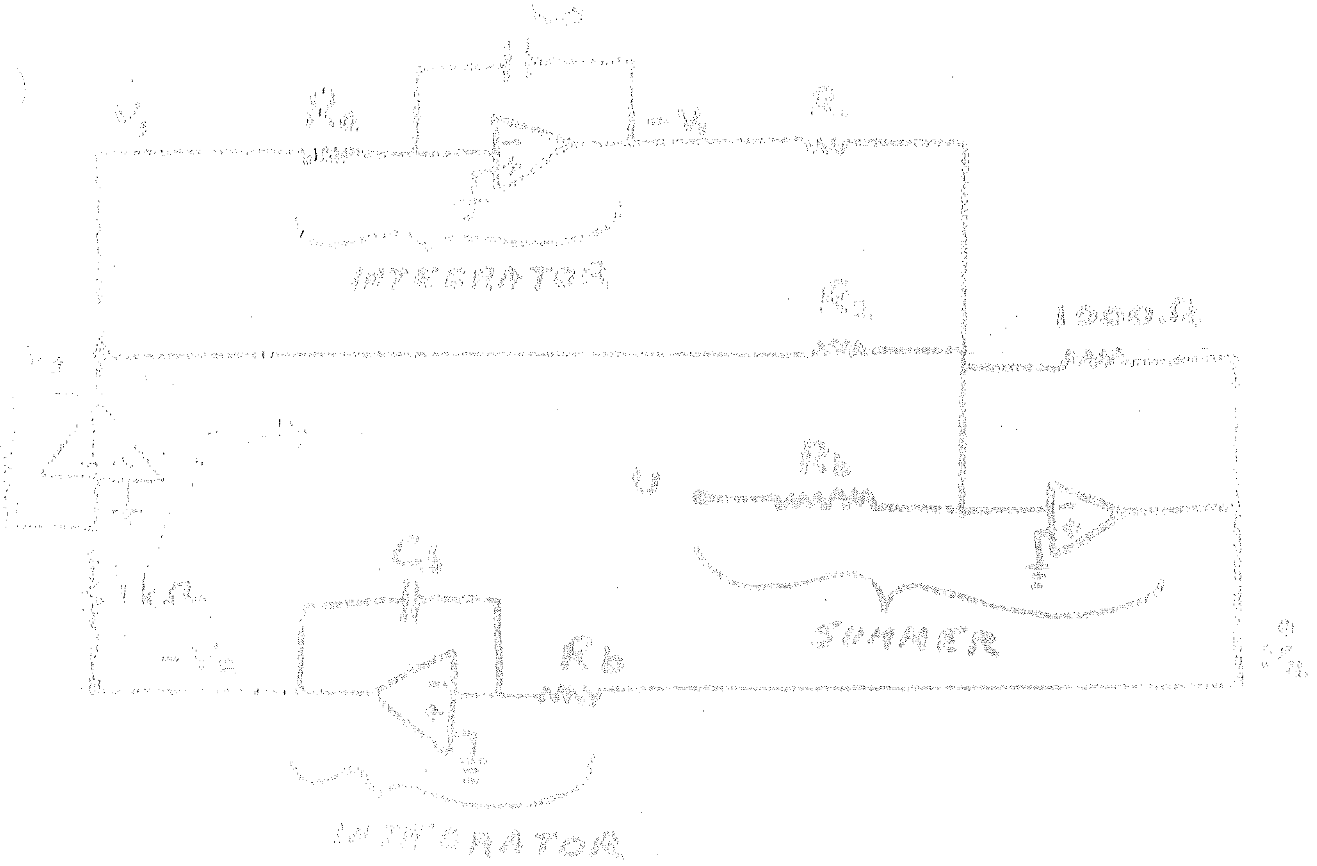
(2) 

AT B, WE HAVE
$V_B = -R_1 C_1\, dv_1/dt$
AT A:
$V_A = (-R_2 C_2)\frac{d}{dt}V_B = R_1 R_2 C_1 C_2 \frac{d^2 V_1}{dt^2}$
SINCE WE REQUIRE $V_A = d^2v_1/dt^2 \Rightarrow R_1R_2C_1C_2 = 1$.
SUMMER OUTPUT IS:

$$-\frac{V_o}{1\Omega} = \frac{V_A}{R_c} + \frac{V_1}{R_b} + \frac{V_2}{R_a}$$

OR $V_o = -\frac{1}{R_c}\frac{d^2V_1}{dt^2} - \frac{1}{R_b}V_1 - \frac{1}{R_a}V_2$

THUS, $c = -1/R_c$, $b = -1/R_b$, $a = -1/R_a$
OR $R_c = -1/c$, $R_b = -1/b$, $R_a = -1/a$



IN THE TOP MOST INTEGRATOR, IN ORDER TO HAVE $-V_1$ AS THE OUTPUT WITH $\dot{V}_1$ THE INPUT, WE MUST HAVE $R_a C_a = 1$. SIMILARLY, FOR THE BOTTOM INTEGRATOR, $R_b C_b = 1$. IN THE SUMMER, WE OBVIOUSLY WANT:

$$R_1 = (1/a_1)k\Omega, \quad R_2 = (1/a_2)k\Omega; \quad R_3 = (1/b)k\Omega$$

"PROVE ALL THINGS; HOLD FAST THAT WHICH IS GOOD"

-THES I: 5:21-

"NOTHING GREAT WAS EVER ACHIEVED WITHOUT ENTHUSIASM"

-EMERSON-

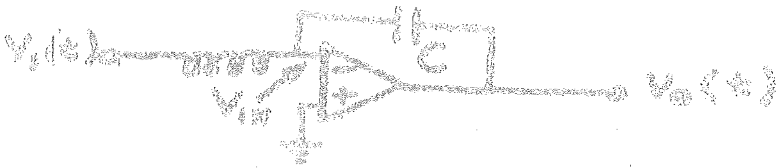
OLD EE PROVERB:

"HOMEWORK IS GOOD FOR YOU"

-OLD EE-

[illegible] (EE 234) MARKS

1. (a) DETERMINE THE RELATIONSHIP BETWEEN [illegible] AND $V_1(t)$ IN THE FOLLOWING OP AMP CIRCUIT (ASSUME $V_{in} \approx \int^{t}\int^{t} V_1\, dt\, dt \approx 0$). WHY MIGHT WE CALL THIS CIRCUIT A "DOUBLE INTEGRATOR"

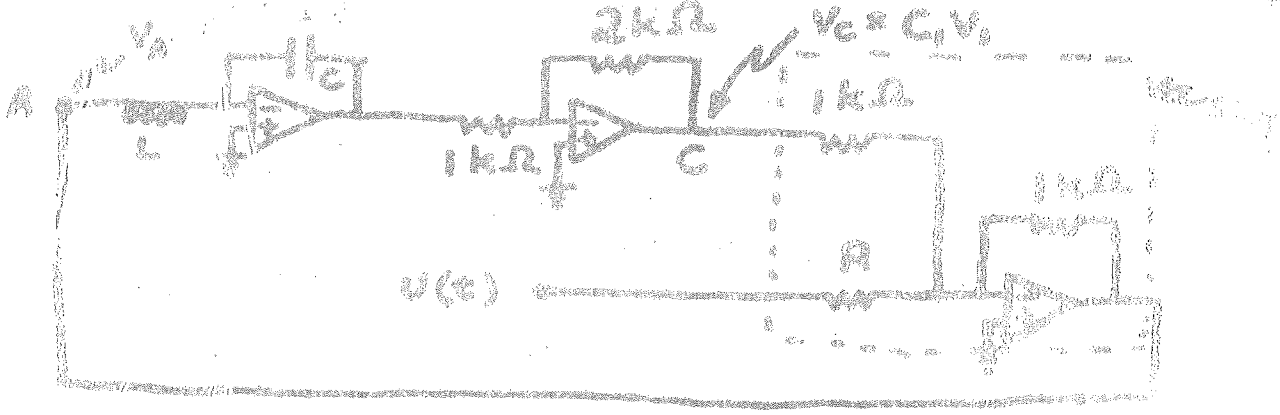


[HINT: YOU WILL NEED TO ASSUME THAT THE OP AMP INPUT CURRENT IS ≈ 0.]

(b) WE MAY USE THIS CIRCUIT TO SOLVE THE "DRIVEN WAVE EQUATION"

$$\frac{d^2V}{dt} = -a\,V(t) - b\,u(t)$$

WHERE $a$ & $b$ ARE POSITIVE KNOWN CONSTANTS AND $u(t)$ IS THE "INPUT" OR "DRIVING TERM".

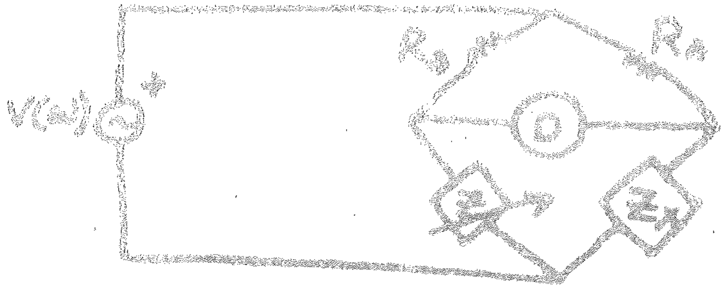


① GIVEN THAT THE VOLTAGE AT TERMINAL A $V_1 = LC\, d^2V_1/dt^2$, FIND THE NECESSARY INTERELATIONS BETWEEN R, L & C IN TERMS OF $a$ AND $b$

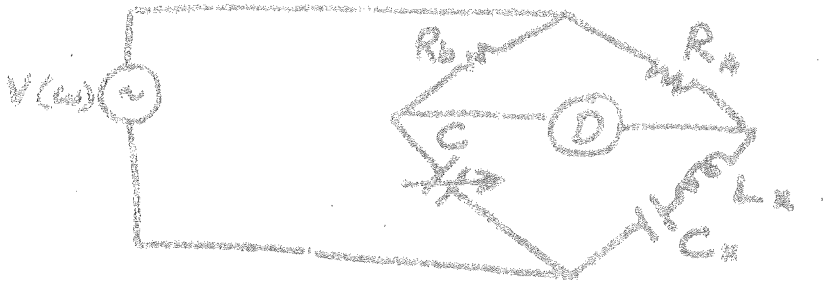
② THE VOLTAGE AT C IS PROPORTIONAL TO OUR SOLUTION. THAT IS, $V_C = C_1 V_1$. WHAT IS THE PROPORTIONALITY CONSTANT, $C_1$

2. WE SAY THAT AN IMPEDANCE, $Z = R + jX$, IS "INDUCTIVE" WHEN $X > 0$. FOR $X < 0$, Z IS "CAPACITIVE."

(a) FOR THE FOLLOWING IMPEDANCE BRIDGE, SHOW THAT, IN ORDER TO ACHEIVE BALANCE, Z AND $Z_x$ MUST BOTH EITHER BE INDUCTIVE OR BOTH CAPACITIVE



(b) FOR WHAT FREQUENCY RANGE WILL THE FOLLOWING BRIDGE BALANCE? [RECALL THA THE RESONANT FREQUENCY OF $L_x$ AND $C_x$ IS $\omega = 1/\sqrt{L_x C_x}$ ] USE THE RESULTS OF (C)]



(c) SHOW THAT, WHEN THE BRIDGE IS BALANCED THAT $L_x$ ANC $C_x$ ARE RELATED TO C AY

$$C = \frac{C_x}{1 - \omega^2 L_x C_x} \frac{R_B}{R_A}$$

WHERE $\omega$ LIES IN THE RANGE DERIVED IN (b).

(d) EXPLAIN WHY THIS BRIDGE (PARTS b & c) IS A POOR SCHEME FOR MEASURING UNKNOWNS $L_x$ AND $C_x$. (AT LEAST TWO REASONS).

3. (a) FOR A SIGNAL, $\sin \omega_m t$, OUR MODULATED SIGNAL:

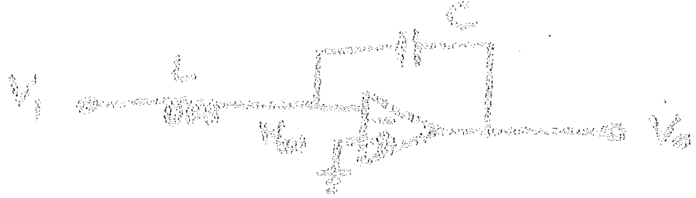
$$V_s(t) = [1 + m \sin \omega_m t]\{V_c \sin \omega_c t\}$$

WHERE $V_c \sin \omega_c t$ IS OUR CARRIER AND $m$, OUR DEGREE OF MODULATION. IF $m > 1$, THE SIGNAL IS SAID TO BE OVER-MODULATED. SHOW, GRAPHICALLY, THAT OVERMODULATION "DISTORTS" OUR SIGNAL. [NOTE: ON THE MODULAT WAVEFORM, OUR SIGNAL IS THE ENVELOPE]

(b) A GOOD QUALITY ACOUSTIC REPRODUCTION SHOULD CONTAIN FREQUENCIES UP TO 20,000 HZ. HOW MANY SUCH SEPARATE REPRODUCTIONS CAN BE SENT OVER A CHANNEL WHOSE FREQUENCY CAPACITY RANGES FROM 0 TO 8 MEGA-HZ?

HOMEWORK #7 SOLUTIONS (by Mark

(2) (a)



SUMMING CURRENTS AT $V_{IN}$:

$$\frac{1}{L}\int^t (V_1 - V_{IN})\,dt + C\left[\frac{dV_o}{dt} - \frac{dV_{IN}}{dt}\right] = 0$$

(THE INPUT CURRENT TO OP AMP ≈ 0)

THUS: $$\frac{d(V_o - V_{IN})}{dt} = \frac{-1}{LC}\int^t (V_1 - V_{IN})\,dt$$

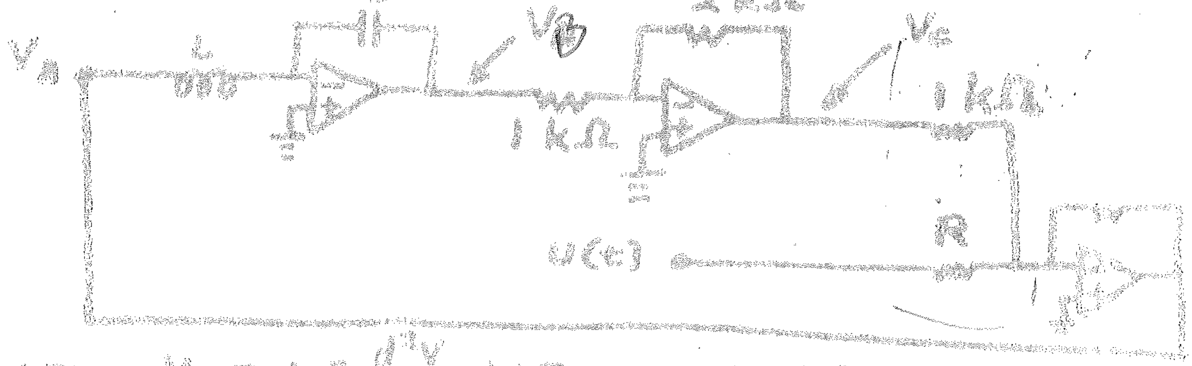
$$\Rightarrow V_o - V_{IN} = \frac{-1}{LC}\int^t\int^t (V_1 - V_{IN})\,dt\,dt$$

OR, SINCE $V_{IN} \approx \int^t\int^t V_{IN}\,dt\,dt \cong 0$:

$$V_o(t) = \frac{-1}{LC}\int^t\int^t V_1(t)\,dt\,dt$$

WE PERFORM A DOUBLE INTEGRATION ON THE INPUT, THUS "DOUBLE INTEGRATOR"

(b)



GIVEN $V_A = LC\frac{d^2V}{dt^2}$, WE HAVE FROM (a) THAT $V_B = -V_1$. THE AMP FOLLOWING HAS A GAIN OF -2. THUS, $V_C = 2V_1$ (AND $C_1 = 2$). THE OUTPUT OF THE SUMMER IS:

$$\frac{V_D}{k\Omega} = \frac{-V_C}{1k\Omega} - \frac{u(t)}{R} \Rightarrow V_D = -V_C - \frac{1k\Omega}{R}u(t)$$

BUT $V_D = V_A = LC\frac{d^2V}{dt^2} = -V_C - \frac{1k\Omega}{R}u(t)$

OR $$\frac{d^2V}{dt^2} = \frac{-1}{LC}V_C - \frac{1k\Omega}{RLC}u(t)$$

IN ORDER FOR THIS TO BE OUR DIFF. EQ:

$$? = \frac{1}{LC}\;,\quad b = \frac{1k\Omega}{RLC} = \frac{a(1k\Omega)}{R}$$

2. (a) WHEN THE BRIDGE IS BALANCED:

$$Z_x = Z \; R_A/R_B$$

LET $Z_x = R_x + jX_x$ AND $Z = R + jX$. EQUATING IMAGINARY PARTS:

$$X_x = \frac{R_A}{R_B} X$$

THUS, IF $X > 0$, THEN $X_x > 0$ (ie, BOTH $Z$ AND $Z_x$ ARE INDUCTIVE). IF $X < 0$, THEN $X_x < 0$ (ie, BOTH $Z$ AND $Z_x$ ARE CAPACITIVE).

(b) FOR THIS CIRCUIT:

$$X = \frac{-1}{\omega C} \qquad X_x = (\omega L_x - \frac{1}{\omega C_x})$$

SINCE, FROM (a), $X_x$ MUST BE NEGATIVE:

$$\omega L_x - \frac{1}{\omega C_x} < 0$$

$$\omega L < \frac{1}{\omega_x C_x} \Rightarrow \omega^2 < \frac{1}{L_x C_x}$$

$$\therefore \; \omega < \frac{1}{\sqrt{L_x C_x}}$$ = RESONANCE OF $L_x$ & C

(c) AT BALANCE:

$$Z_x = Z \; R_A/R_B$$

$$j(\omega L_x - \frac{1}{\omega C_x}) = -j \frac{R_A}{R_B} \frac{1}{\omega C}$$

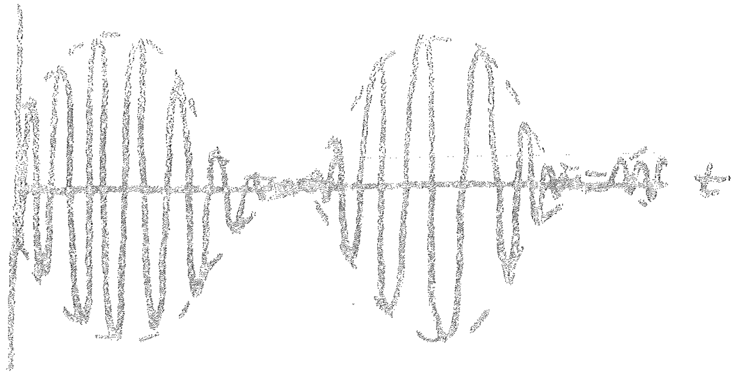
$$\frac{1}{\omega C_x} - \omega L_x = \frac{R_A}{R_B} \frac{1}{\omega C}$$

SOLVING FOR C:

$$C = \frac{C_x}{1 - \omega^2 L_x} \; \frac{R_B}{R_A}$$

(d) THE VALUES OF $L_x$ & $C_x$ ARE NOT UNIQUELY DETERMINED AND THE RESULT IS FREQUENCY DEPENDENT.

3. (a) FOR $m=1$, THE MODULATED SIGNAL LOOKS LIKE



FOR $m>1$:

THE ENVELOPE (OUR SIGNAL) IS DISTORTED

(b) $N = \frac{3 \times 10^6}{2(2 \times 10^4)} = 2 \times 10^2 = 200$ REPRODUCTION

HOMEWORK # 8 (EE 284) MARKS

1. CONSIDER THE FOLLOWING GROUPING OF NUMBERS.

⓪ 1, 3, 5, 7, 9, 11, 13, 15
① 2, 3, 6, 7, 10, 11, 14, 15
② 4, 5, 6, 7, 12, 13, 14, 15
③ 8, 9, 10, 11, 12, 13, 14, 15

IF ONE PICKS A NUMBER BETWEEN 1 AND 15, AND SPECIFIES WHICH OF THE ABOVE ROWS IT IS CONTAINED IN, THE UNKNOWN NUMBER CAN BE COMPUTED BY ADDING THE FIRST NUMBERS IN EACH ROW. FOR EXAMPE, THE NUMBER 13 IS IN ROWS ⓪, ② AND ③. THE FIRST NUMBERS OF THESE ROWS ARE 1, 4, AND 8 AND 1+4+8=13.

(a) EXPLAIN WHY THIS WORKS [HINT: USE BINARY NUMBERS IN YOUR REASONING]

(b) MAKE A SIMILAR TABLE UP TO AND INCLUDING THE NUMBER 31. [HINT: IT WILL HAVE FIVE ROWS WITH 16 NUMBERS IN EACH ROW. HINT HINT: NOTICE THE PATTERN OF THE ROWS (LEFT TO RIGHT).]

2. A CODE WHICH CAN DETECT AND CORRECT A SINGLE BIT ERROR, CALLED THE "HAMMING" CODE, USES THE ABOVE IDEA. SUPPOSE WE WANTED TO SEND AN ELEVEN BIT CODE: 1 1 1 0 0 1 1 1 1 1 0. WE BREAK IT UP INTO THE FOLLOWING:

|  | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BINS → | 1 | 1 | 1 | 0 | 0 | 1 | 1 | $P_3$ | 1 | 1 | 1 | $P_2$ | 0 | $P_1$ | $P_0$ |

NOTE THAT, FOR THE $2^n$TH PLACE, WE HAVE PUT $P_n$ (EX: AT $2^2=4$, WE PUT $P_2$). THESE P'S ARE "PARITY" BITS. NOW WE GO TO COLUMN ⓪ IN PROBLEM 1. WE WANT THE BINS IN THIS ROW TO CONTAIN AN EVEN NUMBER OF 1'S. WE SEE THAT THERE ARE, IN FACT, AN ODD NUMBER (5) ONES IN BINS 15, 13, 11, 9, 7, 5, AND 3. THUS, WE MUST CHOOSE $P_0=1$ SO THAT THE TOTAL NUMBER OF ONES IS EVEN. FOR ROW ① IN PROBLEM 1, BINS 15, 14, 11, 10, 7, 6, AND 3 CONTAIN AN ODD NUMBER (5) OF 1'S SO WE MUST ALSO MAKE $P_1=1$.

(a) SHOW THAT $P_2=0$ AND $P_3=1$ SO THAT OUR TOTAL CODE IS 111 0011 1110 011.

(b) PERFORM A HAMMING CODING ON THE ELEVEN BIT WORD 10101010101.

3. AT THE RECEIVING END OF A HAMMING CODE, WE CAN DETECT AND CORRECT A SINGLE BIT ERROR. SUPPOSE WE SENT THE WORD IN PROBLEM 2 AND RECEIVED

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| | | | | | | | $P_3$ | | | | $P_2$ | | $P_1$ | $P_0$ |

(a) GOING THROUGH THE PROCEDURE IN PROBLEM 2, SHOW THAT THIS WORD SHOULD HAVE PARITY BITS $P_0 = 1$, $P_1 = 0$, $P_2 = 1$, $P_3 = 1$. NOW COMPARE THESE PARITY BITS WITH THOSE RECEIVED ⇒

RECEIVED $\rightarrow P_3P_2P_1P_0 = 1\ 0\ 1\ 1$

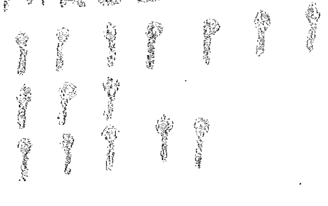
SHOULD BE $\rightarrow P_3P_2P_1P_0 = \underline{1\ 1\ 0\ 1}$

BITS DIFFERING ⟶ 0110

BY "BITS DIFFERING" WE MEAN 0 WHEN $P_n$ MATCHES AND 1 WHEN THEY'RE DIFFERENT. NOTE $(0110)_2 = 6$. THUS, OUR ERROR IS IN BIN 6. COMPARING THE ABOVE RECEIVED CODE TO OUR TRANSMITTED CODE IN PROBLEM 2, WE SEE THAT THIS IS TRUE. (NEAT, HUH?)

(b) IN YOUR HAMMING CODE DERIVED IN 2(b), MAKE AN ERROR IN BIN 13. BE A RECEIVER AND CORRECT YOUR MISTAKE AS WAS DONE IN PART a OF THIS PROBLEM.

4. (EXTRA CREDIT) NIM IS AN OLD CHINESE GAME WHERE THREE ROWS OF MATCHSTICKS ARE LAID OUT. ANY NUMBER OF MATCHSTICKS CAN BE IN ANY ROW. TWO PLAYERS ALTERNATE TURNS. DURING A TURN, A PLAYER CAN TAKE AS MANY MATCHSTICKS FROM ANY ONE ROW AS HE DESIRES. HE MUST TAKE AT LEAST ONE MATCHSTICK. THE PLAYER WHO PICKS UP THE LAST MATCHSTICK OR GROUP OF MATCHSTICKS WINS. BY USING BINARY NUMBERS, YOU CAN ALWAYS WIN (BELEIVE IT OR NOT). CONSIDER THE FOLLOWING "GAME BOARD" OF THREE ROWS OF MATCHSTICKS:



$\rightarrow 7 = (1\ 1\ 1)_2$

$\rightarrow 3 = (0\ 1\ 1)_2$

$\rightarrow 5 = \underline{(1\ 0\ 1)_2}$

2 2 3 ← SUM (GAME #)

NOTE THAT FOR EACH ROW, WE HAVE CONVERTED THE NUMBER OF MATCHSTICKS TO BASE 2 AND HAVE ADDED THEM (IN BASE 10) TO ARIVE AT WHAT WE SHALL CALL THE GAME # (NUMBER). IF THE GAME NUMBER CONTAINS ONLY 0'S AND 2'S, IT IS "SAFE", OTHERWISE (IE IT CONTAINS ONE OR MORE 1'S OR 3'S), IT IS "UNSAFE". HERE IS THE BASIS FOR ALWAYS WINNING NIM: BY THE GAME RULES, IT IS ALWAYS POSSIBLE TO CHANGE AN UNSAFE NUMBER TO A SAFE NUMBER BUT IS IMPOSSIBLE TO CHANGE A SAFE NUMBER INTO ANOTHER SAFE NUMBER.* (THIS IS A VERY HAIRY PROOF WHICH WE WILL NOT GO INTO). THUS, IN PLAYING, THE GAME NUMBER ALTERNATES BETWEEN SAFE AND UNSAFE UNTIL THE WINNING SAFE NUMBER OF 0 IS REACHED.

IN THE GAME BOARD AT THE BOTTOM OF THE PREVIOUS PAGE, THE GAME NUMBER CAN BE MADE SAFE BY TAKING ONE MATCHSTICK FROM THE THIRD ROW. THE NEW GAME NUMBER WILL BE 222.

(a) OBVIOUSLY, IF YOU PLAY NIM WITH ANOTHER PERSON WHO KNOWS HOW TO PLAY, YOU WON'T ALWAYS WIN. IN THIS CASE, HOW DOES THE INITIAL GAME BOARD AND WHO GOES FIRST DETERMINE WHO WINS?

(b) FOR THE FOLLOWING GAME BOARDS, DETERMINE IF THE GAME # IS SAFE OR UNSAFE. IF UNSAFE, TAKE A TURN & MAKE IT SAFE

(1)


(2)


(3)


(c) PLAY AND BEAT SOMEONE WHO DOESN'T KNOW HOW TO PLAY AT LEAST FIVE TIMES.

[*YOU CAN, HOWEVER, MAKE AN UNSAFE # FROM ANOTHER UNSAFE #]

HOMEWORK #8 - SOLUTIONS (by [illegible])

1.(a) CONSIDER THE NUMBER $13 = (1011)_2$. IT HAS 1'S IN THE $2^0, 2^2,$ AND $2^3$ PLACES, AND THUS 13 IN THE ⓪, ②, AND ③ ROWS. IN SHORT, ROW ⓝ CONTAINS ALL THOSE BINARY NUMBERS THAN HAVE A 1 IN THE $2^n$ PLACE.

(b)
⓪ 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31
① 2, 3, 6, 7, 10, 11, 14, 15, 18, 19, 22, 23, 26, 27, 30, 31
② 4, 5, 6, 7, 12, 13, 14, 15, 20, 21, 22, 23, 28, 29, 30, 31
③ 8, 9, 10, 11, 12, 13, 14, 15, 24, 25, 26, 27, 28, 29, 30, 31
④ 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31

2.(a) ROW ② IN PROBLEM (1A) HAS NUMBERS 4, 5, 6, 7, 12, 13, 14, & 15. THE BITS IN THE RESPECTIVE BINS ARE $P_2$, 1, 1, 1, 0, 1, 1, 1 = (6 ONE'S AND $P_2$) THE NUMBER OF ONE'S IS EVEN, SO LET $P_2 = 0$. FOR ③, WE HAVE BINS 8 THRU 15 WHICH HAVE 5 ONE'S AND $P_3$. TO MAKE THE NUMBER OF ONE'S EVEN, $P_3 = 1$.

(b)

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | $P_3$ | 0 | 1 | 0 | $P_2$ | 1 | $P_1$ | $P_0$ |

FOR ⓪ : $P_0$, 1, 0, 0, 1, 1, 1, 1 $\Rightarrow P_0 = 1$ (6 ONES)
① : $P_1$, 1, 1, 0, 0, 1, 0, 1 $\Rightarrow P_1 = 0$ (4 ONES)
② : $P_2$, 0, 1, 0, 0, 1, 0, 1 $\Rightarrow P_2 = 1$ (4 ONES)
③ : $P_3$, 1, 0, 1, 0, 1, 0, 1 $\Rightarrow P_3 = 0$ (4 ONES)

OUR CODE IS THUS
1 0 1 0 1 0 1 0 0 1 0 1 1 0 1

(3)(a) FOR ⓪ : $P_0$, 0, 1, 1, 1, 0, 1, 1 $\Rightarrow P_0 = 1$
① : $P_1$, 0, 0, 1, 1, 0, 1, 1 $\Rightarrow P_1 = 0$
② : $P_2$, 1, 0, 1, 0, 1, 1, 1 $\Rightarrow P_2 = 1$
③ : $P_3$, 1, 1, 0, 0, 1, 1, 1 $\Rightarrow P_3 = 1$

(b)

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
|  |  | ↑ ERROR |  |  |  |  | ↑ $P_3$ |  |  |  | ↑ $P_2$ |  | ↑ $P_1$ | ↑ $P_0$ |

PARITY BITS SHOULD BE

⓪: $P_0$, 1, 0, 0, 1, 1, 0, 1 $\Rightarrow P_0=0$

①: $P_1$, 1, 1, 0, 0, 1, 0, 1 $\Rightarrow P_1=0$

②: $P_2$, 0, 1, 0, 0, 0, 0, 1 $\Rightarrow P_2=0$

③: $P_3$, 1, 0, 1, 0, 0, 0, 1 $\Rightarrow P_3=1 \Rightarrow P_3P_2P_1P_0=1000$

RECEIVED PARITY BITS ARE: $P_3P_2P_1P_0=\underline{0101}$

BITS DIFFERING $\Rightarrow$ 1101

THUS, WE HAVE AN ERROR IN BIN $(1101)_2=13$.

4.(a) A "WHO WINS TABLE" $\Rightarrow$

| INITIAL GAME IS | YOU | OTHER |
|---|---|---|
| SAFE | OTHER | YOU |
| UNSAFE | YOU | OTHER |

(b) (1)

$5 \rightarrow 101$

$5 \rightarrow 101$

$2 \rightarrow \underline{\ \ 10}$

$212$

UNSAFE.
MAY MAKE IS SAFE BY TAKING ALL THE MATCHSTICKS FROM THIRD COLUMN. NOTE: THERE IS USUALLY MORE THAN ONE WAY TO MAKE AN UNSAFE NUMBER SAFE.

(2)

$3 \rightarrow 011$

$6 \rightarrow 110$

$1 \rightarrow \underline{001}$

$122$

UNSAFE. MAY TAKE FOUR FROM SECOND ROW TO GIVE:

$3 \rightarrow 011$

$2 \rightarrow 010$

$1 \rightarrow \underline{001}$

$022 \leftarrow$ SAFE

(3)

$2 \rightarrow 010$

$6 \rightarrow 110$

$4 \rightarrow \underline{100}$

$220 \leftarrow$ SAFE

## Psalm of the Twenty-third year

[illegible] my instructor;
I shall not pass.
He maketh me to exhibit mine ignorance before the
whole class.
He telleth me more than I can write,
He lowereth my grade.
Yea, tho I walk thru the corridors of knowledge,
I do not learn.
He tries to teach me;
He writeth equations before me in hopes that I will
understand them.
He bewildereth my head with integrations.
My slide rule freezeth up.
Surely enthalpies and entropies shall follow me all the
days of my life,
And I shall dwell in the College of Engineering forever.

—Anonymous

(LAST) HOMEWORK #7 (EE 234) BOB MARKS 4-26-7

(1) CONSIDER A BINARY SYMMETRIC CHANNEL OVER WHICH WE SEND AN ELEVEN BIT BINARY SIGNAL. ASSUME $p = q = 0.9$ WHERE $p = P_r[0_R/0_T]$ AND $q = P_r[1_R/1_T]$. ASSUME $p_0 = P_r[0_T] = 1/2$ AND $p_1 = P_r[1_T] = 1/2$.

(a) WHAT IS THE PROBABILITY NO ERROR IS MADE IN TRANSMITTING THIS SIGNAL OF ELEVEN BITS?

(b) SUPPOSE WE CODED THE ELEVEN BIT SIGNAL WITH A HAMMING CODE. THIS REQUIRES AN ADDITIONAL FOUR (PARITY) BITS FOR A TOTAL OF FIFTEEN BITS. FIND THE PROBABILITY THAT WE WILL BE ABLE TO EXACTLY CONSTRUCT THE SIGNAL SENT. SINCE THE HAMMING CODE CAN DETECT AND CORRECT A ONE BIT ERROR, THIS PROBABILITY WILL BE

$P_r$[NO BIT ERRORS] + $P_r$[1 BIT ERROR]

(c) IN (a), WE TRANSMIT DIRECTLY. IN (b), WE USE A HAMMING CODE WHICH REQUIRES THE TRANSMISSION OF MORE BITS. IN TERMS OF CORRECTLY DETECTING WHAT WAS SENT, WHICH IS BETTER?

(2) USING TRUTH TABLES, VERIFY DeMORGAN'S THEM:

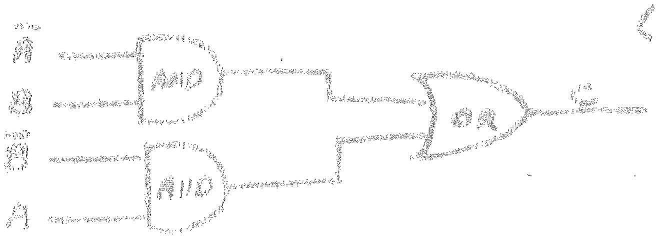
(a) $\overline{AB} = \overline{A} + \overline{B}$ HINT:

(b) $\overline{A+B} = \overline{A}\,\overline{B}$

| $A$ | $B$ | $AB$ | $\overline{AB}$ | $\overline{A}$ | $\overline{B}$ | $\overline{A}+\overline{B}$ |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 |

(3) SHOW THAT THE FOLLOWING IS THE SAME AS AN EXCLUSIVE OR GATE. THAT IS, $C = A \oplus B$

(HINT: USE TRUTH TABLE)



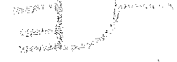
(4) USING ONLY "AND" AND "OR" GATES (INCLUSIVE), DESIGN A CIRCUIT THAT FOLLOWS THE TRUTH TABLE ⟹ (CAN USE "NOT" GATES TOO)

| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

(5) SAME AS (4), BUT TRUTH TABLE IS:

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 |

(YOU MAY USE MULTI-TERMINAL GATES, LIKE



IF YOU WANT (THESE PROBLEMS ARE EASY)

EXTRA CREDIT: SPECIFY THE PERFORMANCE OF A "BUT" GATE, THAT IS, C = A BUT B.

HOMEWORK [illegible]

(1) (a) FOR $p = 0.9$ THE PROBABILITY ALL BITS WILL BE CORRECTLY RECEIVED IS

$(p)^{11} = (0.9)^{11} = 0.3138$ OR ~ 31%

[THIS COMPUTATION REQUIRES $p_0 = p_1 = 1/2$]

(b) $Pr$[NO ERRORS] $= (0.9)^{15} = 20.59\%$

$Pr$[1 BIT ERROR] = $Pr$[ONLY FIRST BIT IS WRONG]
+ $Pr$[ONLY SECOND BIT IS WRONG] + ...
+ $Pr$[ONLY 15TH BIT IS WRONG]

$= (1-p)\, p \cdot p \cdots p + p(1-p)\, p \cdots p + \ldots + p \cdot p \cdot p \cdots (1-p)$

$= 15 \times [(1-p)\, p^{14}]$

$= 15(0.1)(0.9)^{14} = 1.5 \times (0.9)^{14}$

$\Rightarrow Pr$[CORRECT DETECTION] $= (0.9)^{15} + 1.5 \times (0.9)^{14}$

$= [0.9 + 1.5] \times (0.9)^{14} = 0.5490 \sim 55\%$

(c) HAMMING CODE IS BETTER. IT INCREASES OUR PROBABILITY OF CORRECT DETECTION BY OVER 20%.

(2)(a) $\overline{AB} = \bar{A} + \bar{B}$

| $A$ | $B$ | $AB$ | $\overline{AB}$ |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 |

| $\bar{A}$ | $\bar{B}$ | $\bar{A}+\bar{B}$ | $A$ | $B$ |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 |

OBVIOUSLY, $\overline{AB} = \bar{A} + \bar{B}$

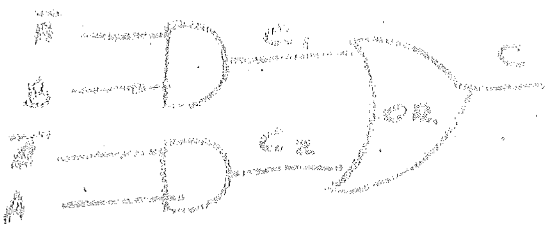
(b) $\overline{A+B} = \bar{A}\bar{B}$

| $A$ | $B$ | $A+B$ | $\overline{A+B}$ |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 |

| $\bar{A}$ | $\bar{B}$ | $\bar{A}\bar{B}$ | $A$ | $B$ |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 |

$\therefore \overline{A+B} = \bar{A}\bar{B}$.

(3) USING THE GATES SHOWN:



$C = C_1 + C_2$
$= \bar{A}B + \bar{B}A$

| $A$ | $B$ | $\bar{A}B$ | $\bar{B}A$ | $C = A\bar{B} + \bar{A}B$ |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 | 0 |

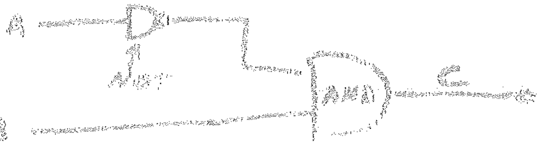
THE VALUES OF C ARE THE SAME AS FOR AN EXCLUSIVE OR GATE.

(4)

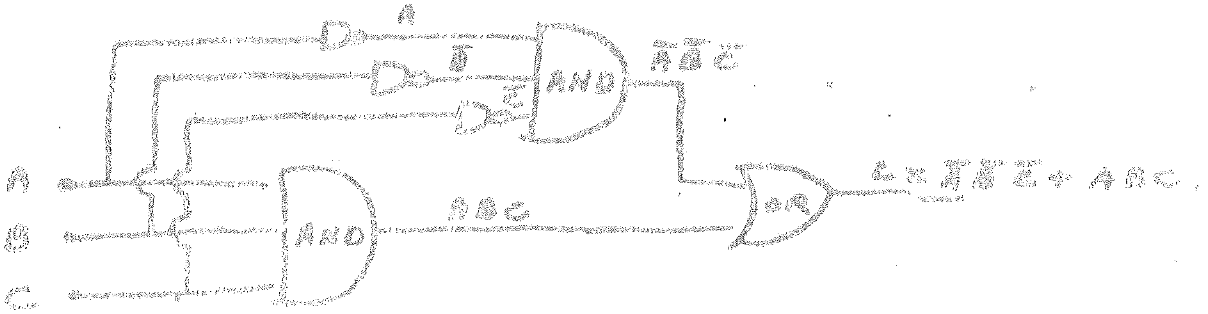
| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

$\Rightarrow C = \bar{A}B$

OR



(5) $D = ABC + \bar{A}\bar{B}\bar{C}$



END OF 234 HOMEWORK!!

A FINAL NOTE OR TWO

- "TAKE WARNING! ALTERNATING CURRENTS ARE DANGEROUS! THEY ARE FIT ONLY FOR POWERING THE ELECTRIC CHAIR. THE ONLY SIMILARITY BETWEEN AN A-C AND A D-C LIGHTING SYSTEM IS THAT BOTH START FROM THE SAME COAL PILE"

  THOMAS ALVA EDISON (1887 PAMPHLET)

- DID YOU KNOW A 100 WATT BULB GIVES OFF 50% MORE LIGHT THAN FOUR 25 WATT BULBS?

"BEAR YE ONE ANOTHER'S BURDEN'S, AND SO FULFILL THE LAW OF CHRIST"

GAL 6:2.

NAME

# TEST 1

EE 234
BOB MARKS
2/17/77

INSTRUCTIONS:

- WORK ALL FIVE PROBLEMS. DO YOUR WORK ON THE BLANK PAGES PROVIDED IN THIS BOOKLET. BUDGET YOUR TIME CAREFULLY.
- THE POINT VALUE OF EACH PROBLEM IS GIVEN AT THE TOP RIGHT CORNER OF EACH PROBLEM STATEMENT. THERE ARE 100 POINTS TOTAL
- THIS TEST IS OPEN BOOK, OPEN NOTES, CLOSED NEIGHBOR.

BEST OF LUCK

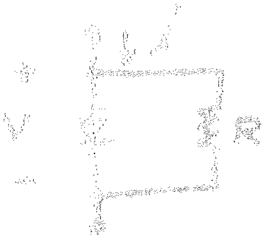
| PROBLEM | SCORE | OUT OF |
|---|---|---|
| 1 | | 15 |
| 2 | | 15 |
| 3 | | 25 |
| 4 | | 25 |
| 5 | | 20 |
| | TOTAL | 100 |

"THE THREE FOUNDATIONS OF LEARNING: SEEING MUCH, SUFFERING MUCH, AND STUDYING MUCH"

CATHERALL

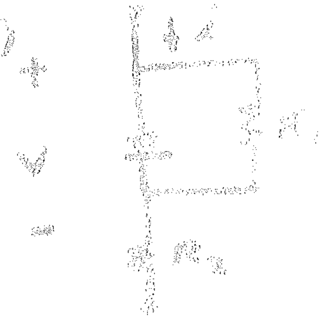
SKETCH THE v-i CURVES FOR THE FOLLOWING RESISTOR-DIODE COMBINATIONS. ASSUME AN IDEAL DIODE. USE i AS VERTICAL AXIS.

(a)

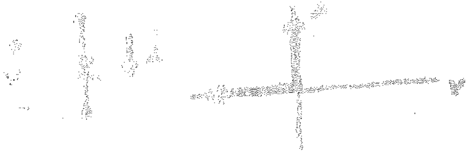


(b)

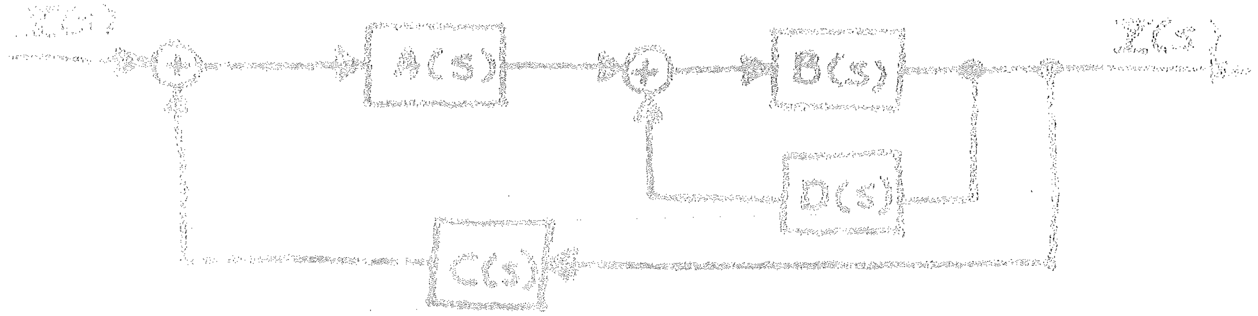
(c)



HINTS:

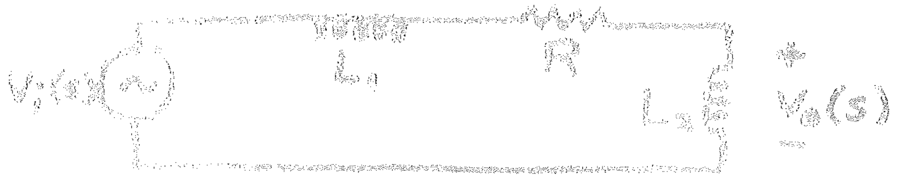


FOR THE FOLLOWING FEEDBACK SYSTEM, FIND THE TRANSFER FUNCTION $T(s) = Y(s)/X(s)$



HINT: USE THE RESULT OF THE FEEDBACK PROBLEM GIVEN AS HOMEWORK

FOR THE FOLLOWING CIRCUIT (25



(a) COMPUTE THE TRANSFER FUNCTION $T(s) = \frac{V_o(s)}{V_i(s)}$

(b) COMPUTE $V_o(t)$ GIVEN THAT $V_i(t) = V_m \mu(t)$
[$\mu(t)$ = UNIT STEP FUNCTION]

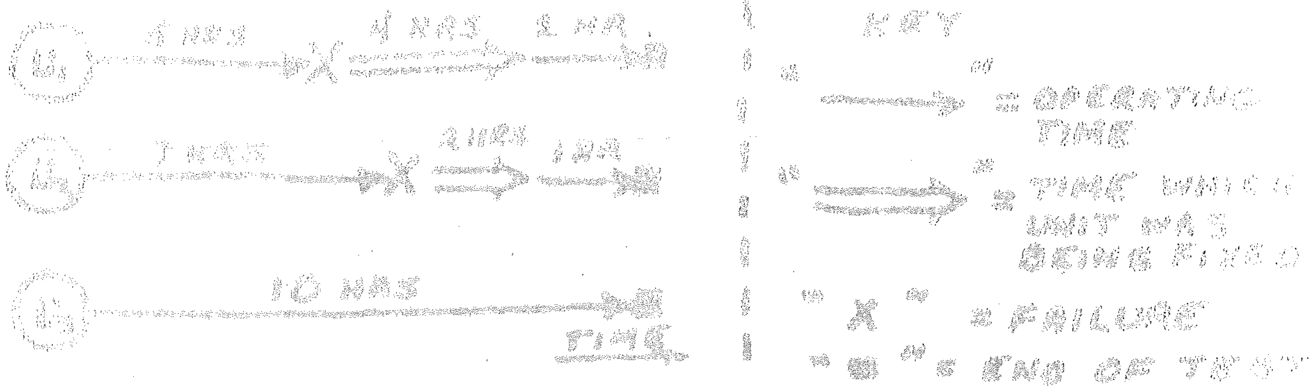
(c) SKETCH THE FREQUENCY RESPONSE $|T(j\omega)|$ NOTING ITS VALUES AT $\omega = 0$ AND $\omega = \infty$

(d) WHAT TYPE OF FILTER IS THIS?
LO PASS, BANDPASS, OR HI PASS?

ME LAPLACE XFORMS

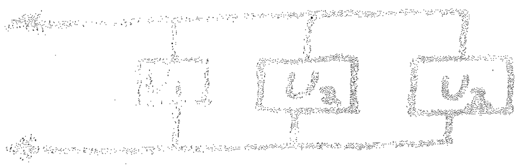
| $x(t)$ | $\mathcal{L}[x(t)]$ |
|---|---|
| $\mu(t)$ | $1/s$ |
| $e^{-at}$ | $1/(s+a)$ |
| $\cos at$ | $s/(s^2+a^2)$ |

(a) THREE IDENTICAL UNITS ARE PLACED ON TEST FOR 10 HOURS EACH. THE RESULTS ARE SHOWN BELOW;



COMPUTE THE UNITS' MTBF, MTTR, AND AVAILABILITY AS ESTIMATED BY THIS TEST.

(b) SUPPOSE THE UNITS TESTED IN (a) WERE CONNECTE IN THE SYSTEM SHOWN. IF THE SYSTEM IS CONSIDERED "OPERABLE" WHEN AT LEAST TWO UNITS ARE WORKING, COMPUTE THE ESTIMATES OF THE SYSTEM'S MTBF, MTTR, AND AVAILABILITY USING THE TEST DATA GIVEN IN PART (a).



CONSIDER THE SIGNAL

$$v(t) = \frac{1}{2} \sin 2\pi t + 2 \cos^2 \pi t$$

(a) WHAT IS THE PERIOD, 2T, OF THIS PERIODIC WAVEFORM? [HINT: $\cos^2\theta = \frac{1}{2} + \frac{1}{2}\cos 2\theta$]

(b) FOR THE FOURIER SERIES:

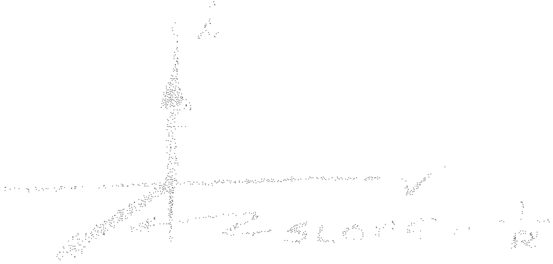
$$v(t) = \sum_{n=-\infty}^{\infty} a_n e^{j2\pi n t/T}$$

DETERMINE $a_n$. (IF YOU ARE CLEVER, NO INTEGRATION IS REQUIRED.)

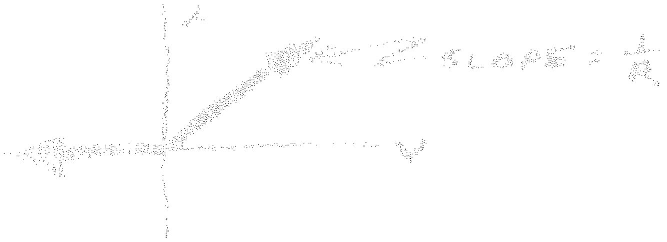
FROM EULER'S $\cos\theta = \frac{1}{2}[e^{j\theta} + e^{-j\theta}]$, $\sin\theta = \frac{1}{2j}[e^{j\theta} - e^{-j\theta}]$

[illegible]

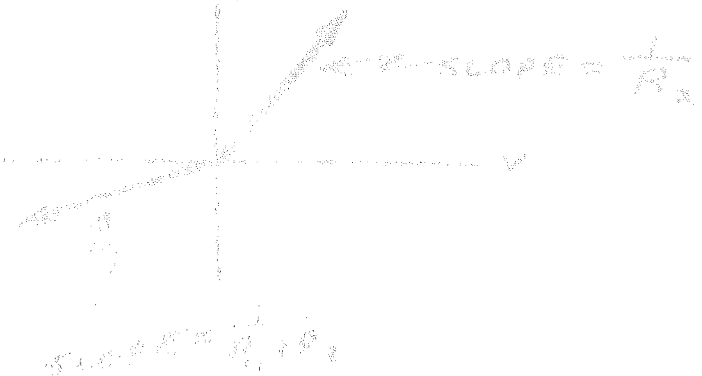
(d) WHEN WE TRY TO MAKE V POSITIVE, THE DIODE IS FORWARD BIASED AND THUS A SHORT. WHEN THE DIODE IS REVERSED BIASED (AN OPEN CIRCUIT), THE COMBINATION ACTS LIKE A RESISTOR:



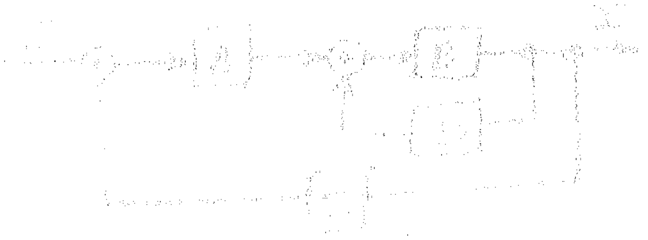
(e) WHEN DIODE IS FORWARD BIASED THE COMBINATION ACTS LIKE A RESISTOR, A REVERSE BIAS GIVES AN OPEN CIRCUIT



(f) WHEN FORWARD BIASED, THIS COMBINATION ACTS LIKE $R_2$, WHEN REVERSE BIASED, LIKE $R_1 + R_2$



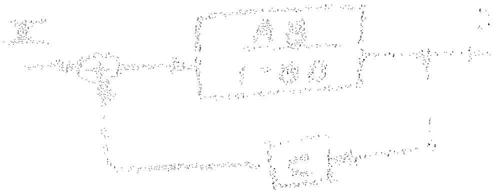
( )



REDUCTION OF EQ'N
WAS SHOWN IN
HW # 2, SEE SOLUT

=

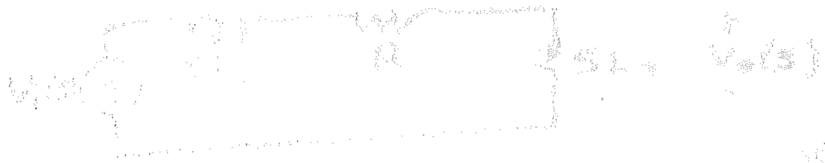
=



$$= \quad X \rightarrow \boxed{\frac{\frac{AB}{1-BD}}{1-\frac{ABC}{1-BD}}} \rightarrow Y \Rightarrow T(s) = \frac{\frac{AB}{1-BD}}{1-\frac{ABC}{1-BD}}$$

$$= \frac{AB}{1-BD-ABC}$$

(2)



(a) BY VOLTAGE DIVIDER, $T(s) = \frac{V_o}{V_i} = \frac{sL_2}{s(L_1+L_2)+R}$

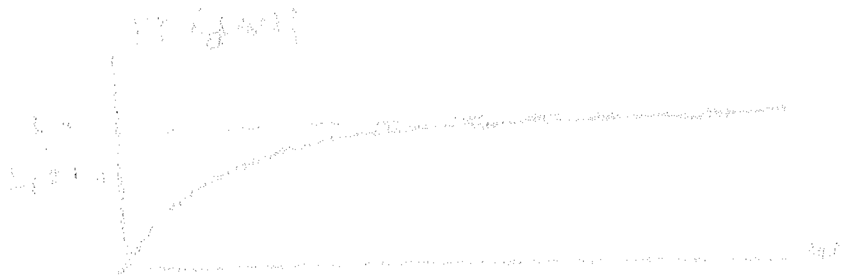
$$= \frac{s\frac{L_2}{L_1+L_2}}{s+\frac{R}{L_1+L_2}}$$

(b) INPUT: $v_i(t) = V_0 u(t) \Rightarrow V_i(s) = \frac{V_0}{s}$

$$V_o(s) = T(s)V_i(s) = \left(\frac{L_2}{L_1+L_2}\right)\frac{V_0}{s+\frac{R}{L_1+L_2}}$$

$$v_o(t) = \mathcal{L}^{-1}\left[V_o(s)\right] = \frac{V_0L_2}{L_1+L_2}e^{-\left[Rt/(L_1+L_2)\right]}$$

(c) $|T(j\omega)| = \frac{L_2}{L_1+L_2}\frac{\omega}{\sqrt{\omega^2+\frac{R^2}{(L_1+L_2)^2}}}$, $|T(j0)| = 0$, $|T(j\infty)| = \frac{L_2}{L_1+L_2}$



(d) THIS IS A HIGH PASS FILTER.

[illegible] $= \frac{[illegible]}{[illegible]} = \frac{2\,\text{hrs}}{[illegible]} = 2$ HRS

[illegible] $= 0.80$

(b) ACCORDING TO OUR DEFINITION OF THE [illegible] SYSTEM WAS OPERATING ONLY FOR [illegible] 7 HRS, IT TOOK 2 ADDITIONAL [illegible] REPAIR AND RAN FOR [illegible] HOUR TO THE TEST'S [illegible] THERE WAS ONLY ONE SYSTEM FAILURE

$MTBF = \frac{8\ \text{HRS}}{1\ \text{FAILURE}} = 8\ \text{HRS}$

$MTTR = \frac{2\ \text{HRS}}{1\ \text{FAILURE}} = 2\ \text{HRS}$

$A = \frac{MTBF}{MTBF + MTTR} = \frac{8}{10} = 0.80$

(c) [illegible] $\sin \pi t + 2\cos^2 \pi t$

$= [illegible] + 1 + \cos 2\pi t$

$= \frac{1}{2j}\left[e^{j\pi t} - e^{-j\pi t}\right] + \frac{1}{2}\left[e^{j2\pi t} + e^{-j2\pi t}\right] [illegible]$

$= [illegible] e^{j2\pi t}$

$x(t) = \sum_{n=-\infty}^{\infty} \alpha_n e^{j2n\pi t/(2T)}$

BY INSPECTION [illegible]

$\alpha_n = \begin{cases} 1 & ; n = 0 \\ 1 & ; n = 1 \\ 0 & ; \text{FOR ALL OTHER } n, \end{cases}$

(NAME)

# TEST 2

EE 234
BOB MARKS
3/31/77

INSTRUCTIONS:

- WORK ALL 5 PROBLEMS. DO YOUR WORK ON THE BLANK PAGES PROVIDED IN THIS BOOKLET. BUDGET YOUR TIME CAREFULLY.
- EACH OF THE 5 PROBLEMS IS WORTH 20 PTS FOR A TOTAL OF 100 PTS.
- THIS TEST IS OPEN BOOK, OPEN NOTES, AND CLOSED NEIGHBOR.

-BEST OF LUCK-

| PROBLEM | SCORE | OUT OF |
|---|---|---|
| 1 | | 20 |
| 2 | | 20 |
| 3 | | 20 |
| 4 | | 20 |
| 5 | | 20 |
| | | 100 |
| | TOTAL | |

"WHEN LIFE HANDS YOU A LEMON... MAKE LEMONAIDE"

DALE CARNEGIE

(1) 20%

TRUE-FALSE: MARK T OR F AFTER EACH OF THE FOLLOWING STATEMENTS. MARKS SUCH AS "Ŧ" WILL NOT BE GRADED. DO NOT GUESS. THERE WILL BE A PENALTY FOR WRONG ANSWERS

1. THE OUTPUT IMPEDANCE OF AN IDEAL OP AMP IS THE SAME AS THAT OF A SHORT CIRCUIT WHICH HAS AN IMPEDANCE OF ZERO. . . . . . ______

2. THE EQUIVALENT CIRCUIT FOR A BJT WHICH CONTAINS IDEAL CURRENT SOURCES, IS A GOOD MODEL FOR THE ENTIRE OPERATING RANGE OF THE TRANSISTOR. . . . . . . . . . . . . ______

3. THE THREE TERMINALS OF A MOSFET ARE THE COLLECTOR, BASE, AND EMITTER. . . . . ______

4. ANALOG COMPUTERS ARE LESS EXACT IN GENERAL THAN DIGITAL COMPUTERS. . . . ______

5. AN AMPLITUDE MODULATED SINUSOID CONTAINS ONLY TWO FREQUENCIES. . . . . . . . . . . . . . . . ______

6. WE MAY SEND, AT MOST, 10 VOICES OF MAXIMUM FREQUENCY 3000 HZ OVER A 60,000 HZ CAPACITY CHANNEL. . . . . . . . . ______

7. SELF BIASING CIRCUITRY REDUCES THE EFFECTS OF TEMPERATURE CHANGE ON BJT TRANSISTOR'S PARAMETERS. . . . . . . ______

8. THE UNKNOWN RESISTANCE ON A BALANCED WHEATSTONE BRIDGE IS A FUNCTION OF THE APPLIED VOLTAGE. . . . . . . . . . . . . . . . ______

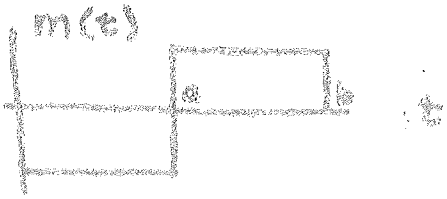
9. SHORTCIRCUITING THE VOLTAGE SUPPLY TO A BALANCED WHEATSTONE BRIDGE WILL HAVE NO EFFECT ON THE VOLTAGES AND CURRENTS WITHIN THE CIRCUIT. . . ______

10. IF WE EXCEED 100% MODULATION IN AM, WE DISTORT OUR SIGNAL. . . . . . ______

11. EE IS GOOD FOR YOU. . . . . . . . . . . . ______

(2) 20%

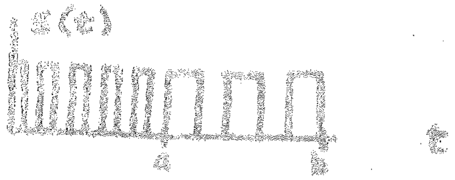
WE WISH TO MODULATE THE SIGNAL:



IN EACH OF THE FOLLOWING, STATE WHAT TYPE OF MODULATION IS USED

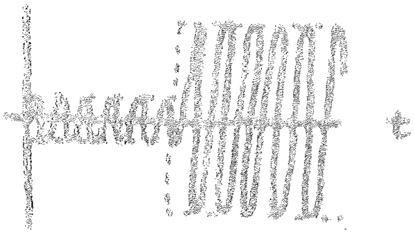
[CHOICES: AM, FM, PM, PAM, PDM, PPM]

(a)



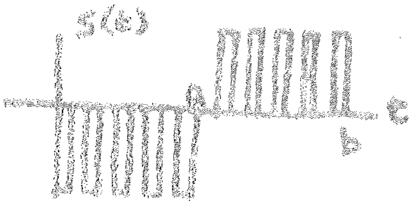
TYPE ________

(b)



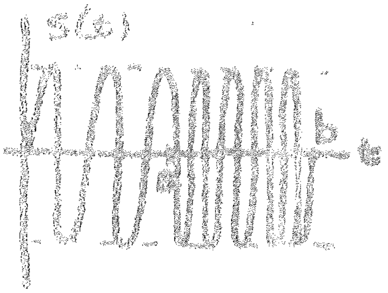
TYPE ________

(c)



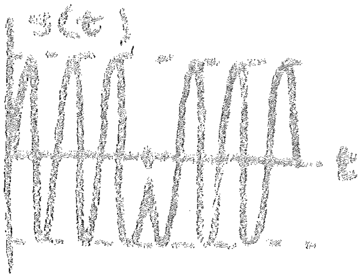
TYPE ________

(d)



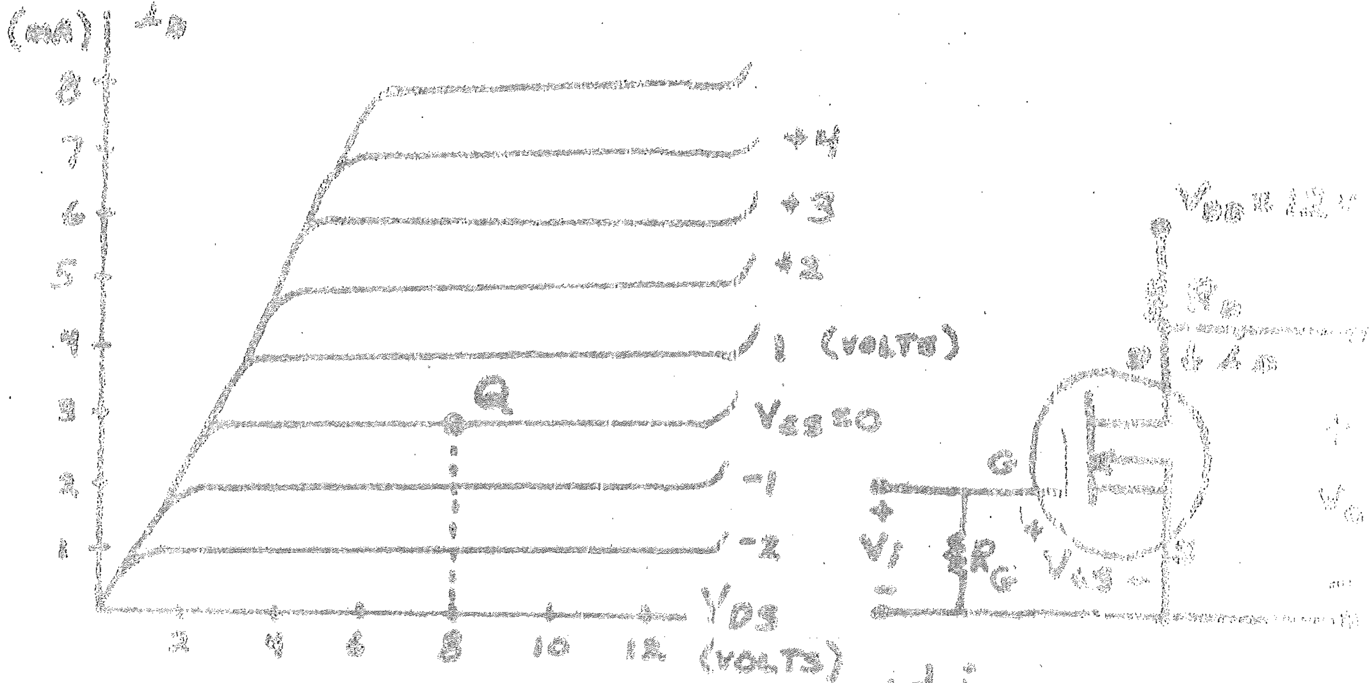
TYPE ________

(e)



TYPE ________

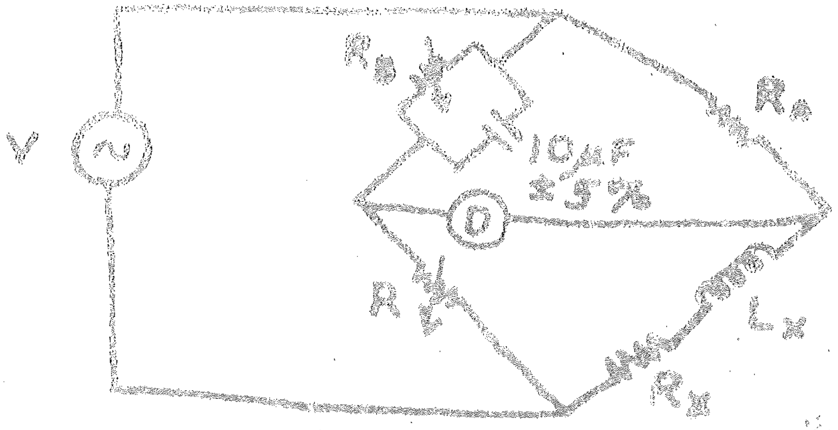
(3) 20%



(a) DETERMINE THE GAIN $G = \frac{d i_D}{d V_{GS}}$, IN MHOS, OF THIS DE MOSFET CIRCUIT. [USE ONLY TWO POINTS TO DETERMINE THE LINE ON THE $i_D$ VS. $V_{GS}$ CURVE. CONFINE ANALYSIS TO THE LINEAR PORTION OF THE TRANSISTOR CURVE.]

(b) SKETCH THE LOAD LINE ON THE ABOVE $i_D$ VS $V_{DS}$ CURVE USING THE QUIESCENT POINT SHOWN.

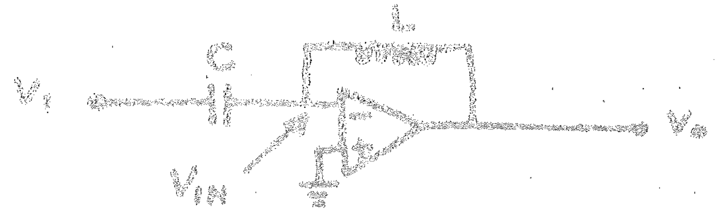
(4) 20%



THIS "MAXWELL" BRIDGE BALANCES WHEN $R_B = 100\,\Omega$ ±2% AND $R = 1000\,\Omega$ ±2%, IF WE KNOW THAT $R_A$ LIES SOMEWHERE BETWEEN 99. AND 101 Ω, FIND $L_x$ AND $R_x$ AND THEIR CORRESPONDING TOLERENCES IN ±( )%. USE THE USUAL APPROXIMATIONS.

(5) 20%

DETERMINE $V_o(t)$ AS A FUNCTION OF $V_1(t)$ IN THE FOLLOWING OP-AMP CIRCUIT:



ASSUME THE OP AMP HAS (INFINATE INPUT IMPEDANCE (IE, ZERO INPUT CURRENT) AND THAT

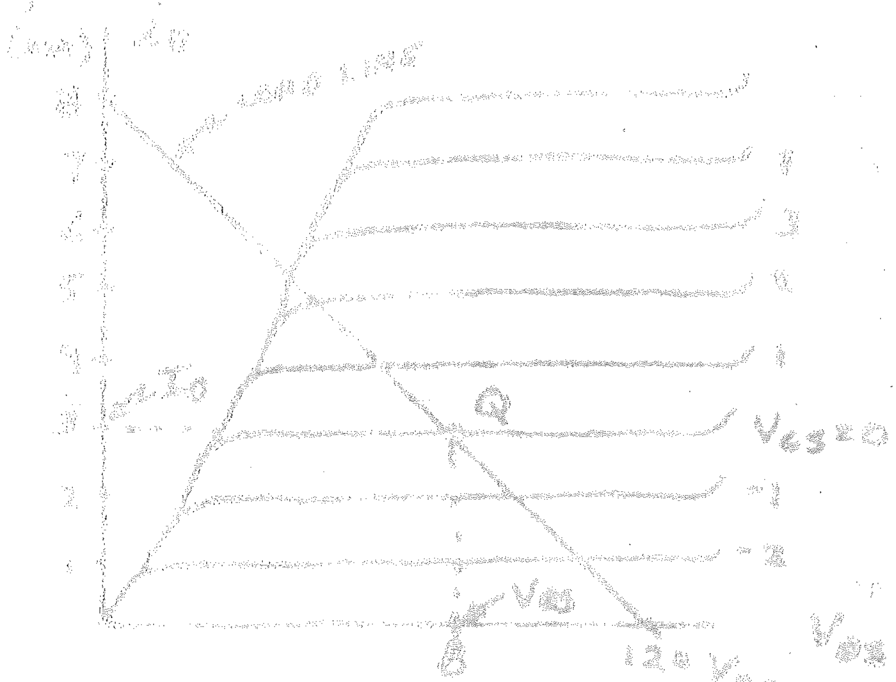
$$\frac{d^2 V_{IN}}{dt^2} \approx V_{IN} \approx 0$$

EE 234 TEST #2 SOLUTIONS (Dog MAR

(1) 1T, 2F, 3F, 4T, 5F, 6T, 7T, 8F, 9F, 10T

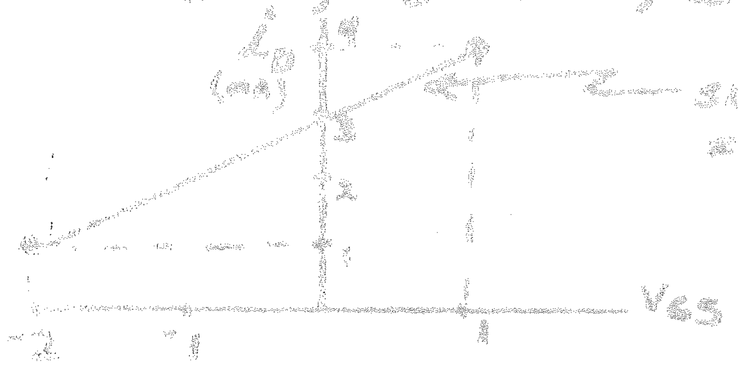
(2) (a) PDM, (b) AM, (c) PAM, (d) FM, (e) PM

(3)



(a) $V_{DD}$ = 12 V AND Q DETERMINE LOAD LIN

(b) @ $V_{GS}$ = 1, $i_D$ = 4 mA ; @ $V_{GS}$ = -2, $i_D$ =



SLOPE = GAIN = $\frac{3 mA}{3 V}$

= 1.0 m℧

mA

0.001 ℧

(4) $R_A$ : $99\Omega < R_A < 101\Omega \Rightarrow R_A = 100\Omega \pm 1$ % [illegible]

WE SHOWED IN HOMEWORK #5, PROBLEM 2, THAT

$$R_x = R R_A / R_B \quad \text{AND} \quad L_x = C_B R R_A$$

THUS

$$R_x = \frac{(10^3)(10^2)}{(10^2)} \cdot \frac{(1 \pm 0.02)(1 \pm 0.02)}{(1 \pm 0.01)}$$

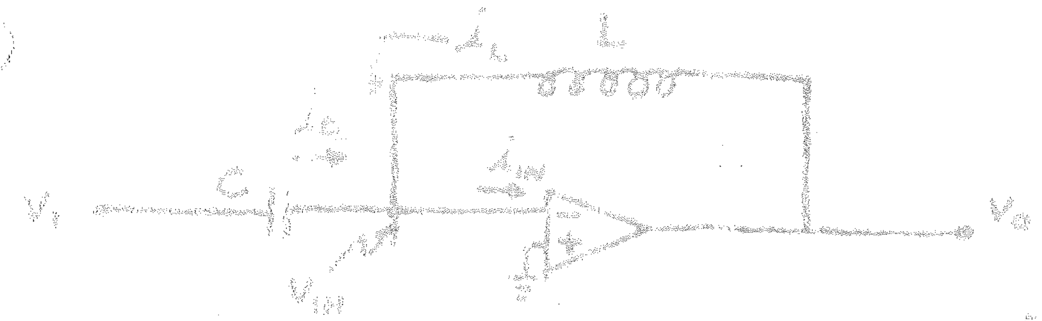
$$= 1000\Omega \cdot [(1 \pm 0.02)(1 \pm 0.02)(1 \pm 0.01)]$$

$$= 1000\Omega \cdot (1 \pm 0.05) = 1000\Omega \pm 5\%$$

$$L_x = (10^{-5})(10^3)(10^2)[(1 \pm 0.05)(1 \pm 0.02)(1 \pm 0.01)]$$

$$= 1\ H \pm 8\%$$

(5)



SUMMING CURRENTS AT $V_{IN}$ WITH $i_{IN} = 0$:

$$i_C + i_L = 0 = C \frac{d(V_1 - V_{IN})}{dt} + \frac{1}{L} \int^t (V_0 - V_{IN}) dt$$

OR

$$\int^t (V_0 - V_{IN}) dt = -LC \frac{d(V_1 - V_{IN})}{dt}$$

DIFFERENTIATING:

$$V_0 - V_{IN} = -LC \left[ \frac{d^2 V_1}{dt^2} - \frac{d^2 V_{IN}}{dt^2} \right]$$

ASSUMING $V_{IN} \approx d^2 V_{IN}/dt \approx 0$ GIVES

$$V_0 = -LC \frac{d^2 V_1}{dt^2} \Leftarrow \text{"DOUBLE DIFFERENTIATOR"}$$

(NAME)

# TEST 3

EE 334
Bob Mar
4/26/7

INSTRUCTIONS

- WORK ALL 5 PROBLEMS. DO YOUR WORK ON THE PAGES IN THIS BOOKLE BUDGET YOUR TIME CAREFULLY
- EACH PROBLEM IS WORTH 20 PTS. (TOTAL = 100 POINTS)
- TEST IS OPEN BOOK, OPEN NOTE

-BEST OF LUCK

| PROB | TOTAL | OUT OF |
|---|---|---|
| 1 | | 20 |
| 2 | | 20 |
| 3 | | 20 |
| 4 | | 20 |
| 5 | | 20 |
| | | 100 |
| | TOTAL | |

"WISDOM IS T
PAINCIPAL TH
THEREFORE, G
WISDOM, AND W
ALL THY GETT
GET UNDERSTAN

PROV. 4-

(1) YOU RUN A FIELD WITH OIL WELLS A, B, AND C. EACH WELL IS FITTED WITH A SMOKE DETEC WHICH PUTS OUT A LOGIC "1" IF THE WEL ON FIRE. OTHERWISE, IT'S LOGIC ZERO.

(a) SUPPOSE YOU WANTED A SINGLE RED "IDIO LIGHT" TO GO ON WHEN TWO OR MORE O YOUR WELLS IS ON FIRE. ASSIGNING A TO THIS LIGHT BEING ON, COMPUTE THE CORRESPONDING TRUTH TABLE.

(b) FROM YOUR TRUTH TABLE, DESIGN A LOG CIRCUIT TO LITE YOUR LITE USING THE SMOKE DETECTOR SIGNAL LEVELS AS INP

| A | B | C | L |
|---|---|---|---|
| 0 | 0 | 0 | |
| 0 | 0 | 1 | |
| 0 | 1 | 0 | |
| 0 | 1 | 1 | |
| 1 | 0 | 0 | |
| 1 | 0 | 1 | |
| 1 | 1 | 0 | |
| 1 | 1 | 1 | |

(2)(a) USING THE "AMERICAN STANDARD CODE FOR INFORMATION EXCHANGE" ON PAGES 5-8 TO 5-11 OF VINE'S BOOK, WRITE THE CODE FOR THE MESSAGE:

I␣LIKE␣JEE

AFTER EACH LETTER (OR SPACE), PUT AN EVEN ONES PARITY BIT FOR THAT CODED LETTER (OR SPACE). USE THE SPACES BELOW FOR YOUR CODE:

(b) LET $P_c$ BE THE PROBABILITY OF RECEIVING THE CODE EXACTLY AS IT WAS SENT AND $P$ BE THE PROBABILITY A BIT IS SENT OVER THE CHANNEL WITH NO ERROR. WHAT IS $P_c$ FOR $P=0.9$? FOR $P=0.99$? FOR $P=0.999$?

(c) WHAT MUST $P$ BE IF $P_c=0.95$? (CARRY $P$ TO AT LEAST FIVE PLACES).

(3) IN CLASS, WE DEVELOPED THE BOOLEAN LOGIC FOR A TWO AND A THREE WAY LIGHT SWITCH. HERE, WE CONSIDER A FOUR WAY LIGHT SWITCH WITH SWITCHES A, B, C, + D, [illegible] LIGHT, L.

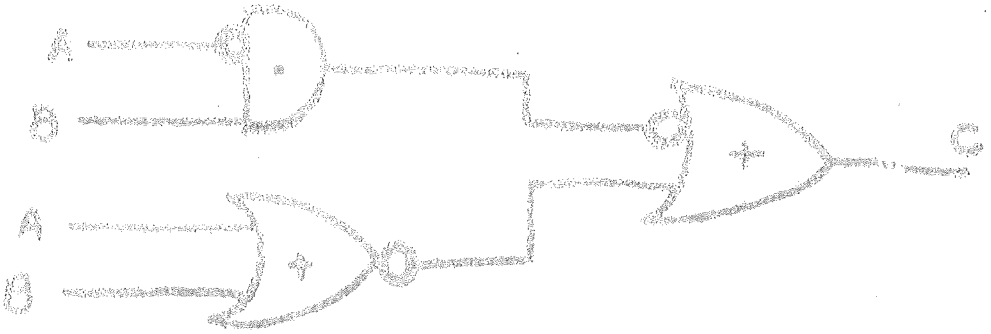
(a) DETERMINE THE TRUTH TABLE FOR THIS SYSTEM. ASSUME, AS A STARTING POINT, THAT IF (ABCD) = (0,0,0,0), THEN OUR LIGHT IS OFF (L=0).

(b) FROM (a), WRITE THE BOOLEAN FUNCTION FOR L (YOU NEED NOT SIMLIFY NOR IMPLEMENT).

TRUTH TABLE:

| A | B | C | D | L | A | B | C | D | L |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | |
| 0 | 0 | 0 | 1 | | 1 | 0 | 0 | 1 | |
| 0 | 0 | 1 | 0 | | 1 | 0 | 1 | 0 | |
| 0 | 0 | 1 | 1 | | 1 | 0 | 1 | 1 | |
| 0 | 1 | 0 | 0 | | 1 | 1 | 0 | 0 | |
| 0 | 1 | 0 | 1 | | 1 | 1 | 0 | 1 | |
| 0 | 1 | 1 | 0 | | 1 | 1 | 1 | 0 | |
| 0 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | |

(4) CONSIDER THE FOLLOWING LOGIC CIRCUIT:



(a) COMPUTE THE TRUTH TABLE FOR THE OUTPUT, C, GIVEN THE INPUT A, B

(b) WRITE THE BOOLEAN FUNCTION FOR C IN TERMS OF A AND B.

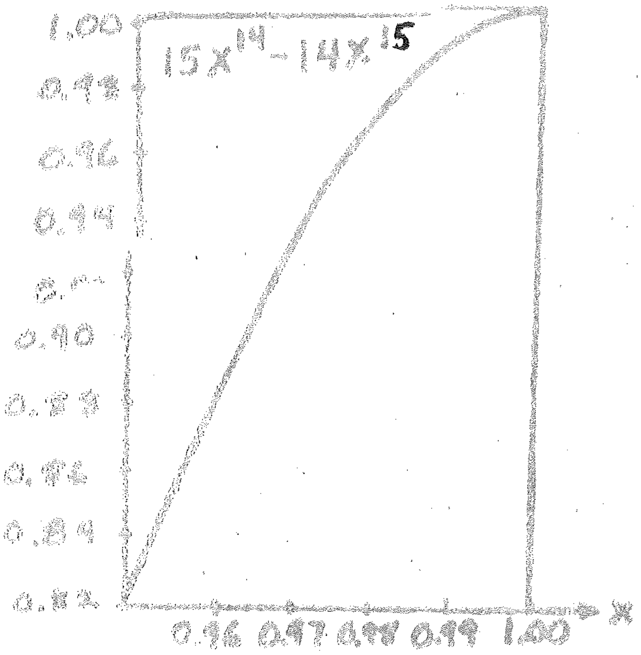
| A | B | C |
|---|---|---|
| 0 | 0 | — |
| 0 | 1 | — |
| 1 | 0 | — |
| 1 | 1 | — |

(5) WE WISH TO SEND AN ARBITRARY ELEVEN BIT WORD OVER A BINARY SYMMETRIC CHANNEL (p WITH $p_0 = p_1 = 1/2$. WE WISH TO HAVE A PROBABILITY OF CORRECT DETECTION OF 90%. COMPUTE THE REQUIRED VALUE OF CORRECTLY SENDING AN INDIVIDUAL BIT, $p$, FOR THE FOLLOWING TWO CASES.

(a) WE SEND THE ELEVEN BIT MESSAGE DIRECTL WITH NO CODING.

(b) WE SEND THE ELEVEN BIT MESSAGE IN A SINGLE BIT ERROR CORRECTION HAMMING CODE. (FOUR PARITY BITS FOR A TOTAL OF FIFTEEN BITS). YOU MAY FIND THE FOLLOWIN GRAPH HELPFUL SHOW YOUR WORK.

(c) WHICH OF THE TWO SCHEMES REQUIRES THE LESS NOISY CHANNEL?



# TEST # 3 (SOLUTIONS) by Mark

(1)(a) ANY TIME THERE ARE TWO OR MORE "1"'S, IN A, B, & C, WE WANT OUR LIGHT TO GO ON:

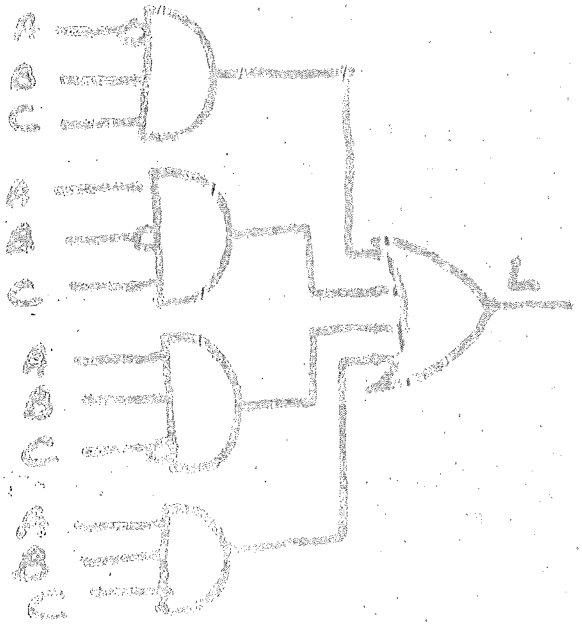
| A | B | C | L |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

← TRUTH TABLE

(b) FROM OUR TRUTH TABLE:

$$L = \bar{A}BC + A\bar{B}C + AB\bar{C} + ABC$$

THUS, A SCHEME WOULD BE:



NOTE: IN NO WAY IS THIS THE OPTIMAL IMPLEMENTATION SCHE
CAN YOU REDUCE THE NUMBER OF REQUIRED GATES?

[illegible]

[illegible]

SPACE

[illegible]

SPACE

[illegible]

(b) THERE ARE 72 BINITS IN THE ABOVE [illegible]

THUS $P_c = p^{72}$

$p = 0.9 \Rightarrow P_c = (0.9)^{72} = 0.00051 = 5.1 \times 10^{[illegible]}$

$p = 0.99 \Rightarrow P_c = (0.99)^{72} = 0.48$

$p = 0.999 \Rightarrow P_c = (0.999)^{72} = 0.93$

(c) $P_c = p^{72} \Rightarrow p = P_c^{1/72} = (0.95)^{1/72}$

$= 0.99929$

(3)(a)

| A | B | C | D | L |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 |

| A | B | C | D |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 |

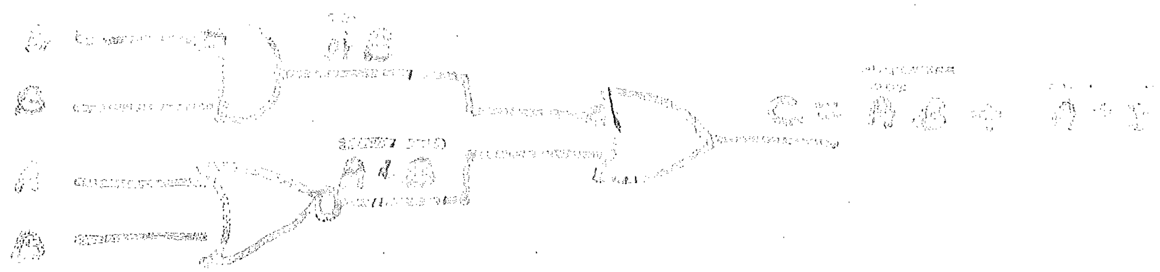
[illegible]

(b) FROM TRUTH TABLE:

$L = \bar{A}\bar{B}\bar{C}D + \bar{A}\bar{B}C\bar{D} + \bar{A}B\bar{C}\bar{D} + \bar{A}BCD$

$+ A\bar{B}\bar{C}\bar{D} + A\bar{B}CD + AB\bar{C}D + ABC\bar{D}$

(4)



(a) $A = 0,\ B = 0 \Rightarrow \bar{A}B = 1 \cdot 0 = 0$

$\overline{A+B} = \overline{0+0} = 1$

$C = 1 + 0 = 1$

$A = 0,\ B = 1 \Rightarrow \bar{A}B = 1 \cdot 1 = 1$

$\overline{A+B} = \overline{0+1} = \bar{1} = 0$

$C = 0 + 0 = 0$

$A = 1,\ B = 0 \Rightarrow \bar{A}B = 0 \cdot 0 = 0$

$\overline{A+B} = \overline{1+0} = \bar{1} = 0$

$C = 1 + 0 = 1$

$A = 1,\ B = 1 \Rightarrow \bar{A}B = 0 \cdot 1 = 0$

$\overline{A+B} = \overline{1+1} = \bar{1} = 0$

$C = 1 + 0 = 1$

TRUTH TABLE IS

| A | B | C |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

(b) FROM FIGURE, $C = \overline{\bar{A}B} + \overline{A+B}$

OR, FROM TRUTH TABLE,

$\bar{C} = \bar{A}B \Rightarrow C = \overline{\bar{A}B} = A + \bar{B}$

OR $C = \bar{A}\bar{B} + A\bar{B} + AB$

(ALL OF THESE ARE CORRECT ANSWERS)

(b) [illegible]

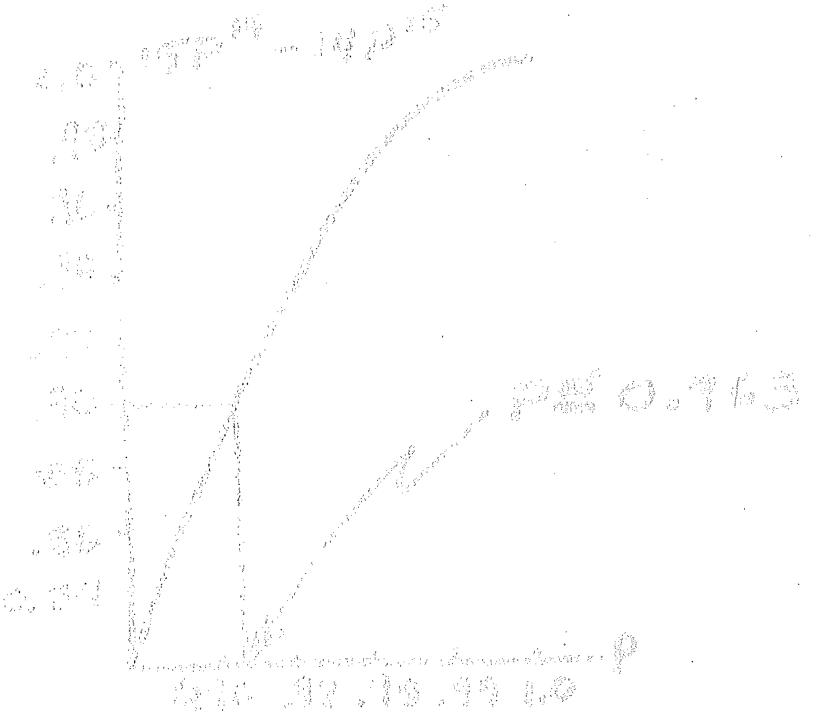
(c) [illegible] AND

$A =$ [illegible] $+$ [illegible]

$= p^{16} + 16 p^{15}(1-p)$

$= p^{16} + 16 p^{15} - 16 p^{16} = 16 p^{15} - 15 p^{16}$

ROUGHS THE GRAPH:



(d) THE CURVE SHOWS THAT [illegible]

0.963 < 0.970

NAME

# FINAL

EE 234
BOB MARKS
MAY 6, 1977

INSTRUCTIONS:

THIS TEST IS DIVIDED IN TO TWO SECTIONS:

I. 100 TRUE-FALSE QUESTIONS (200 POINTS)

II. FOUR PROBLEMS (200 POINTS EACH)

THE TOTAL # OF POINTS IS 400.

"ALL WISDOM OF THIS WORLD
IS FOOLISHNESS WITH GOD"

1 COR 3:19

SOME RELATIONS:

$e^{j\theta} = \cos\theta + j\sin\theta$ ⇐ EULER

$R(t) = e^{-\lambda t}$ ⇐ CONSTANT FAILURE RATE RELIABILITY

$\frac{1}{(s+a)(s+b)} = \frac{1}{(s+a)(b-a)} + \frac{1}{(s+b)(a-b)}$ ⇐ PARTIAL FRACTIONS

$\mathcal{L}[u(t)] = 1/s$

$\mathcal{L}[e^{-at}] = \frac{1}{s+a}$

$Pr[$k ERRORS IN n TRIALS EACH WITH PROBABILITY $p] = \binom{n}{k}(1-p)^k p^{n-k}$

| | | |
|---|---|---|
| TRUE FALSE | | 200 |
| 1 | | 150 |
| 2 | | 50 |
| 3 | | 50 |
| 4 | | 50 |
| | | |

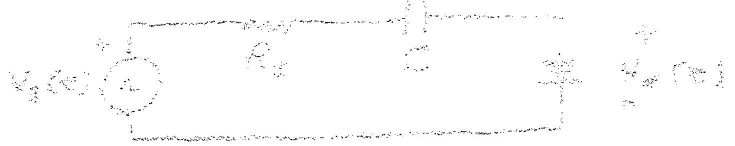
[illegible] (b) [illegible] THAT

$V_s(t)$ [illegible] SHIFTED [illegible] INPUT AND [illegible] YOUR

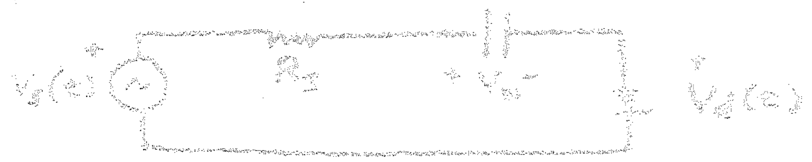
[illegible] (c) WHAT IS [illegible] FACTOR OF $V_d(t)$

[illegible] WITH THE CIRCUIT [illegible] CALLED A "DIODE

CLAMPER."



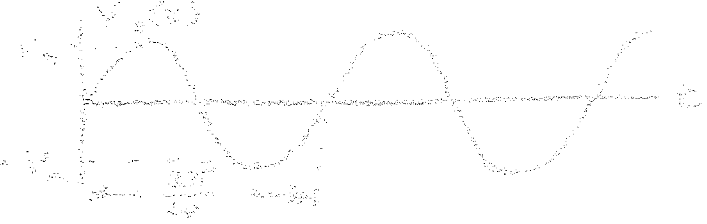
(a) AS $V_s(t)$ FIRST STARTS TO RISE, THE DIODE IS FORWARD BIASED AND THE CAPACITOR CHARGES TO (APPROXIMATELY) THE PEAK VALUE OF $V_s(t)$ WHICH IS $V_m$. IT FURTHERMORE RETAINS THIS CHARGE IN THE STEADY STATE. AS SUCH, WE HAVE THE CIRCUIT:



ASSUMING NEGLIGIBLE VOLTAGE DROP ACROSS $R_s$, WE FIND, FROM KIRCHHOFF'S VOLTAGE LAW, THAT

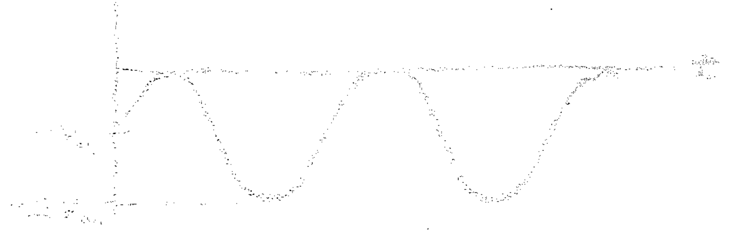
$$V_d(t) = V_s(t) - V_m$$
$$= V_m\left[\sin\omega t - 1\right]$$

OUR SOURCE VOLTAGE LOOKS LIKE



THUS OUR DIODE VOLTAGE IS

$$V_d(t) = V_s(t) - V_m$$



(c) WE CALL THIS CIRCUIT A "DIODE CLAMPER" SINCE IT "CLAMPS" THE SINUSOIDAL INPUT TO THE $V_d=0$ AXIS.

(b) $r^2 = \frac{V_{rms}^2}{V_{av}^2} - 1$

$V_{av} = \frac{1}{T}\int_T V_L(t)\,dt = \frac{\omega V_m}{2\pi}\int_0^{2\pi/\omega}(1 - \sin\omega t)\,dt$

$= \frac{\omega V_m}{2\pi}\left[\frac{2\pi}{\omega} - \frac{0}{\omega}\right] = V_m$

$V_{rms}^2 = \frac{1}{T}\int_T v_L^2(t)\,dt$

$= \frac{\omega V_m^2}{2\pi}\int_0^{2\pi/\omega}(1 - \sin\omega t)^2\,dt$

$= \frac{1}{2\pi}\omega V_m^2\left[\int_0^{2\pi/\omega} dt - 2\int_0^{2\pi/\omega}\sin\omega t\,dt + \int_0^{2\pi/\omega}\sin^2\omega t\,dt\right]$

$= \frac{1}{2\pi}\omega V_m^2\left[\frac{2\pi}{\omega} - 2(0) + \frac{1}{2}\int_0^{2\pi/\omega}[1 - \cos 2\omega t]\,dt\right]$

$= \frac{1}{2\pi}\omega V_m^2\left[\frac{2\pi}{\omega} + 0 + \frac{1}{2}\left(\frac{2\pi}{\omega} - 0\right)\right]$

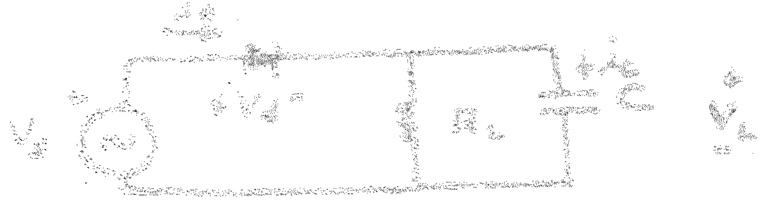
$= \frac{1}{2\pi}\omega V_m^2\left(\frac{3\pi}{\omega}\right)$

$= \frac{3}{2}V_m^2$

$\Rightarrow r^2 = \frac{3/2\,V_m^2}{V_m^2} - 1 = \frac{1}{2} \Rightarrow r = \frac{1}{\sqrt{2}}$

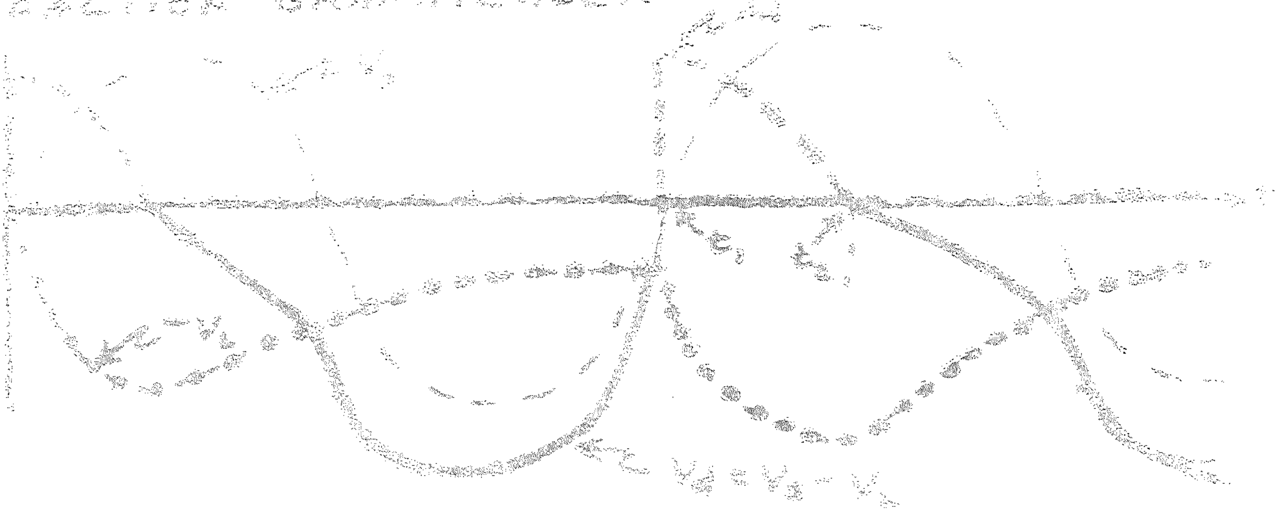
$\approx 0.707$

2. FOR THE HALF-WAVE RECTIFIER WITH CAPACITIVE FILTER, SKETCH THE SOURCE VOLTAGE, DIODE VOLTAGE, AND DIODE CURRENT ON THE SAME GRAPH. DOCUMENT YOUR RESULTS.



THE GRAPH OF SOURCE VOLTAGE VS. $V_L$ WAS GIVEN IN CLASS:

FROM KIRCHHOFF'S VOLTAGE LAW: $V_d = V_s - V_L$. FROM THE PREVIOUS SKETCH, WE MAKE THIS SUBTRACTION GRAPHICALLY:



THE DIODE WILL BE CONDUCTING IN THAT REGION ONLY, THE TIME WHEN $V_d = 0$. AT $t_1$, THE SUPPLY VOLTAGE, $V_s$, SLIGHTLY EXCEEDS $V_L$ AND THE DIODE CONDUCTS. THE DIODE CURRENT RISES ABRUPTLY TO SATISFY THE RELATION $i_c = C\,dV/dt$ AND THEN GOES BACK DOWN TO ZERO.

"WHATEVER THE MIND OF MAN CAN CONCEIVE AND BELIEVE, IT CAN ACHIEVE"

NAPOLEON HILL

HOMEWORK #2

DUE 2/10/77
IN CLASS

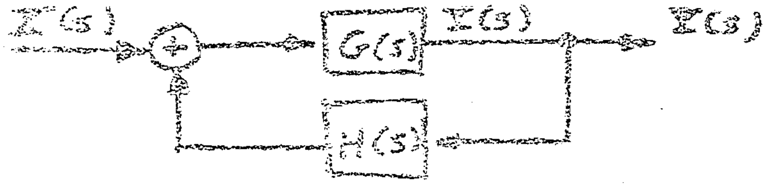
1.(a) SHOW THAT, IF $X(s) = \mathcal{L}[x(t)]$ AND $x(t) = 0$ FOR $t<0$, THEN $\mathcal{L}[x(t-\tau)] = X(s)\, e^{-s\tau}$

(b) THE INPUT-OUTPUT RELATION OF A LINEAR TIME-INVARIANT SYSTEM CAN BE EXPRESSED BY THE "CONVOLUTION INTEGRAL"

$$y(t) = \int_0^\infty x(\tau)\, T(t-\tau)\, d\tau$$

WHERE $T(t) = \mathcal{L}^{-1}[T(s)]$. USING THE RESULTS OF (a), SHOW THAT IT FOLLOWS THAT $Y(s) = X(s)\, T(s)$.

2. CONSIDER TWO SYSTEMS CONNECTED IN A "FEEDBACK" CONFIGURATION:



DERIVE THE TRANSFER FUNCTION $T(s) = Y(s)/X(s)$
(HINT: SEE P. 233 OF SMITH)

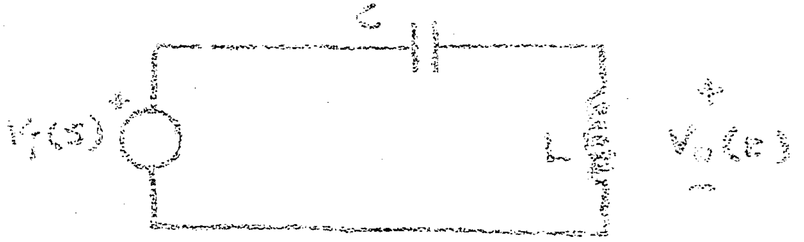
3. CLASSIFY THE FOLLOWING SYSTEMS ACCORDING TO LINEARITY, TIME INVARIANCE, AND CAUSALITY.

(a) $y(t) = \frac{d^2}{dt^2} x(t)$
(b) $y(t) = a\,x(t) + b$
(c) $y(t) = \int_0^t x(t)\,dt$
(d) $y(t) = [x(t) - d]^2$
(e) $y(t) = t\,x(t)$
(f) $y(t) = x(t-4)$

WHICH SYSTEMS CAN WE USE LAPLACE TRANSFORMS ON?

4. FOR THE FOLLOWING CIRCUIT

(a) FIND THE TRANSFER FUNCTION $T(s) = V_0(s)/V_i(s)$
(b) FIND THE OUTPUT FOR $v(t) = V_0\, u(t)$
(c) DISCUSS YOUR RESULT IN (b)
(d) COMPUTE AND SKETCH THE FREQUENCY RESPONSE $|T(j\omega)|$.



HOMEWORK #2

DUE 2/10/77
IN CLASS

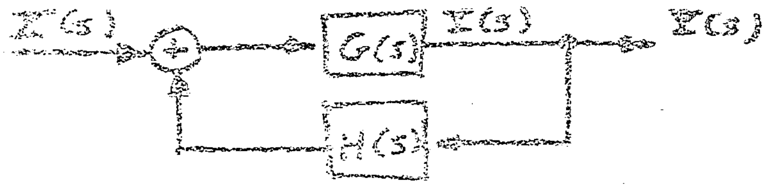
1. (a) SHOW THAT, IF $X(s) = \mathcal{L}[x(t)]$ AND $x(t) = 0$ FOR $t<0$, THEN $\mathcal{L}[x(t-T)] = X(s)e^{-sT}$

(b) THE INPUT-OUTPUT RELATION OF A LINEAR TIME-INVARIANT SYSTEM CAN BE EXPRESSED BY THE "CONVOLUTION INTEGRAL"

$$Y(t) = \int_0^\infty x(\tau)\, T(t-\tau)\, d\tau$$

WHERE $T(t) = \mathcal{L}^{-1}[T(s)]$. USING THE RESULTS OF (a), SHOW THAT IT FOLLOWS THAT $Y(s) = X(s)\,T(s)$.

2. CONSIDER TWO SYSTEMS CONNECTED IN A "FEEDBACK" CONFIGURATION:



DERIVE THE TRANSFER FUNCTION $T(s) = Y(s)/X(s)$
(HINT: SEE p. 233 OF SMITH)

3. CLASSIFY THE FOLLOWING SYSTEMS ACCORDING TO LINEARITY, TIME INVARIANCE, AND CAUSALITY.

(a) $y(t) = \frac{d^n}{dt^n}x(t)$

(b) $y(t) = a\,x(t) + b$

(c) $y(t) = \int_0^t x(t)\,dt$

(d) $y(t) = [x(t) - d]^k$

(e) $y(t) = t\,x(t)$

(f) $y(t) = x(t-4)$

WHICH SYSTEMS CAN WE USE LAPLACE TRANSFORMS ON?

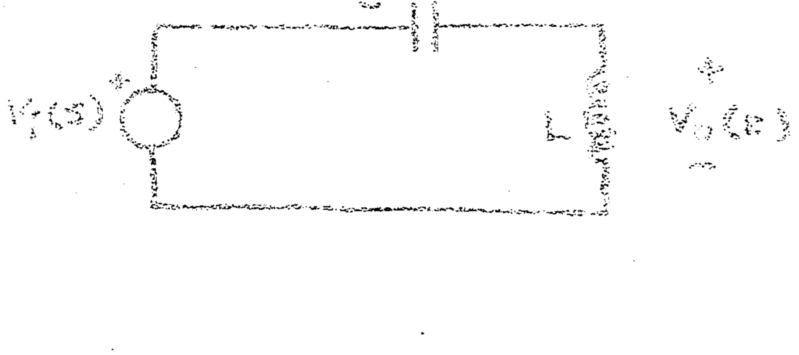
4. FOR THE FOLLOWING CIRCUIT

(a) FIND THE TRANSFER FUNCTION $T(s) = V_o(s)/V_i(s)$

(b) FIND THE OUTPUT FOR $V(t) = V_o\,\mu(t)$

(c) DISCUSS YOUR RESULT IN (b)

(d) COMPUTE AND SKETCH THE FREQUENCY RESPONSE $|T(j\omega)|$.



HOMEWORK # 2 : SOLUTIONS

1. (a) $Y(s) = \mathcal{L}[x(t-T)] = \int_0^\infty x(t-T)\, e^{-st} dt$

LET $t' = t - T \Rightarrow dt' = dt$

$\Rightarrow Y(s) = \int_{-T}^{\infty} x(t')\, e^{-s(t'+T)} dt'$ , BUT $x(t) = 0$ FOR $t < 0$

$\Rightarrow Y(s) = \int_0^\infty x(t')\, e^{-s(t'+T)} dt' = \int_0^\infty x(t')\, e^{-st'} dt'\, e^{-sT}$

$= \int_0^\infty x(t)\, e^{-st} dt\, e^{-sT} = X(s)\, e^{-sT}$

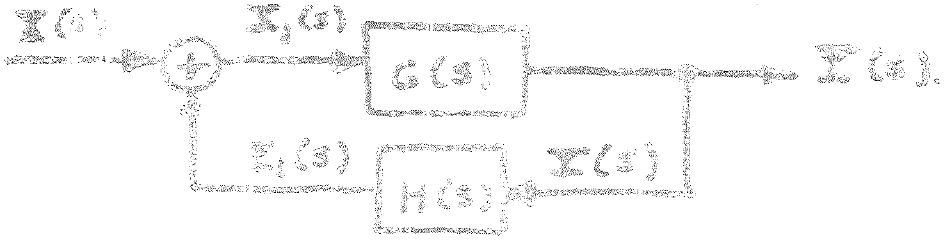
(b) $Y(t) = \int_0^\infty x(\tau)\, T(t-\tau)\, d\tau$

$\mathcal{L}[Y(t)] = \int_0^\infty x(\tau)\, \mathcal{L}[T(t-\tau)]\, d\tau = \int_0^\infty x(\tau)\, \mathcal{L}[T(t)]\, e^{-s\tau} d\tau$

$= \int_0^\infty x(\tau)\, e^{-s\tau} d\tau\, \mathcal{L}[T(t)] = \mathcal{L}[x(t)]\, \mathcal{L}[T(t)]$

THUS $Y(s) = X(s)\, T(s)$

2.



$X_1(s) = X(s) + X_2(s) = X(s) + Y(s)H(s)$ ①

ALSO $Y(s) = X_1(s)\, G(s) \Rightarrow X_1(s) = Y(s)/G(s)$ ②

EQUATING ① AND ②:

$X(s) + Y(s)H(s) = Y(s)/G(s)$

SOLVING FOR $Y(s)$ GIVES $\Longrightarrow Y(s) = \frac{G(s)\, X(s)}{1 - G(s)H(s)}$

THUS $T(s) = Y(s)/X(s) = \frac{G(s)}{1 - G(s)H(s)}$

3. (a) $Y(t) = \frac{d^2}{dt^2} x(t)$

- $\frac{d^2}{dt^2}[a x_1(t) + b x_2(t)] = a \frac{d^2}{dt^2} x_1(t) + b \frac{d^2}{dt^2} x_2(t) \Leftarrow$ LINEAR
- $Y(t-T) = \frac{d^2}{dt^2} x(t-T) \Longleftarrow$ TIME INVARIANT
- $Y(t)$ DEPENDS ONLY ON $x(t)$ TO $t \Leftarrow$ CAUSAL

(b) $Y(t) = a\, x(t) + b$

- $[a x_1(t) + b] + [a x_2(t) + b] \neq a[x_1(t) + x_2(t)] + b \Leftarrow$ NOT LINEAR
- $Y(t-T) = a\, x(t-T) + b \Longleftarrow$ TIME INVARIANT
- CAUSAL

(c) $Y(t) = \int_0^t x(t) dt$

- $a \int_0^t x_1(t) dt + b \int_0^t x_2(t) dt = \int_0^t [a x_1(t) + b x_2(t)] dt \Longleftarrow$ LINEAR
- $Y(t-T) = \int_0^{t-T} x(t) dt \Leftarrow$ TIME INVARIANT
- CAUSAL

(b) $y(t) = [x(t) - d]^2$

- $[a x_1(t) + b x_2(t) - d]^2 \neq a[x_1(t) - d]^2 + b[a x_2(t) - d]^2 \Rightarrow$ NONLINEAR
- $y(t-T) = [x(t-T) - d]^2 \Rightarrow$ TIME-INVARIANT
- CAUSAL

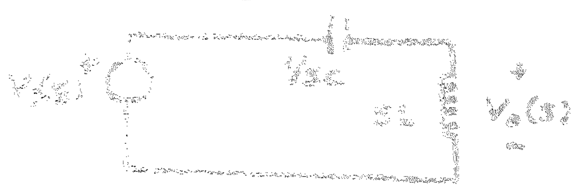
(c) $y(t) = t\,x(t)$:

- $t[a x_1(t) + b x_2(t)] = a t x_1(t) + b t x_2(t) \Rightarrow$ LINEAR
- $y(t-T) \neq$ [illegible] $x(t-T) \Rightarrow$ TIME-VARIANT (t appears outside [illegible])
- CAUSAL

(f) [illegible]

- LINEAR
- TIME INVARIANT
- ~~[illegible]~~ CAUSAL

4.



(a) BY VOLTAGE DIVIDER: $V_o(s) = \dfrac{sL}{sL + \frac{1}{sC}} V_i(s)$

$\Rightarrow T(s) = \dfrac{V_o(s)}{V_i(s)} = \dfrac{sL}{sL + \frac{1}{sC}} = \dfrac{s^2 LC}{1 + s^2 LC}$

(b) $v_i(t) = V_0 u(t) \Rightarrow V_i(s) = \dfrac{V_0}{s}$

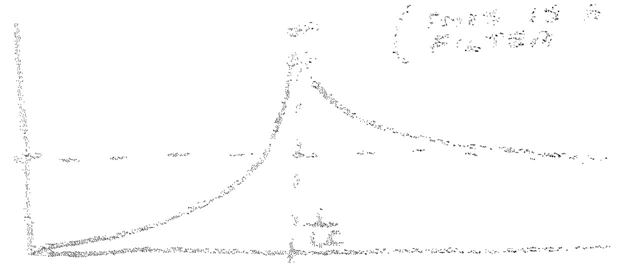
$V_o(s) = T(s) V_i(s) = \dfrac{V_0 sLC}{1 + s^2 LC} = \dfrac{V_0 s}{\left(\frac{1}{\sqrt{LC}}\right)^2 + s^2}$

FROM LAPLACE TRANSFORM TABLE:

$v_o(t) = V_0 \cos \dfrac{1}{\sqrt{LC}} t$

(d) $|T(j\omega)| = \left|\dfrac{\omega^2 LC}{1 - \omega^2 LC}\right|$

(THIS IS A HIGH-PASS FILTER)



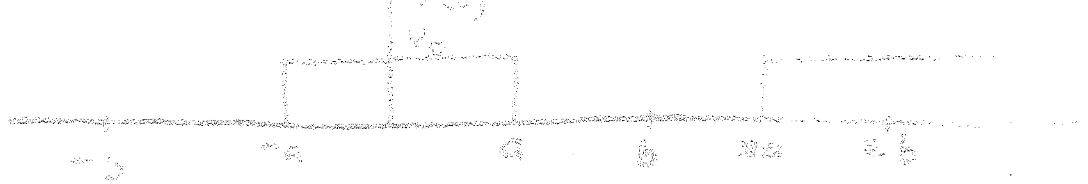
(c) THIS CIRCUIT IS AN OSCILLATOR. IN PRACTICE, THE COSINE WILL BE "DAMPED" SINCE SOME RESISTANCE IN THE CIRCUIT WILL ABSORB POWER. IN ACTUAL PHYSICAL WORLD

$v_o(t) \approx V_0 \cos \omega t \; e^{-t/\tau}$

WHERE $\tau$ IS DETERMINED BY CIRCUIT PARAMETERS.

[illegible] )

(1) FOR THE FOLLOWING PERIODIC WAVEFORM(S) [illegible]
THE FOURIER SERIES COEFFICIENTS, $\alpha_n$. ASSUME
THAT $b > a$



[HINT: $\frac{1}{j2}[e^{j\theta} - e^{-j\theta}) = \sin\theta$]

(b) ASSUME THAT $b = 2a$. WHAT IS $\alpha_n$ FOR

$n = 0$ [HINT: $\lim_{x \to 0} \frac{\sin \pi x}{\pi x} = 1$]

$n$ EVEN

$n = 1, 5, 9, 13, 17, \ldots$

$n = 3, 7, 11, 15, 19, \ldots$

(c) PLOT $\pi|\alpha_n|/V_0$ FOR $n$ UP TO [illegible]

(2) FOR $x(t) = \sum_{n=-\infty}^{\infty} \alpha_n e^{j2\pi nt/T}$

(a) SHOW THAT $\int_{2T} x(t)\,dt = \sum_{n=-\infty}^{\infty}$ [illegible]

[HINT: $\int_{2T} e^{j2\pi nt/T}\,dt = \frac{1}{2T}$]

(b) PROVE "PARCEVAL'S THEOREM":

$$\int_{2T} |x(t)|^2\,dt = \sum_{n=-\infty}^{\infty} \frac{|\alpha_n|^2}{2T}$$

[HINTS: $|\sum_n B_n|^2 = \sum_n \sum_m B_n B_m^*$

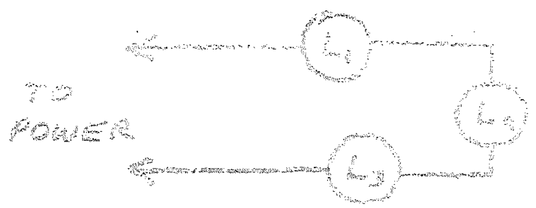
$$\int_{2T} e^{j2\pi t(n-m)/T}\,dt = \frac{1}{2W}\,\delta_{nm}$$

$$\delta_{nm} = \left\{\begin{array}{ll} 1 & ; n = m \\ 0 & ; n \neq m \end{array}\right\} \Leftarrow \text{KRONECKER DE}$$

(3) JOHNNY CASH AND TINY TIM (LO & HI VOICE RE
A 3 MINUTE 55 SECOND RECORDING. IF NE +E
VOICE EXCEEDED 20 kHz (=20,000 CYCL ES)
WE WISHED TO STORE THE RECORD IN S PLE
FORM, HOW MANY SAMPLES WOULD WE EO
STORE? IF WE LOST EVERY OTHER SA LE
WHOSE VOICE WOULD BE DISTORTED SE

NO

(4) CONSIDER A SYSTEM CONSISTING OF THREE LIGHTBULBS HOOKED IN SERIES:



WE CONSIDER THE SYSTEM OP[illegible] TWO OR MORE OF THE LIGHTS [illegible]

(a) ASSUMING THAT THE MTBF [illegible] BULB IS TWO MONTHS. AND [illegible] ARE ON THE RANDOM FAILURE [illegible] PORTION OF THE BATHTUB CU[illegible] THE SYSTEM MTBF AND THE [illegible] THAT THE SYSTEM WILL BE [illegible] TWO MONTHS OF USE.

(b) IF IT TAKES 30 MINUTES (O[illegible] TO REPLACE A BULB, COMPUTE [illegible] AVAILABILITY. (ASSUME 1 MONTH [illegible]

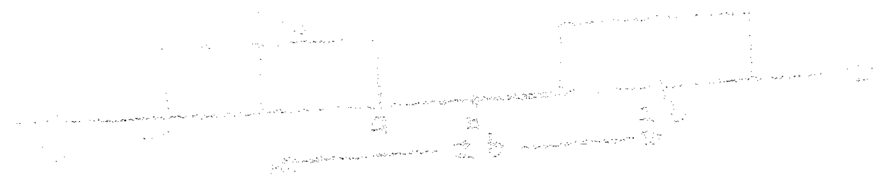
(c) CONSIDERING OUR DEFINITION [illegible] SUGGEST A BETTER WAY OF [illegible] THE LIGHTS SO THAT THE [illegible] RELIABILITY IS INCREASED. [illegible] THIS EFFECT THE SYSTEM [illegible] [CAN YOU COMPUTE THE MTB[illegible] NEW SYSTEM?].

(d) IN THE IMPROVED SYSTEM OF [illegible] EXPLAIN HOW THE AVAILAB[illegible] RELIABILITY OF THE SYSTEM [illegible] IMPROVED BY INTRODUCING [illegible] OF *"PREVENTATIVE MAINTENANCE" [illegible] WILL THIS EFFECT THE MTBF [illegible]

* i.e, REPLACING A BURNT OUT BULB BEFORE THE SYSTEM IS "INOPERABLE"

"HE THAT REFUSETH INSTRUCTION DESPISETH HIS OWN SOUL."

PROV. 15:32



$b > a$

(a) $x_n = \frac{1}{T}\int x(t)\, e^{-j2\pi nt/T}\, dt$

$\Rightarrow x_n = \frac{1}{T}\left[\int (0)\,dt + \int_{-b}^{b} e^{-j2\pi nt/T}\, V_0\, dt\right]$

$= \frac{V_0}{T}\int_{-b}^{b} e^{-j2\pi nt/T}\, dt$

$= \frac{V_0}{T}\,\frac{1}{-j2\pi n/T}\, e^{-j2\pi nt/T}\Big|_{-b}^{b}$

$= \frac{V_0}{-j2\pi n}\left[e^{-j2\pi nb/T} - e^{j2\pi nb/T}\right]$

$= \frac{V_0}{n\pi}\sin 2\pi\left(\frac{b}{T}\right) n$

(b) [illegible] $\Rightarrow x_n = \frac{V_0}{n\pi}\sin \pi n$ [illegible]

$= \frac{V_0}{n\pi}$ [illegible] OTHERWISE

(c)

(d) (a) $x(t) = \sum_{n=-\infty}^{\infty} x_n e^{j2\pi nt/T}$

$\int_T x(t)\,dt = \sum_{n=-\infty}^{\infty} x_n \int_T e^{j2\pi nt/T}\,dt$ [illegible]

(b) $|x(t)|^2 = \sum_{n=-\infty}^{\infty}\sum_{m=-\infty}^{\infty} x_n x_m^* e^{j2\pi(n-m)t/T}$

$\int_T |x(t)|^2\,dt = \sum_{n=-\infty}^{\infty}\sum_{m=-\infty}^{\infty} x_n x_m^* \int_T e^{j2\pi(n-m)t/T}\,dt$

$= \sum_n \sum_m x_n x_m^* \left(T\,\delta_{nm}\right)$

$= \sum_n |x_n|^2$

(3) S = TOTAL SAMPLES

$= (3 \text{ MIN } 55 \text{ SEC})(2 \times 20 \text{ KHZ})$

$= (235 \text{ SEC})(40{,}000/\text{SEC}) = 9.4$ MILLION SAMP[illegible]

UNDER-SAMPLING DISTORTS THE HIGHER FREQUENCIES. THUS, TINY TIM, [illegible] HIGHER VOICE, WOULD BE DISTORTED [illegible]

12 (4)(a) SINCE ONE LIGHT BULB FAILURE [illegible] IN SYSTEM FAILURE, THE SYSTEM MTBF IS

$$MTBF_S = \frac{MTBF_L}{3} = \frac{2}{3} \text{ MONTH}$$

$$R_S(t) = e^{-t/MTBF_S} \Rightarrow R_S(2 \text{ MONTH}) = e^{-3}$$

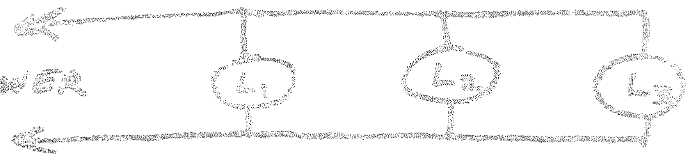
$= e^{-3} \cong 0.05 \Rightarrow$ THERE IS ABOUT A 5% CHANCE THE SYSTEM WILL OPERATE FOR TWO STRAIGHT MONTHS.

(b) MTTR = 30 MIN

$$A = \frac{MTBF}{MTBF + MTTR} = \frac{\frac{2}{3} \times 30 \times 24 \times 60}{\frac{2}{3} \times 30 \times 24 \times 60 + 30}$$

$$= \frac{28800}{28830} = 99.896\%$$

(c) IT WOULD BE BETTER TO CONNECT [illegible] IN PARALLEL



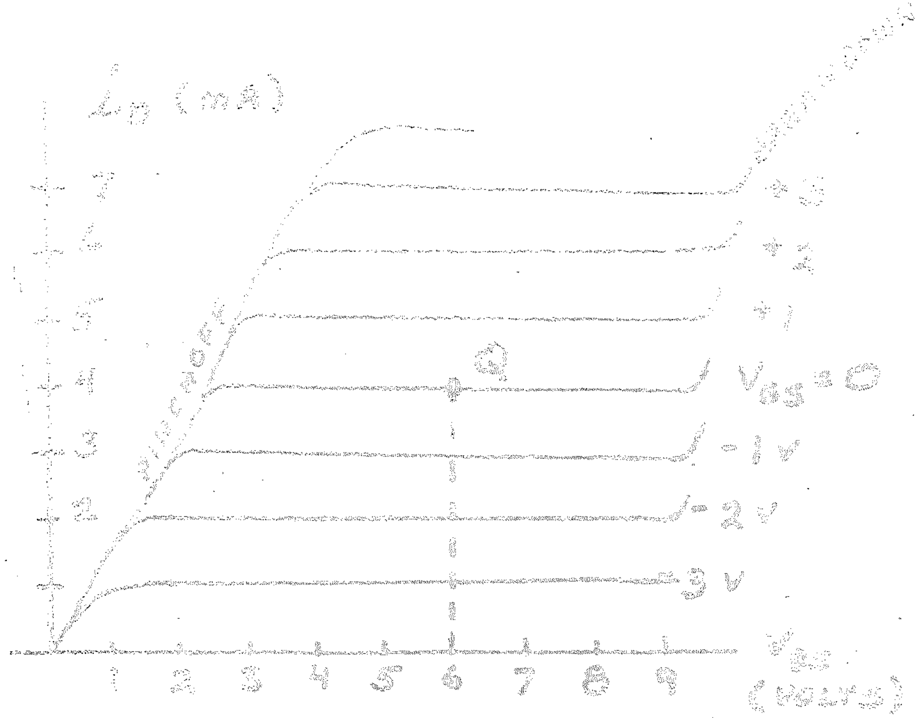
HERE, IF ONLY ONE LIGHT FAILS, THE SYSTEM IS STILL "OPERABLE"

(d) BY REPLACING A LIGHT WHICH HAS BURNT OUT WHILE THE SYSTEM IS "OPERABLE" WE ARE PERFORMING "PREVENTIVE MAINTENANCE". THE MTTR IS ~~STILL THE SAME~~ REDUCED, BUT THE MTBF (AND THUS THE AVAILABILITY) IS INCREASED.

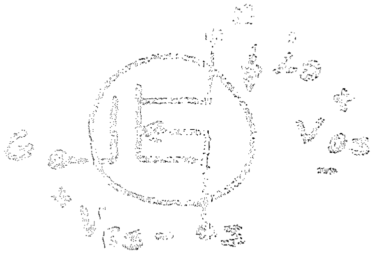
"HE THAT HANDLETH A MATTER WISELY SHALL FIND GOOD: AND WHOSO TRUSTETH IN THE LORD, HAPPY IS HE"

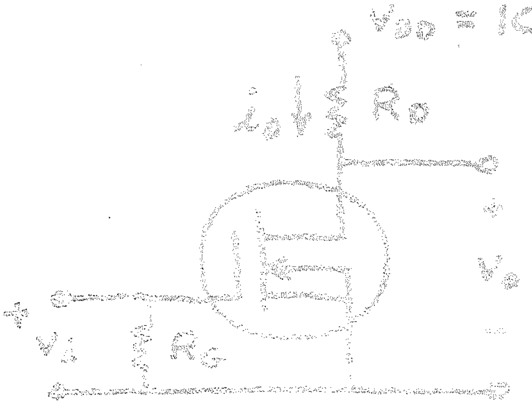
[illegible]

DUE MARCH 4



DE MOSFET





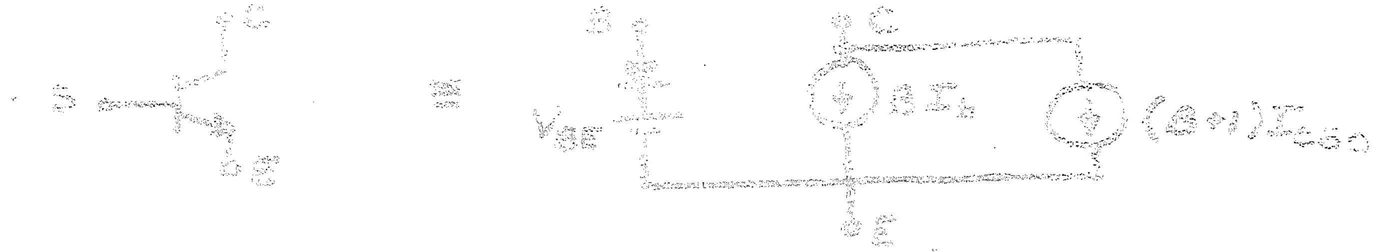
(a) DETERMINE $R_D$ TO ESTABLISH QUIESCENCE AT THE POINT INDICATED. $V_{DD}=10^V$

(b) DETERMINE THE EQUATION FOR THE LOAD LINE AND SKETCH IT ON THE ABOVE DE-MOSFET V-I CURVE.

(c) FROM (b), MAKE A PLOT OF SOME POINTS FOR THE CURVE $i_D$ vs. $V_{GS}$. ASSUMING $V_{GS}$ IS THE INPUT AND $i_D$ THE OUTPUT, WHAT IS THE "GAIN" OF THIS TRANSDUCER IN MHO'S ?

(d) GIVE AN ESTIMATE OF THE INTERVAL $V_{GS}$ MUST BE LIMITED TO TO AVOID GROSS OUTPUT "DISTORTION"

(2) OUR TRANSISTOR D.C. MODEL WAS



(a) FOR $I_{CBO} = 5nA$, SKETCH $i_c$ (VERTICAL AXIS) VS. $V_{CE}$ ON THE SAME GRAPH FOR $I_B = 0.1, 0.2, 0.3, 0.4$ mA. ASSUME $\beta = 100$

(b) REPEAT (a) FOR $\beta = 200$. HOW HAS THE CURVE CHANGED ?

(c) COMPARE YOUR SKETCH IN (a) TO THE CORRESPONDING TRANSISTOR CURVE.

(d) EXPLAIN WHY WE WOULD REQUIRE $I_b > 0$ (IN THE MODEL AND PHYSICALLY)

(3) IN A CERTAIN TRANSISTOR, THE PARAMETERS CHANGE WITH TEMPERATURE BUT ARE KNOWN TO FALL WITHIN THE BOUNDS:

$$30 < \beta < 180$$

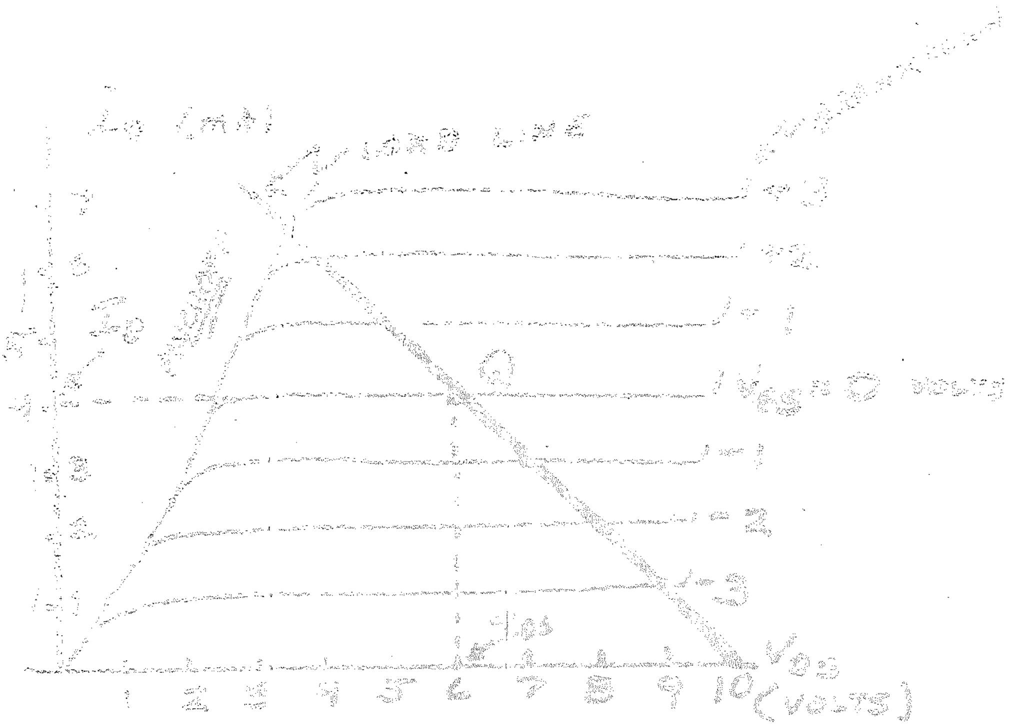
$$0.5 < V_{BE} < 0.9 \text{ VOLTS}$$

$$1 < I_{CBO} < 10nA.$$

BY ASSUMING WORST CASE CONDITIONS, FIND THE BOUNDS ON THE VARIATION OF $I_c$ IN A SELF-BIASING CIRCUIT. THAT IS, FIND $I_{minimum}$ AND $I_{maximum}$ SUCH THAT

$$I_{minimum} \le I_c \le I_{maximum}$$

ASSUME THAT THE CIRCUIT VALUES ARE $R_1 = 10k\Omega$, $R_2 = 100k\Omega$, $R_E = 1k\Omega$ $R_C = 5k\Omega$ AND $V_{CC} = 22$ VOLTS.



(a) $V_{DS} = V_{DD} - R_D I_D$

$\Rightarrow R_D = (V_{DD} - V_{DS})/I_D = \frac{10 \text{ VOLTS} - 6 \text{ VOLTS}}{4 \text{ mA}} = 1 k\Omega$

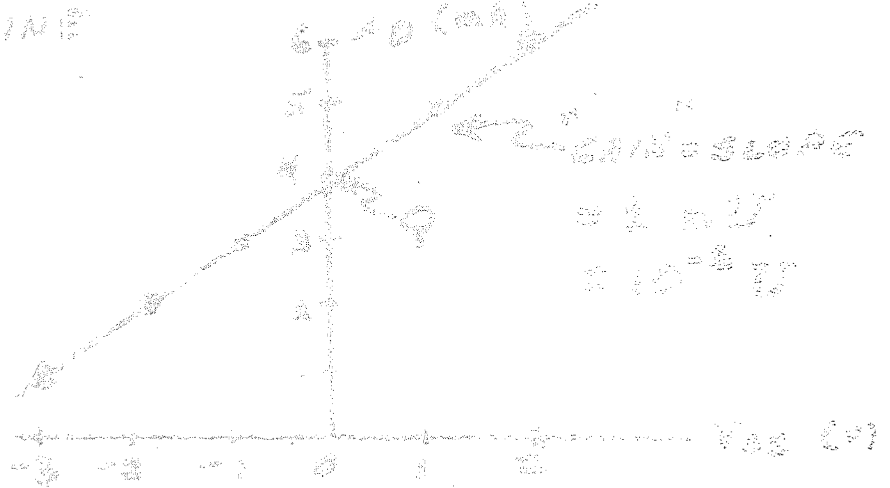
(b) LOAD LINE: $V_{DS} = V_{DD} - R_D i_D$

$\Rightarrow V_{DS} = 10 - 10^3 i_D$

$\Rightarrow i_D = 10^{-3} (V_{DS} - 10)$

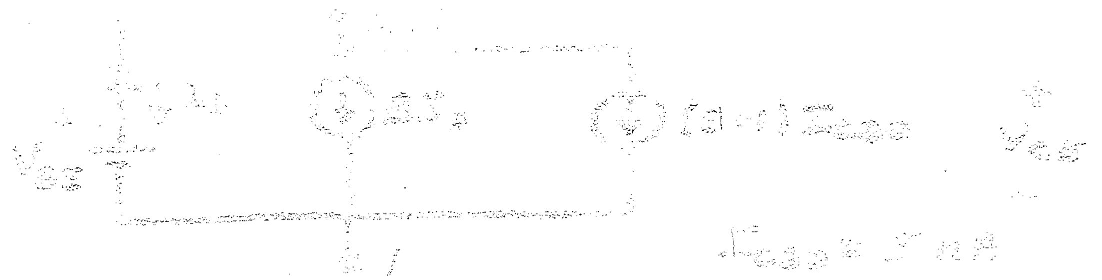
(c) FROM LOAD LINE

| $V_{GS}$ (V) | $i_D$ (mA) |
|---|---|
| 2 | 6 |
| 1 | 5 |
| 0 | 4 |
| −1 | 3 |
| −2 | 2 |
| −3 | 1 |



← GAIN = SLOPE = 1 m℧ = $10^{-3}$ ℧

(d) FOR $V_{GS} > -3V$, WE GET "PINCHOFF"; FOR $V_{GS} < -3$, WE GET BREAKDOWN. THUS, THE RANGE LIMIT IS $-3 V < V_{GS} < 2 V$



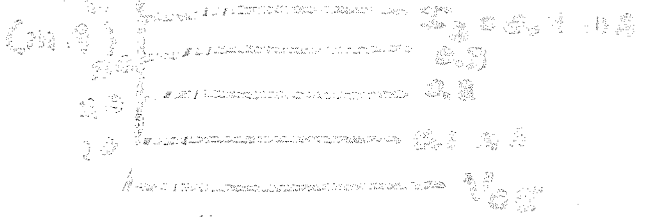
$I_{CBO} = 5$ nA

(a) SUMMING CURRENT AT COLLECTOR: $I_C = \beta I_B + (\beta+1) I_{CBO}$

$\beta = 100$  $I_C = 100 I_B + 101 I_{CBO}$

FOR $I_B = 0.1, 0.2, 0.3, 0.4$ mA

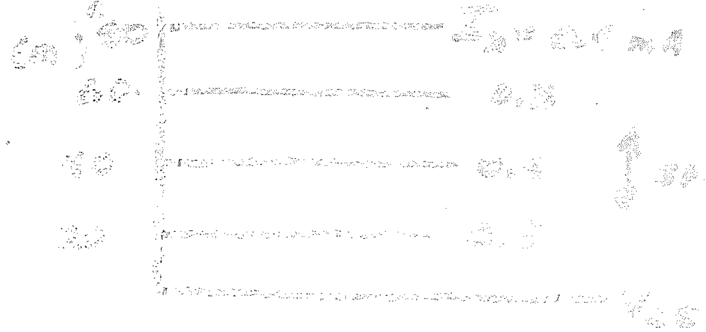
$I_C \approx 100 I_B = 10, 20, 30, 40$ mA



(b) FOR $\beta = 200$, CURVE IS SIMPLY "SPREAD OUT"

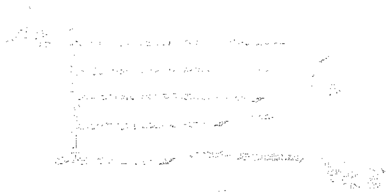
$I_C \approx 200 I_B$

$= 20, 40, 60, 80$ mA

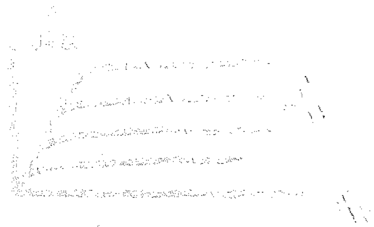


SPREAD OUT BY FACTOR 2

(c)



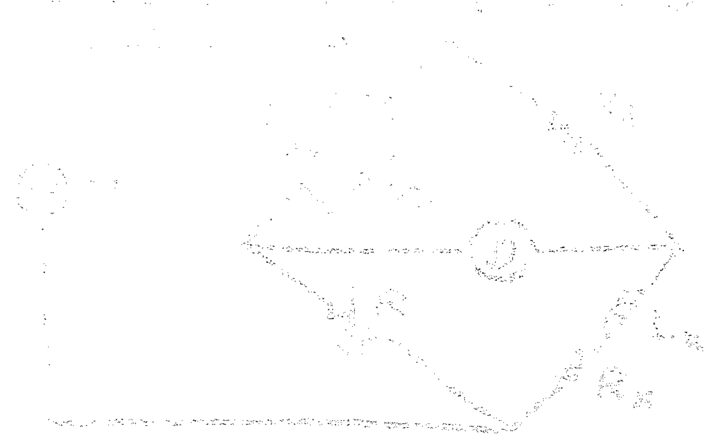
IDEAL



ACTUAL

(d) $r_o$ SIMPLY SO THAT $I_C$ [illegible]
THROUGH THE SLOPE IN OUR MODEL
(OR THE Early Effect (B-C) JUNCTION
IN OUR ACTUAL TRANSISTOR).

⑧ THIS PROBLEM IS WORKED IN EXAMPLE
2, PAGE 421 OF SMITH, 2ND ED.



[illegible] BRIDGE [illegible] ARE [illegible] TWO [illegible], L [illegible] ADJUSTING $R_B$ [illegible] R UNTIL THE NULL DETECTOR $D$ DETECTS NO VOLTAGE. (a) SHOW THAT, WHEN THIS BRIDGE IS BALANCED, THAT $R_x = RR_1/R_B$ AND $L_x = C_B R R_A$. (b) IF THE VARIABLE RESISTORS HAVE ACCURACY [illegible] $R_1$ [illegible] ± 1%, AND $C_B$ IS ± 5%, [illegible] ACCURACY OF OUR MEASUREMENTS OF $L_x$ AND $R_x$. (c) WHAT DEPENDENCE DOES OUR MEASUREMENT HAVE ON THE AMPLITUDE AND FREQUENCY OF OUR SOURCE. IN [illegible] WHY [illegible] SET THE AMPLITUDE AND/OR FREQUENCY TO ZERO?

(2)

IN THIS BRIDGE, [illegible] AND [illegible] ARE FIXED, [illegible] IS [illegible] AND $Z_x$ IS UNKNOWN. IF THIS BRIDGE IS [illegible] FIND $Z_x$ [illegible] $Z_1$, $Z_2$, AND $Z_3$. [illegible] HAPPEN IF [illegible] TERMINALS [illegible] BRIDGE IS [illegible]

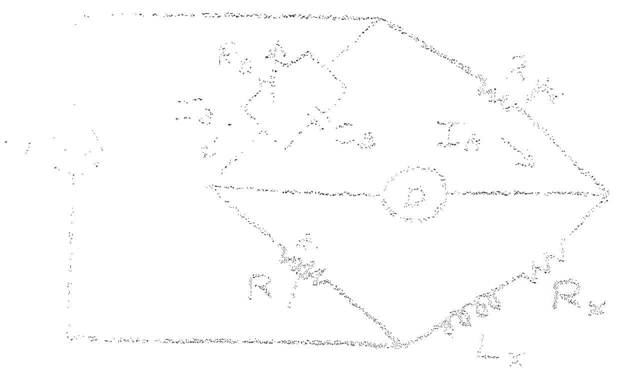
(3)

[illegible] $R_s$ [illegible] $R_x$ AND C [illegible] CAN THIS BRIDGE BE BALANCED [illegible] FIND [illegible] OF $R_s$, $R$, [illegible] (HINT: USE [illegible])

[illegible] CIRCUIT DESC[illegible] CREATION [illegible] EXAMPLE

HOMEWORK #5 SOLUTIONS (by Manas )

1)



(a) UNDER BALANCED CONDITIONS

1° $I_B Z_B = I_A R_A$

WHERE $Z_B = \dfrac{R_B/j\omega C_B}{R_B + \dfrac{1}{j\omega C_B}} = \dfrac{R_B}{1 + j\omega C_B R_B}$

AND 2° $I_B R = I_A Z_x$

WHERE $Z_x = R_x + j\omega L_x$

DIVIDING 1° BY 2° AND SOLVING FOR $Z_x$ GIVES

$$Z_x = R_A R / Z_B = R_A R \,(j\omega C_B R_B + 1)/R_B$$

$$\Rightarrow R_x + j\omega L_x = \frac{R_A R}{R_B} + j\omega\left[C_B R R_A\right]$$

EQUATING REAL $ IMAGINARY COMPONENTS

$R_x = R_A R/R_B$   $L_x = C_B R R_A$

(b) $\varepsilon[R_x] = [1 \pm 0.0001][1 \pm 0.0002][1 \pm 0.0002]$

$\approx 1 \pm 0.0005 \Rightarrow \pm 5\%$

$\varepsilon[L_x] = [1 \pm 0.0005][1 \pm 0.0002][1 \pm 0.0001]$

$= 1 \pm 0.0008 \Rightarrow \pm 8\%$

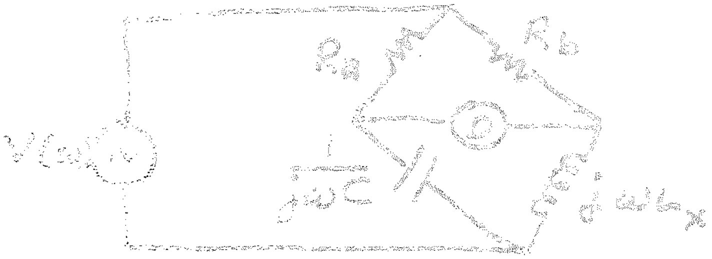
(c) THERE IS NO DEPENDENCE ON ω OR V,
IF WE SET EITHER TO ZERO, THEN
ALL OUR EQUATIONS BECOME
DEGENERATE, IN THE SENSE OF
GOING TO ZERO, INFINITY, OR
BEING UNDEFINED.

(a) WHEN THE VOLTAGE BETWEEN a & b IS ZERO, WE HAVE

$$\left.\begin{array}{l} I_1 Z_a = I_2 Z_b \\ I_1 Z = I_2 Z_x \end{array}\right\} \Rightarrow \frac{Z_a}{Z} = \frac{Z_b}{Z_x} \Rightarrow Z_x = \frac{Z_b Z}{Z_a}$$

(b) HENCE, THE POTENTIAL AT a & b IS THE SAME

(3)



USING RESULTS OF ②: IF BRIDGE IS BALANCED

$$Z_x = \frac{Z_b}{Z_a} Z$$

$$j\omega L_x = \frac{R_b}{R_a} \frac{1}{j\omega C}$$

$$-\omega L_x = \frac{R_a}{R_b} \frac{1}{\omega C} \Rightarrow L_x = -\frac{R_a}{R_b} \frac{1}{\omega^2 C}$$

BUT, ALL INDUCTANCE MUST BE POSITIVE. THUS, WE CONCLUDE THAT THE BRIDGE CANNOT BE BALANCED.

[illegible] (MAR[illegible]

(1) [illegible] GAIN IS MANY TIMES EXPRESSED IN "DECIBELS" AS "db". THE DC GAIN, $A_{DB}$, IS RELATED TO THE GAIN $A_F$ [$V_{out}/V_{in}$] BY THE RELATION

$$A_{DB} = 20 \log_{10} A_F$$

(a) DESIGN [illegible] AMP BASIC INVERTING CIRCUIT WITH A GAIN OF $A_{DB} = 20$ db AND AN INPUT IMPEDANCE (RESISTANCE) OF 100Ω

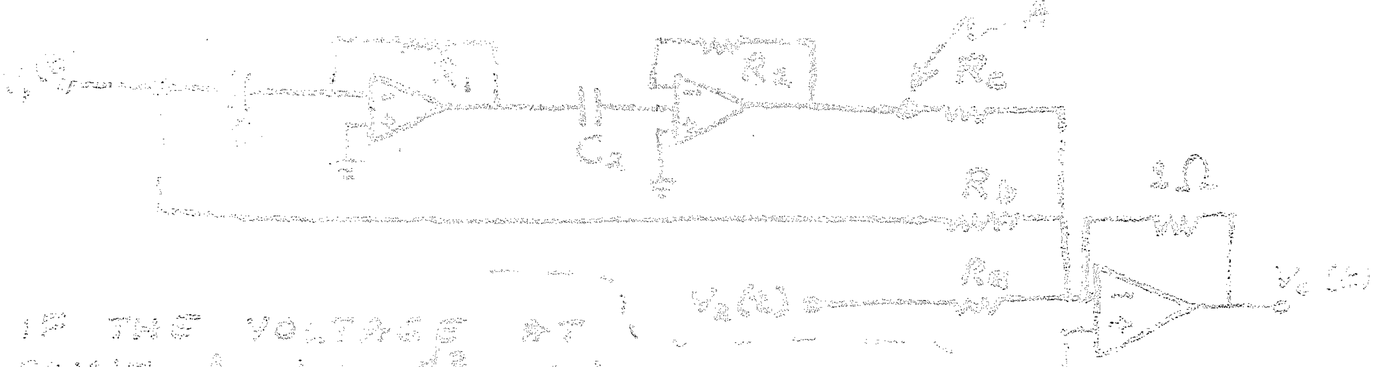
(b) SAME AS (a), BUT $A_{DB} = 40$db

(c) IN GENERAL, IF WE DOUBLE THE db GAIN, $A_{DB}$, WHAT MUST WE DO TO THE GAIN, $A_F$?

(2) WE WISH TO COMBINE TWO VOLTAGES, $V_1(t)$ AND $V_2(t)$ INTO $V_0(t)$ WHERE

$$V_0(t) = a V_2(t) + b V_1(t) + c \frac{d^2 V_1(t)}{dt^2}$$

WHERE a, b, AND c ARE KNOWN NEGATIVE CONSTANTS. THE FOLLOWING ANALOG COMPUTER WILL DO THE TRICK:



IF THE VOLTAGE AT POINT A IS $\frac{d^2}{dt^2}V_1(t)$, FIND THE REQUIRED RELATIONSHIP BETWEEN THE PARAMETERS $R_1$, $C_1$, $R_2$, $C_2$, $R_a$, $R_b$, AND $R_c$ WITH THE NEGATIVE CONSTANTS a, b, AND c. [HINT: IF $V_A(t) = d^2V_1/dt^2$, THEN $R_1 C_1 R_2 C_2$ = CONSTANT. FINDING THIS CONSTANT WILL BE THE SOLUTION TO HALF THIS PROBLEM. CONSTANT IS INDEPENDENT OF a, b, AND c]

(3) OP AMPS AND ANALOG COMPUTERS CAN BE USED TO SOLVE DIFFERENTIAL EQUATIONS. CONSIDER:

$$\frac{d^2 v_1(t)}{dt^2} = -a_2 \frac{d v_1(t)}{dt} + a_1 v_1(t) - b u(t)$$

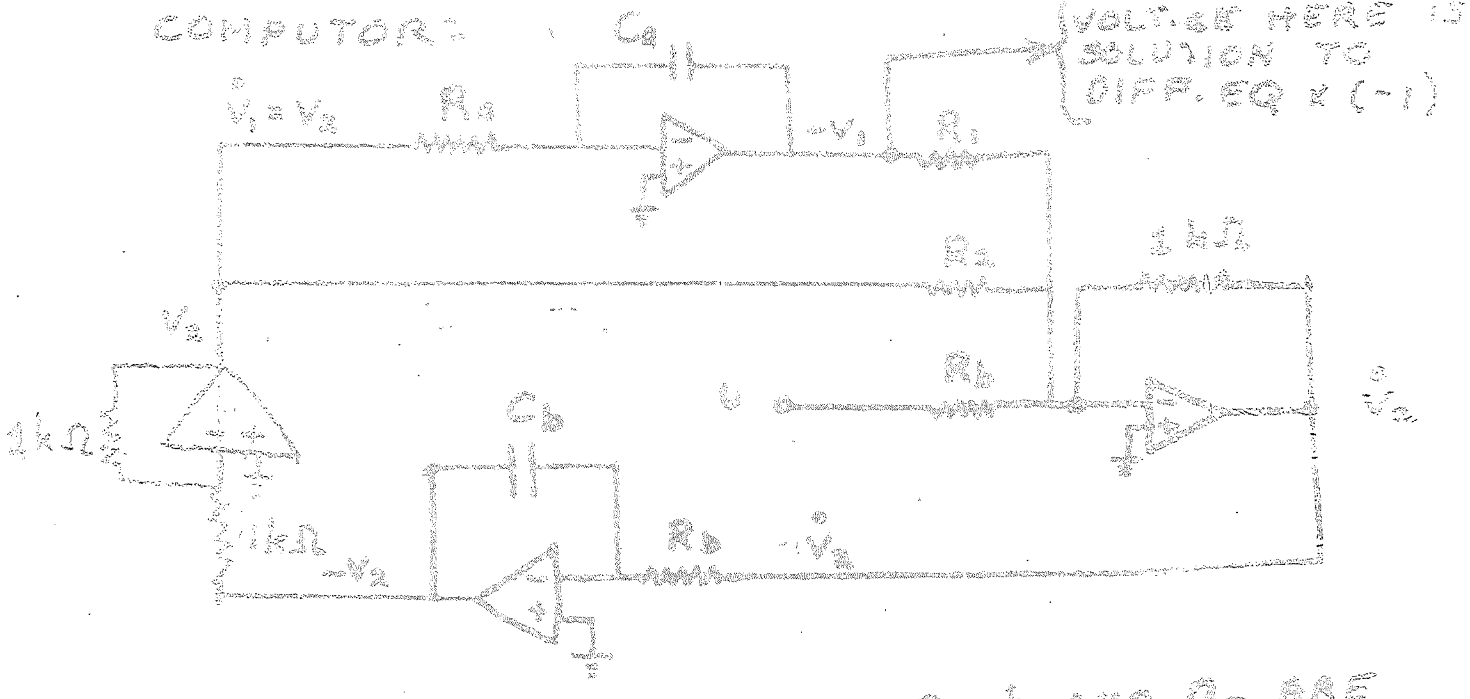
WE WISH TO FIND $v_1(t)$ FOR A GIVEN INPUT, (OR "FORCING FUNCTION") $u(t)$. LET

$v_2(t) = dv_1(t)/dt$ (a) SHOW THAT WE CAN COMBINE THESE ABOVE TWO RELATIONS INTO "STATE EQUATIONS":

$$\dot{v}_2 = a_1 v_1 - a_2 v_2 - bU$$

$$\dot{v}_1 = v_2 \qquad \left[\dot{v} = dv/dt\right]$$

(b) ASSUMING ZERO INITIAL CONDITIONS, FIND THE RELATIONSHIPS BETWEEN THE CONSTANTS $a_1$, $a_2$, AND $b$ AND THE R'S AND C'S IN THE FOLLOWING COMPUTOR:



ASSUME THAT CONSTANTS $a_1$, $b$, AND $a_2$ ARE POSITIVE (HINT; AS AN EXAMPLE, $R_a C_a = 1$ AND $R_1 = (1/a_1)$ kΩ USE VOLTAGES SHOWN ON CIRCUIT).

[illegible]

(1)

[illegible] IDEAL INVERTING CIRCUIT

GAIN = $A_F$ = $-R_F/R_1$

INPUT IMPEDANCE = $R_1$ = 100Ω

(a) $A_{dB}$ = 20dB ⇒ $A_F$ = 10, SINCE 20 $\log_{10}$ 10 = 20

$A_F = R_F/R_1 = R_F/100 = 10$ ⇒ $R_F = 10^3 Ω = 1 kΩ$

(b) $A_{dB}$ = 40dB ⇒ $|A_F|$ = 100 SINCE 20 $\log_{10} 10^2$ = 40

$|A_F| = R_F/100 = 100$ ⇒ $R_F = 10^4 = 10kΩ$

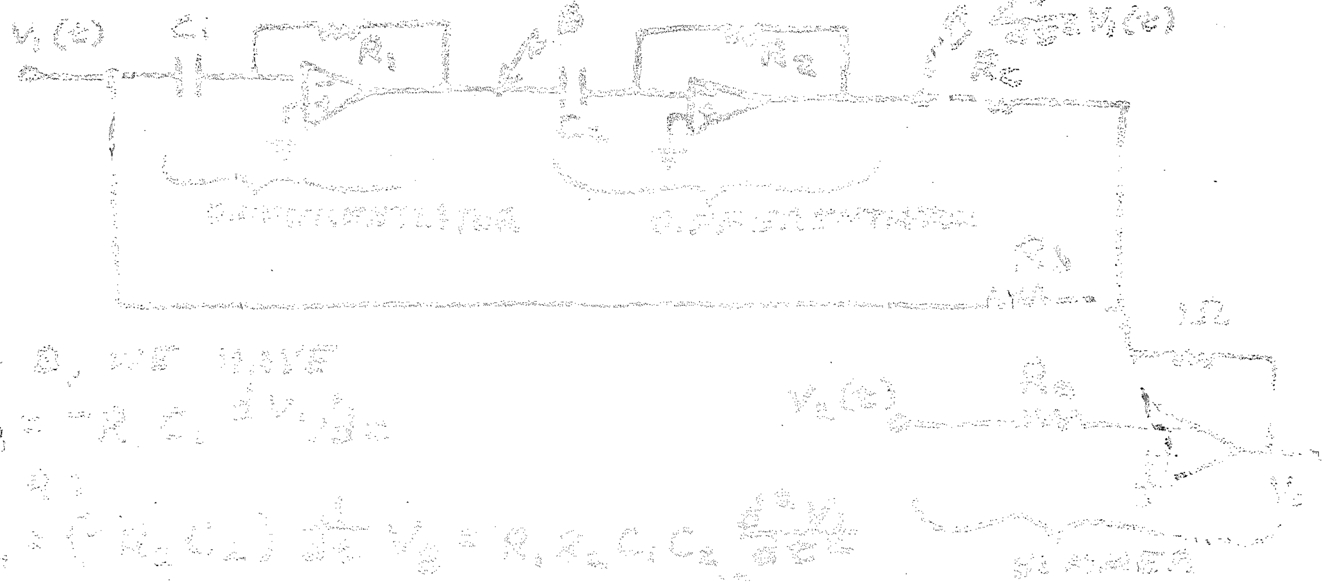
(c) LET $|A_F|$ CORRESPOND TO $A_{dB}$ = 20 $\log_{10} A_F$

THUS $A_F = 10^{A_{dB}/20}$. LET $\hat{A}_{dB} = 2A_{dB}$. THEN

$\hat{A}_F = 10^{\hat{A}_{dB}/20} = 10^{2A_{dB}/20} = (10^{A_{dB}/20})^2 = A_F^2$.

THUS, IF WE DOUBLE $A_{dB}$, WE SQUARE $A_F$.

(2)



AT B, WE HAVE

$V_B = -R_1C_1\, dV_1/dt$

AT D:

$V_D = (-R_2C_2)\frac{d}{dt}V_B = R_1R_2C_1C_2\frac{d^2V_1}{dt^2}$

SINCE WE REQUIRE $V_D = d^2V_1/dt^2$ ⇒ $R_1R_2C_1C_2 = 1$.

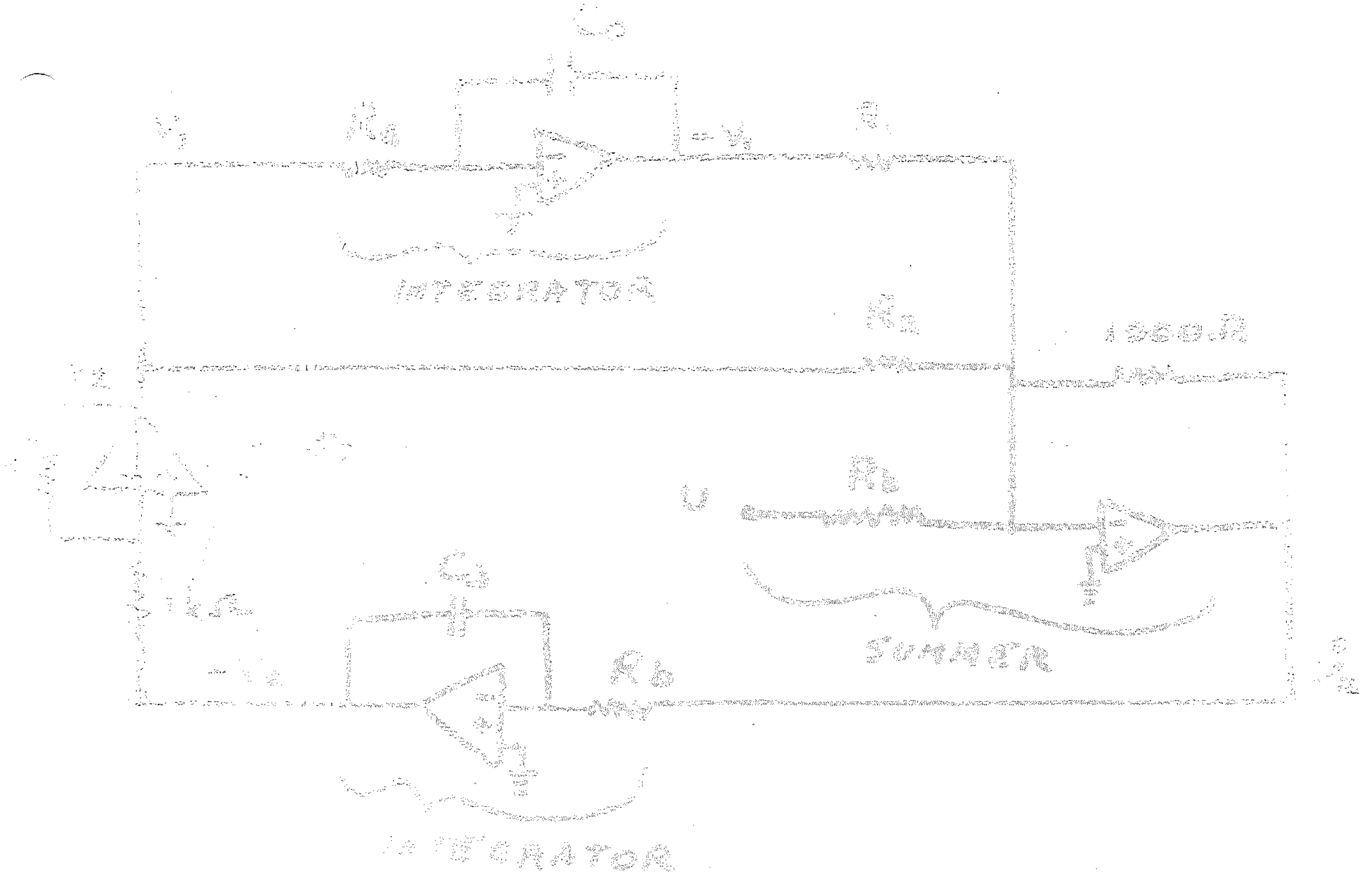
SUMMER OUTPUT IS:

$$-\frac{V_o}{1Ω} = \frac{V_D}{R_c} + \frac{V_1}{R_b} + \frac{V_2}{R_a}$$

$$\text{OR } V_o = -\frac{1}{R_c}\frac{d^2V_1}{dt^2} - \frac{1}{R_b}V_1 - \frac{1}{R_a}V_2$$

THUS, $c = -1/R_c$, $b = -1/R_b$, $a = -1/R_a$

OR $R_c = -1/c$, $R_b = -1/b$, $R_a = -1/a$



[illegible] THE TOP MOST INTEGRATOR, IN ORDER TO HAVE $-V_2$ AS ITS OUTPUT WITH $V_1$ THE INPUT, WE MUST HAVE $R_aC_a = 1$. SIMILARLY, FOR THE BOTTOM INTEGRATOR, $R_bC_b = 1$. IN THE SUMMER, WE OBVIOUSLY WANT:

$$R_1 = (1/a_1)k\Omega,\ R_2 = (1/a_2)k\Omega;\ R_3 = (1/b$$

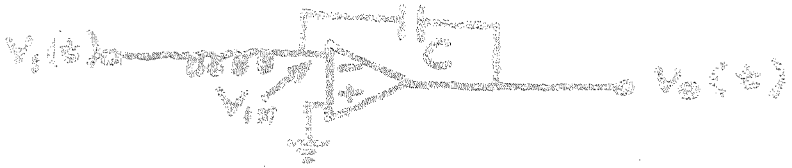
"PROVE ALL THINGS; HOLD FAST THAT WHICH IS GOOD"
-THES I: 5,21-

"NOTHING GREAT WAS EVER ACHIEVED WITHOUT ENTHUSIASM"
-EMERSON-

OLD EE PROVERB:
"HOMEWORK IS GOOD FOR YOU"
-OLD EE-

(EE 234) MARKS

(a) DETERMINE THE RELATIONSHIP BETWEEN $V_0$ AND $V_1(t)$ IN THE FOLLOWING OP AMP CIRCUIT (ASSUME $V_{in} \approx \int^{t}\int^{t} V_1\,dt\,dt \approx 0$). WHY MIGHT WE CALL THIS CIRCUIT A "DOUBLE INTEGRATOR"?

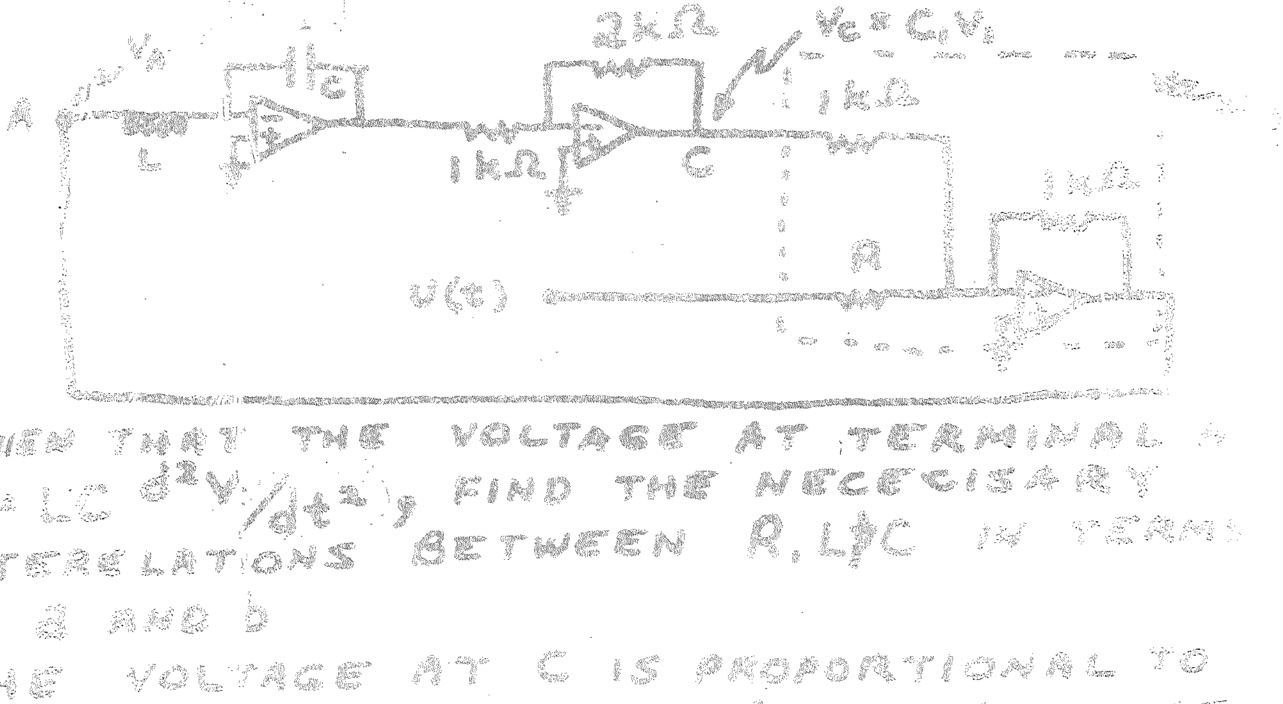


[HINT: YOU WILL NEED TO ASSUME THAT THE OP AMP INPUT CURRENT IS ≈ 0.]

(b) WE MAY USE THIS CIRCUIT TO SOLVE THE "DRIVEN WAVE EQUATION"

$$\frac{d^2V}{dt^2} = -aV(t) - bu(t)$$

WHERE a & b ARE POSITIVE KNOWN CONSTANT AND u(t) IS THE "INPUT" OR "DRIVING TERM"

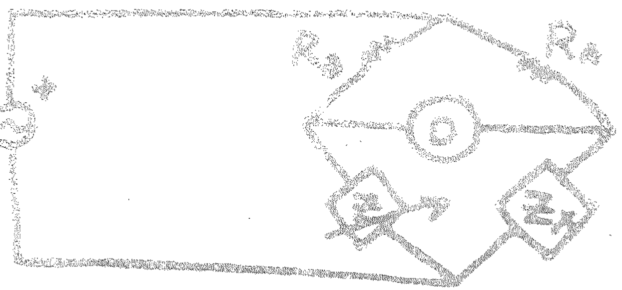


① GIVEN THAT THE VOLTAGE AT TERMINAL A $V_1 = LC\, d^2V/dt^2$, FIND THE NECESSARY INTERRELATIONS BETWEEN R, L & C IN TERMS OF a AND b

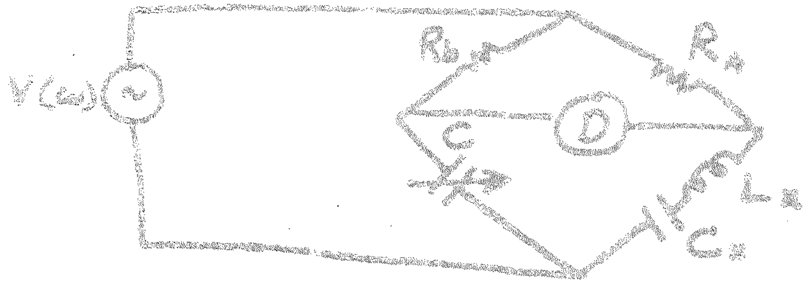
② THE VOLTAGE AT C IS PROPORTIONAL TO OUR SOLUTION. THAT IS, $V_C = C_1V_1$. WHAT IS THE PROPORTIONALITY CONSTANT, $C_1$

2. WE SAY THAT AN IMPEDANCE, $Z = R + jX$, IS "INDUCTIVE" WHEN $X > 0$. FOR $X < 0$, $Z$ IS "CAPACITIVE."

(a) FOR THE FOLLOWING IMPEDANCE BRIDGE, SHO THAT, IN ORDER TO ACHEIVE BALANCE, $Z$ AN $Z_x$ MUST BOTH EITHER BE INDUCTIVE OR BOTH CAPACITIVE



(b) FOR WHAT FREQUENCY RANGE WILL THE FOLLOWING BRIDGE BALANCE? [RECALL THA THE RESONANT FREQUENCY OF $L_x$ AND $C_x$ IS $\omega = 1/\sqrt{L_x C_x}$. USE THE RESULTS OF (



(c) SHOW THAT, WHEN THE BRIDGE IS BALANCE THAT $L_x$ AND $C_x$ ARE RELATED TO C BY

$$C = \frac{C_x}{1 - \omega^2 L_x C_x} \frac{R_B}{R_A}$$

WHERE $\omega$ LIES IN THE RANGE DERIVED IN (b).

(d) EXPLAIN WHY THIS BRIDGE (PARTS b & c) IS A POOR SCHEME FOR MEASURING UNKNOWNS $L_x$ AND $C_x$. (AT LEAST TWO REASONS).

3. (a) FOR A SIGNAL, $\sin \omega_m t$, OUR MODULATED SIGNAL

$$V_s(t) = [1 + m \sin \omega_m t]\{V_c \sin \omega_c t\}$$

WHERE $V_c \sin \omega_c t$ IS OUR CARRIER AND m, OUR DEGREE OF MODULATION. IF $m > 1$, THE SIGNAL IS SAID TO BE OVER-MODULATED. SHOW, GRAPHICALLY, THAT OVERMODULATION "DISTORTS" OUR SIGNAL. [NOTE: ON THE MODULATED WAVEFORM, OUR SIGNAL IS THE ENVELOPE]

(b) A GOOD QUALITY ACOUSTIC REPRODUCTION SHOULD CONTAIN FREQUENCIES UP TO 20,000 HZ. HOW MANY SUCH SEPARATE REPRODUCTIONS CAN BE SENT OVER A CHANNEL WHOSE FREQUENCY CAPACITY RANGES FROM 0 TO 8 MEGA-HZ?

HOMEWORK #7 SOLUTIONS (by Mark)

(2)

(a)

SUMMING CURRENTS AT $V_{IN}$:

$$\frac{1}{L}\int^t (V_1 - V_{IN})\,dt + C\left[\frac{dV_0}{dt} - \frac{dV_{IN}}{dt}\right] = 0$$

(THE INPUT CURRENT TO OP AMP ≈ 0)

THUS: $$\frac{d(V_0 - V_{IN})}{dt} = \frac{-1}{LC}\int^t (V_1 - V_{IN})\,dt$$

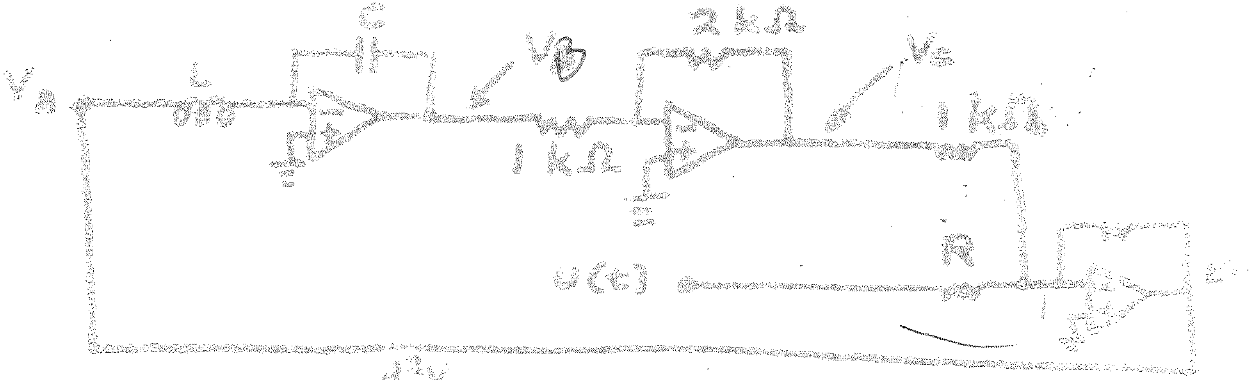
$$\Rightarrow V_0 - V_{IN} = \frac{-1}{LC}\int^t\int^t (V_1 - V_{IN})\,dt\,dt$$

OR, SINCE $V_{IN} \approx \int^t\int^t V_{IN}\,dt\,dt \approx 0$ :

$$V_0(t) = \frac{-1}{LC}\int^t\int^t V_1(t)\,dt\,dt$$

WE PERFORM A DOUBLE INTEGRATION ON THE INPUT, THUS "DOUBLE INTEGRATOR"

(b)



GIVEN $V_A = LC\frac{d^2y}{dt^2}$, WE HAVE FROM (a) THAT $V_B = -V_1$. THE AMP FOLLOWING HAS A GA OF -2. THUS, $V_C = 2V_1$ (AND $C_1 = 3$). THE OUTPUT OF THE SUMMER IS:

$$\frac{V_D}{k\Omega} = \frac{-V_C}{1k\Omega} - \frac{u(t)}{R} \Rightarrow V_D = -V_C - \frac{1k\Omega}{R}u(t)$$

BUT $V_D = V_A = LC\frac{d^2y}{dt^2} = -V_C - \frac{1k\Omega}{R}u(t)$

OR $$\frac{d^2y}{dt^2} = \frac{-1}{LC}V_C - \frac{1k\Omega}{RLC}u(t)$$

IN ORDER FOR THIS TO BE OUR DIFF. EQ.:

$$z = \frac{1}{LC}\ , \quad b = \frac{1k\Omega}{RLC} = \frac{a(1k\Omega)}{R}$$

2. (a) WHEN THE BRIDGE IS BALANCED:

$$Z_x = Z\, R_A/R_B$$

LET $Z_x = R_x + jX_x$ AND $Z = R + jX$. EQUATING IMAGINARY PARTS:

$$X_x = \frac{R_A}{R_B} X$$

THUS, IF $X > 0$, THEN $X_x > 0$ (i.e., BOTH $Z$ AND $Z_x$ ARE INDUCTIVE). IF $X < 0$, THEN $X_x <$ (i.e., BOTH $Z$ AND $Z_x$ ARE CAPACITIVE).

(b) FOR THIS CIRCUIT:

$$X = \frac{-1}{\omega C} \qquad X_x = \left(\omega L_x - \frac{1}{\omega C_x}\right)$$

SINCE, FROM (a), $X_x$ MUST BE NEGATIVE:

$$\omega L_x - \frac{1}{\omega C_x} < 0$$

$$\omega L < \frac{1}{\omega_x C_x} \Rightarrow \omega^2 < \frac{1}{L_x C_x}$$

$$\therefore\ \omega < \frac{1}{\sqrt{L_x C_x}}$$ = RESONANCE OF $L_x$ & C

(c) AT BALANCE:

$$Z_x = Z\, R_A/R_B$$

$$j\left(\omega L_x - \frac{1}{\omega C_x}\right) = -j \frac{R_A}{R_B} \frac{1}{\omega C}$$

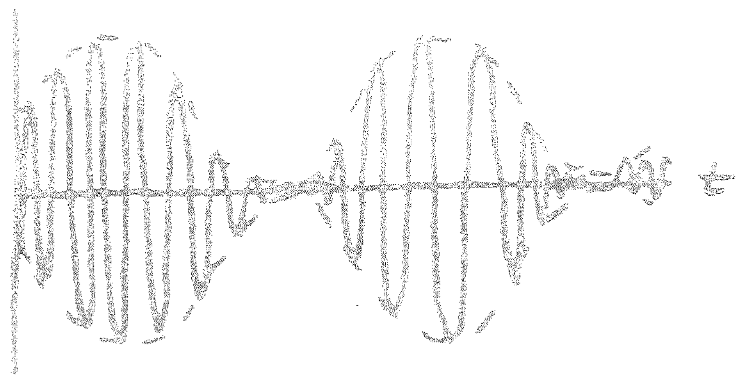
$$\frac{1}{\omega C_x} - \omega L_x = \frac{R_A}{R_B} \frac{1}{\omega C}$$

SOLVING FOR C:

$$C = \frac{C_x}{1 - \omega^2 L_x} \frac{R_B}{R_B}$$

(d) THE VALUES OF $L_x$ & $C_x$ ARE NOT UNIQUELY DETERMINED AND THE RESULT IS FREQUENCY DEPENDENT.

3. (a) FOR $m=1$, THE MODULATED SIGNAL LOOKS LIKE



FOR $m>1$:

THE ENVELOPE (OUR SIGNAL) IS DISTORTED

(b) $N = \frac{8 \times 10^6}{2(2 \times 10^4)} = 2 \times 10^2 = 200$ REPRODUCTIONS

HOMEWORK #8 (EE284) M.PAKS

1. CONSIDER THE FOLLOWING GROUPING OF NUMBERS.

⓪ 1, 3, 5, 7, 9, 11, 13, 15
① 2, 3, 6, 7, 10, 11, 14, 15
② 4, 5, 6, 7, 12, 13, 14, 15
③ 8, 9, 10, 11, 12, 13, 14, 15

IF ONE PICKS A NUMBER BETWEEN 1 AND 15, AND SPECIFIES WHICH OF THE ABOVE ROWS IT IS CONTAINED IN, THE UNKNOWN NUMBER CAN BE COMPUTED BY ADDING THE FIRST NUMBERS IN EACH ROW. FOR EXAMPE, THE NUMBER 13 IS IN ROWS ⓪, ② AND ③. THE FIRST NUMBERS OF THESE ROWS ARE 1, 4, AND 8 AND 1+4+8=13.

(a) EXPLAIN WHY THIS WORKS [HINT: USE BINARY NUMBERS IN YOUR REASONING]

(b) MAKE A SIMILAR TABLE UP TO AND INCLUDING THE NUMBER 31. [HINT: IT WILL HAVE FIVE ROWS WITH 16 NUMBERS IN EACH ROW. HINT HINT: NOTICE THE PATTERN OF THE ROWS (LEFT TO RIGHT)]

2. A CODE WHICH CAN DETECT AND CORRECT A SINGLE BIT ERROR, CALLED THE "HAMMING" CODE, USES THE ABOVE IDEA. SUPPOSE WE WANTED TO SEND AN ELEVEN BIT CODE: 111 00 11111 0. WE BREAK IT UP INTO THE FOLLOWING:

| | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BINS → | 1 | 1 | 1 | 0 | 0 | 1 | 1 | $P_3$ | 1 | 1 | 1 | $P_2$ | 0 | $P_1$ | $P_0$ |

NOTE THAT, FOR THE $2^n$TH PLACE, WE HAVE PUT $P_n$ (EX: AT $2^2=4$, WE PUT $P_2$). THESE P'S ARE "PARITY" BITS. NOW WE GO TO COLUMN ⓪ IN PROBLEM 1. WE WANT THE BINS IN THIS ROW TO CONTAIN AN EVEN NUMBER OF 1'S. WE SEE THAT THERE ARE, IN FACT, AN ODD NUMBER (5) ONES IN BINS 15, 13, 11, 9, 7, 5, AND 3. THUS, WE MUST CHOOSE $P_0=1$ SO THAT THE TOTAL NUMBER OF ONES IS EVEN. FOR ROW ① IN PROBLEM 1, BINS 15, 14, 11, 10, 7, 6, AND 3 CONTAIN AN ODD NUMBER (5) OF 1'S SO WE MUST ALSO MAKE $P_1=1$.

(a) SHOW THAT $P_2=0$ AND $P_3=1$ SO THAT OUR TOTAL CODE IS 111 0011 111 0 011.

(b) PERFORM A HAMMING CODING ON THE ELEVEN BIT WORD 10101010101.

3. AT THE RECEIVING END OF A HAMMING CODE, WE CAN DETECT AND CORRECT A SINGLE BIT ERROR. SUPPOSE WE SENT THE WORD IN PROBLEM 2 AND RECEIVED

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| | | | | | | | $P_3$ | | | | $P_2$ | | $P_1$ | $P_0$ |

(a) GOING THROUGH THE PROCEDURE IN PROBLEM 2, SHOW THAT THIS WORD SHOULD HAVE PARITY BITS $P_0=1$, $P_1=0$, $P_2=1$, $P_3=1$.

NOW COMPARE THESE PARITY BITS WITH THOSE RECEIVED ⇒

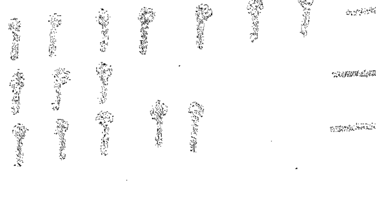
$$\text{RECEIVED} \rightarrow P_3P_2P_1P_0 = 1\,0\,1\,1$$
$$\text{SHOULD BE} \rightarrow P_3P_2P_1P_0 = \underline{1\,1\,0\,1}$$
$$\text{BITS DIFFERING} \longrightarrow 0\,1\,1\,0$$

BY "BITS' DIFFERING" WE MEAN 0 WHEN $P_n$ MATCHES AND 1 WHEN THEY'RE DIFFERENT. NOTE $(0110)_2 = 6$, THUS, OUR ERROR IS IN BIN 6. COMPARING THE ABOVE RECEIVED CODE TO OUR TRANSMITTED CODE IN PROBLEM 2, WE SEE THAT THIS IS TRUE. (NEAT, HUH?)

(b) IN YOUR HAMMING CODE DERIVED IN 2(b), MAKE AN ERROR IN BIN 13. BE A RECEIVER AND CORRECT YOUR MISTAKE AS WAS DONE IN PART a OF THIS PROBLEM.

4. (EXTRA CREDIT) NIM IS AN OLD CHINESE GAME WHERE THREE ROWS OF MATCHSTICKS ARE LAID OUT. ANY NUMBER OF MATCHSTICKS CAN BE IN ANY ROW. TWO PLAYERS ALTERNATELY TAKE TURNS. DURING A TURN, A PLAYER CAN TAKE FROM ANY ONE ROW AS MANY MATCHSTICKS AS HE DESIRES. HE MUST TAKE AT LEAST ONE MATCHSTICK. THE PLAYER WHO PICKS UP THE LAST MATCHSTICK OR GROUP OF MATCHSTICKS WINS. BY USING BINARY NUMBERS, BELIEVE IT OR NOT, YOU CAN ALWAYS WIN. (ALMOST

CONSIDER THE FOLLOWING "GAME BOARD" OF THREE ROWS OF MATCHSTICKS:



$$\rightarrow 7 = (1\,1\,1)_2$$
$$\rightarrow 3 = (0\,1\,1)_2$$
$$\rightarrow 5 = (1\,0\,1)_2$$
$$\overline{2\,2\,3} \leftarrow \text{SUM (GAME \#)}$$

NOTE THAT FOR EACH ROW, WE HAVE CONVERTED THE NUMBER OF MATCHSTICKS TO BASE 2 AND HAVE ADDED THEM (IN BASE 10) TO ARIVE AT WHAT WE SHALL CALL THE GAME # (NUMBER). IF THE GAME NUMBER CONTAINS ONLY 0'S AND 2'S, IT IS "SAFE," OTHERWISE (IE IT CONTAINS ONE OR MORE 1'S OR 3'S), IT IS "UNSAFE."

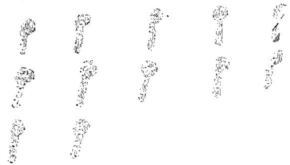
HERE IS THE BASIS FOR ALWAYS WINNING NIM: BY THE GAME RULES, IT IS ALWAYS POSSIBLE TO CHANGE AN UNSAFE NUMBER TO A SAFE NUMBER BUT IS IMPOSSIBLE TO CHANGE A SAFE NUMBER INTO ANOTHER SAFE NUMBER.* (THIS IS A VERY HAIRY PROOF WHICH WE WILL NOT GO INTO). THUS, IN PLAYING, THE GAME NUMBER ALTERNATES BETWEEN SAFE AND UNSAFE UNTIL THE WINNING SAFE NUMBER OF 0 IS REACHED.

IN THE GAME BOARD AT THE BOTTOM OF THE PREVIOUS PAGE, THE GAME NUMBER CAN BE MADE SAFE BY TAKING ONE MATCHSTICK FROM THE THIRD ROW. THE NEW GAME NUMBER WILL BE 222.

(a) OBVIOUSLY, IF YOU PLAY NIM WITH ANOTHER PERSON WHO KNOWS HOW TO PLAY, YOU WON'T ALWAYS WIN. IN THIS CASE, HOW DOES THE INITIAL GAME BOARD AND WHO GOES FIRST DETERMINE WHO WINS?

(b) FOR THE FOLLOWING GAME BOARDS, DETERMINE IF THE GAME # IS SAFE OR UNSAFE. IF UNSAFE, TAKE A TURN + MAKE IT SAFE

(1)



(2)

(3)

(c) PLAY AND BEAT SOMEONE WHO DOESN'T KNOW HOW TO PLAY AT LEAST FIVE TIMES.

*YOU CAN, HOWEVER, MAKE AN UNSAFE # FROM ANOTHER UNSAFE #

HOMEWORK #3 - SOLUTIONS (by [illegible])

1.(a) CONSIDER THE NUMBER 13 = (1011)₂. IT HAS 1'S IN THE $2^0$, $2^1$, AND $2^3$ PLACES, AND THUS IS IN THE ⓪, ①, AND ③ ROWS. IN SHORT, ROW ⓝ CONTAINS ALL THOSE BINARY NUMBERS THAT HAVE A 1 IN THE $2^n$ PLACE.

(b)
⓪ 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31
① 2, 3, 6, 7, 10, 11, 14, 15, 18, 19, 22, 23, 26, 27, 30, 31
② 4, 5, 6, 7, 12, 13, 14, 15, 20, 21, 22, 23, 28, 29, 30, 31
③ 8, 9, 10, 11, 12, 13, 14, 15, 24, 25, 26, 27, 28, 29, 30, 31
④ 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31

2.(a) ROW ② IN PROBLEM (1a) HAS NUMBERS 4, 5, 6, 7, 12, 13, 14, & 15. THE BITS IN THE RESPECTIVE BINS ARE $P_2$, 1, 1, 1, 0, 1, 1, 1 = (6 ONE'S AND $P_2$). THE NUMBER OF ONE'S IS EVEN, SO LET $P_2 = 0$. FOR ③, WE HAVE BINS 8 THRU 15 WHICH HAVE 5 ONE'S AND $P_3$. TO MAKE THE NUMBER OF ONE'S EVEN, $P_3 = 1$.

(b)

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1 0 1 0 1 0 1 $P_3$ 0 1 0 $P_2$ 1 $P_1$ $P_0$

FOR ⓪ : $P_0$, 1, 0, 0, 1, 1, 1, 1 ⇒ $P_0 = 1$ (6 ONES)
① : $P_1$, 1, 1, 0, 0, 1, 0, 1 ⇒ $P_1 = 0$ (4 ONES)
② : $P_2$, 0, 1, 0, 0, 1, 0, 1 ⇒ $P_2 = 1$ (4 ONES)
③ : $P_3$, 1, 0, 1, 0, 1, 0, 1 ⇒ $P_3 = 0$ (4 ONES)

OUR CODE IS THUS
1 0 1 0 1 0 1 0 0 1 0 1 1 0 1

(3)(a) FOR ⓪ : $P_0$, 0, 1, 1, 1, 0, 1, 1 ⇒ $P_0 = 1$
① : $P_1$, 0, 0, 1, 1, 0, 1, 1 ⇒ $P_1 = 0$
② : $P_2$, 1, 0, 1, 0, 1, 1, 1 ⇒ $P_2 = 1$
③ : $P_3$, 1, 1, 0, 0, 1, 1, 1 ⇒ $P_3 = 1$

(b)
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1 1 1 0 0 1 1 1 1 0 1 1 0 0 1

↑ ERROR (13) ↑ $P_3$ ↑ $P_2$ ↑ $P_1$ ↑ $P_0$

PARITY BITS SHOULD BE

⓪: $P_0$, 1, 0, 0, 1, 1, 0, 1 ⇒ $P_0 = 0$

①: $P_1$; 1, 1, 0, 0, 1, 0, 1 ⇒ $P_1 = 0$

②: $P_2$, 0, 1, 0, 0, 0, 0, 1 ⇒ $P_2 = 0$

③: $P_3$, 1, 0, 1, 0, 0, 0, 1 ⇒ $P_3 = 1$ ⇒ $P_3P_2P_1P_0 = 1000$

RECEIVED PARITY BITS ARE: $P_3P_2P_1P_0 = \underline{0101}$

BITS DIFFERING ⇒ 1101

THUS, WE HAVE AN ERROR IN BIN $(1101)_2 = 13$.

4.(a) A "WHO WINS TABLE" ⇒

INITIAL GAME IS → SAFE / UNSAFE

| | YOU | OTHER |
|---|---|---|
| SAFE | OTHER | YOU |
| UNSAFE | YOU | OTHER |

(b) (1)

$$\begin{array}{rl} 5 \rightarrow & 101 \\ 5 \rightarrow & 101 \\ 2 \rightarrow & \underline{\ \ 10} \\ & 212 \end{array}$$

UNSAFE.
MAY MAKE IS SAFE BY TAKING ALL THE MATCHSTICKS FROM THIRD COLUMN. NOTE: THERE IS USUALLY MORE THAN ONE WAY TO MAKE AN UNSAFE NUMBER SAFE.

(2)

$$\begin{array}{rl} 3 \rightarrow & 011 \\ 6 \rightarrow & 110 \\ 1 \rightarrow & \underline{001} \\ & 122 \end{array}$$

UNSAFE. MAY TAKE FOUR FROM SECOND ROW TO GIVE:

$$\begin{array}{rl} 3 \rightarrow & 011 \\ 2 \rightarrow & 010 \\ 1 \rightarrow & \underline{001} \\ & 022 \leftarrow \text{SAFE} \end{array}$$

(3)

$$\begin{array}{rl} 2 \rightarrow & 010 \\ 6 \rightarrow & 110 \\ 4 \rightarrow & \underline{100} \\ & 220 \leftarrow \text{SAFE} \end{array}$$

## Psalm of the Twenty-third year

[illegible]h my instructor;
I shall not pass.
He maketh me to exhibit mine ignorance before the
whole class.
He telleth me more than I can write,
He lowereth my grade.
Yea, tho I walk thru the corridors of knowledge,
I do not learn.
He tries to teach me;
He writeth equations before me in hopes that I will
understand them.
He bewildereth my head with integrations.
My slide rule freezeth up.
Surely enthalpies and entropies shall follow me all the
days of my life,
And I shall dwell in the College of Engineering forever.

—Anonymous

(LAST) HOMEWORK #7 (EE 234) BOB MARKS [illegible]

(1) CONSIDER A BINARY SYMMETRIC CHANNEL OVER WHICH WE SEND AN ELEVEN BIT BINARY SIGNAL. ASSUME $p=q=0.9$ WHERE $p=P_r[0_R/0_T]$ AND $q=P_r[1_R/1_T]$. ASSUME $p_0=P_r[0_T]=1/2$ AND $p_1=P_r[1_T]=1/2$.

(a) WHAT IS THE PROBABILITY NO ERROR IS MADE IN TRANSMITTING THIS SIGNAL OF ELEVEN BITS?

(b) SUPPOSE WE CODED THE ELEVEN BIT SIGNAL WITH A HAMMING CODE. THIS REQUIRES AN ADDITIONAL FOUR (PARITY) BITS FOR A TOTAL OF FIFTEEN BITS. FIND THE PROBABILITY THAT WE WILL BE ABLE TO EXACTLY CONSTRUCT THE SIGNAL SENT. SINCE THE HAMMING CODE CAN DETECT AND CORRECT A ONE BIT ERROR, THIS PROBABILITY WILL BE

$P_r[\text{NO BIT ERRORS}] + P_r[1 \text{ BIT ERROR}]$

(c) IN (a), WE TRANSMIT DIRECTLY. IN (b), WE USE A HAMMING CODE WHICH REQUIRES THE TRANSMISSION OF MORE BITS. IN TERMS OF CORRECTLY DETECTING WHAT WAS SENT, WHICH IS BETTER?

(2) USING TRUTH TABLES, VERIFY DEMORGAN'S THEM.

(a) $\overline{AB} = \bar{A} + \bar{B}$

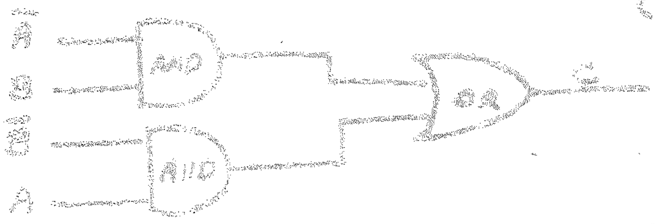
(b) $\overline{A+B} = \bar{A}\,\bar{B}$

HINT:

| A | B | AB | $\overline{AB}$ | $\bar{A}$ | $\bar{B}$ | $\bar{A}+\bar{B}$ |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 |

(3) SHOW THAT THE FOLLOWING IS THE SAME AS AN EXCLUSIVE OR GATE. THAT IS, $C = A \oplus B$

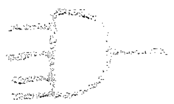
(HINT: USE TRUTH TABLE)



(4) USING ONLY "AND" AND "OR" GATES (INCLUSIVE) DESIGN A CIRCUIT THAT FOLLOWS THE TRUTH TABLE ⟹ (CAN USE "NOT" GATES TOO)

| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

[YOU MAY US MULTI-TERMI GATES, LIK



IF YOU WANT (THESE PROBLEMS ARE EASY)]

(5) SAME AS (4), BUT TRUTH TABLE IS

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |

| A | B | C | D |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 |

EXTRA CREDIT: SPECIFY THE PERFORMANCE OF A "BUT" GATE. THAT IS, C = A <u>BUT</u> B.

HOMEWORK [illegible]

(1) (a) FOR $p = q$, THE PROBABILITY ALL BITS WILL BE CORRECTLY RECEIVED IS

$(p)^{11} = (0.9)^{11} = 0.3138$ OR ~ 31%

[THIS COMPUTATION REQUIRES $p_0 = p_1 = \frac{1}{2}$]

(b) $P_r$[NO ERRORS] = $(0.9)^{15}$ = 20.59%

$P_r$[1 BIT ERROR] = $P_r$[ONLY FIRST BIT IS WRONG] + $P_r$[ONLY SECOND BIT IS WRONG] + ... + $P_r$[ONLY 15TH BIT IS WRONG]

$= (1-p)\,p \cdot p \cdots p + p(1-p)\,p \cdots p + \ldots + p \cdot p \cdot p \cdots (1-p)$

$= 15 \times [(1-p)\,p^{14}]$

$= 15\,(0.1)(0.9)^{14} = 1.5 \times (0.9)^{14}$

$\Rightarrow P_r$[CORRECT DETECTION] $= (0.9)^{15} + 1.5 \times (0.9)^{14}$

$= [0.9 + 1.5] \times (0.9)^{14} = 0.5490 \sim 55\%$

(c) HAMMING CODE IS BETTER. IT INCREASES OUR PROBABILITY OF CORRECT DETECTION BY OVER 20%.

(2) (a) $\overline{AB} = \bar{A} + \bar{B}$

| $A$ | $B$ | $AB$ | $\overline{AB}$ |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 |

| $\bar{A}$ | $\bar{B}$ | $\bar{A}+\bar{B}$ | $A$ | $B$ |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 |

OBVIOUSLY, $\overline{AB} = \bar{A} + \bar{B}$

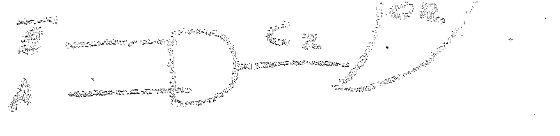
(b) $\overline{A+B} = \bar{A}\bar{B}$

| $A$ | $B$ | $A+B$ | $\overline{A+B}$ |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 |

| $\bar{A}$ | $\bar{B}$ | $\bar{A}\bar{B}$ | $A$ | $B$ |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 | 1 |

$\therefore \overline{A+B} = \bar{A}\bar{B}$.

(3) USING THE GATES SHOWN:



$C = C_1 + C_2$

$= \bar{A}B + \bar{B}A$

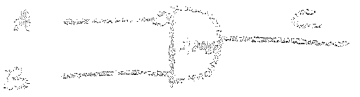
| $A$ | $B$ | $\bar{A}B$ | $\bar{B}A$ | $C = \bar{A}B + \bar{B}A$ |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 | 0 |

THE VALUES OF C ARE THE SAME AS FOR AN EXCLUSIVE OR GATE.

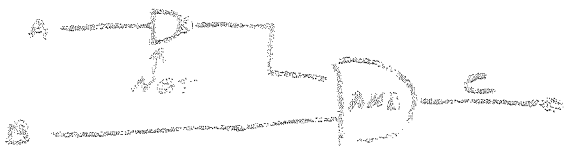
(4)

| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

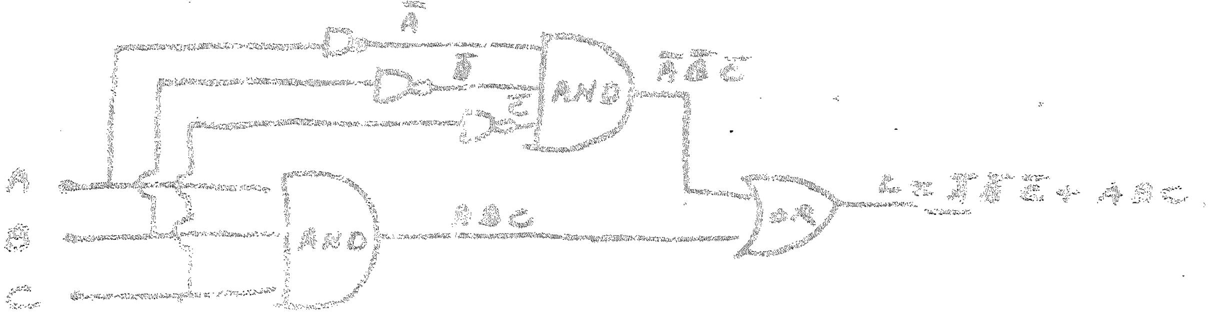
⇒ $C = \bar{A}B$



OR



(5) $D = ABC + \bar{A}\bar{B}\bar{C}$



END OF 234 HOMEWORK!!

A FINAL NOTE OR TWO

- "TAKE WARNING! ALTERNATING CURRENTS ARE DANGEROUS! THEY ARE FIT ONLY FOR POWERING THE ELECTRIC CHAIR. THE ONLY SIMILARITY BETWEEN AN A-C AND A D-C LIGHTING SYSTEM IS THAT BOTH START FROM THE SAME COAL PILE."

THOMAS ALVA EDISON (1887 PAMPHLET)

- DID YOU KNOW A 100 WATT BULB GIVES OFF 50% MORE LIGHT THAN FOUR 25 WATT BULBS?

"BEAR YE ONE ANOTHER'S BURDENS, AND SO FULFILL THE LAW OF CHRIST"

GAL 6:2.

NAME

# TEST 1

EE 234
BOB MARKS
2/17/77

INSTRUCTIONS:

- WORK ALL FIVE PROBLEMS. DO YOUR WORK ON THE BLANK PAGES PROVIDED IN THIS BOOKLET. BUDGET YOUR TIME CAREFULLY.
- THE POINT VALUE OF EACH PROBLEM IS GIVEN AT THE TOP RIGHT CORNER OF EACH PROBLEM STATEMENT. THERE ARE 100 POINTS TOTAL
- THIS TEST IS OPEN BOOK, OPEN NOTES, CLOSED NEIGHBOR.

BEST OF LUCK

---

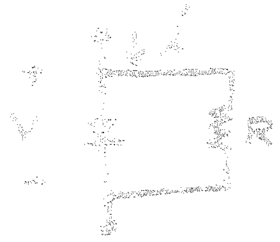
| PROBLEM | SCORE | OUT OF |
|---|---|---|
| 1 | | 15 |
| 2 | | 15 |
| 3 | | 25 |
| 4 | | 25 |
| 5 | | 20 |
| | TOTAL | 100 |

"THE THREE FOUNDATIONS OF LEARNING:
SEEING MUCH,
SUFFERING MUCH,
AND
STUDYING MUCH"

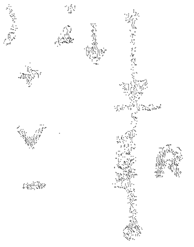
CATHERALL

SKETCH THE V-I CURVES FOR THE FOLLOWING RESISTOR-DIODE COMBINATIONS. ASSUME AN IDEAL DIODE. USE *i* AS VERTICAL AXIS.

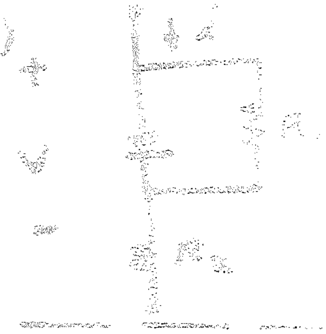
(a)



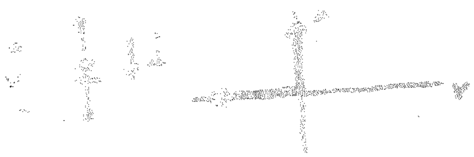
(b)



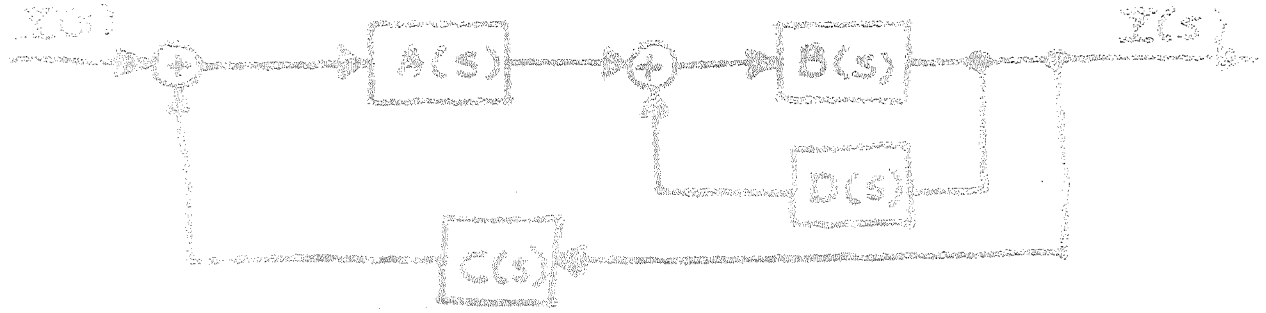
(c)



HINTS:

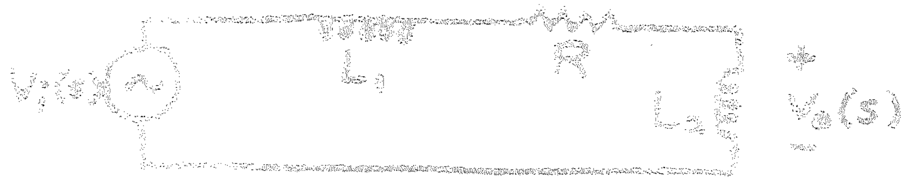


FOR THE FOLLOWING FEEDBACK SYSTEM,
FIND THE TRANSFER FUNCTION $T(s)=Y(s)/X(s)$.



HINT: USE THE RESULT OF THE FEEDBACK PROBLEM
GIVEN AS HOMEWORK

FOR THE FOLLOWING CIRCUIT (25



(a) COMPUTE THE TRANSFER FUNCTION $T(s) = \frac{V_o(s)}{V_i(s)}$

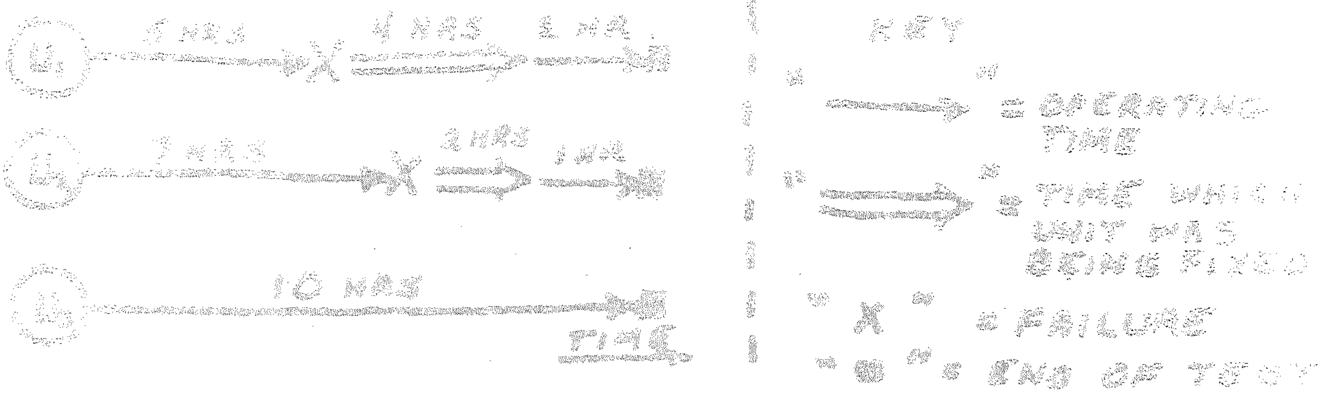
(b) COMPUTE $V_o(t)$ GIVEN THAT $V_i(t) = V_m\mu(t)$
[$\mu(t)$ = UNIT STEP FUNCTION]

(c) SKETCH THE FREQUENCY RESPONSE $|T(j\omega)|$ NOTING ITS VALUES AT $\omega = 0$ AND $\omega = \infty$

(d) WHAT TYPE OF FILTER IS THIS? LO PASS, BANDPASS, OR HI PASS?

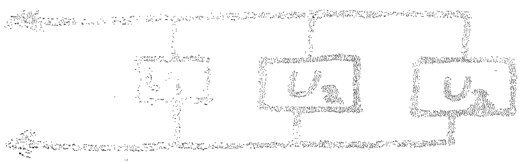
| SOME LAPLACE XFORMS | |
|---|---|
| $x(t)$ | $\mathcal{L}[x(t)]$ |
| $\mu(t)$ | $1/s$ |
| $e^{-at}$ | $1/(s+a)$ |
| sin at | $a/(s^2+a^2)$ |

(a) THREE IDENTICAL UNITS ARE PLACED ON TEST FOR 10 HOURS EACH. THE RESULTS ARE SHOWN BELOW;



COMPUTE THE UNITS' MTBF, MTTR, AND AVAILABILITY AS ESTIMATED BY THIS TEST.

(b) SUPPOSE THE UNITS TESTED IN (a) WERE CONNECTED IN THE SYSTEM SHOWN.



IF THE SYSTEM IS CONSIDERED "OPERABLE" WHEN AT LEAST TWO UNITS ARE WORKING, COMPUTE THE ESTIMATES OF THE SYSTEM'S MTBF, MTTR, AND AVAILABILITY USING THE TEST DATA GIVEN IN PART (a).

CONSIDER THE SIGNAL

$$v(t) = j \sin 2\pi t + 2 \cos^2 \pi t$$

(a) WHAT IS THE PERIOD, T, OF THIS PERIODIC WAVEFORM? [HINT: $\cos^2\theta = \frac{1}{2} + \frac{1}{2}\cos 2\theta$]

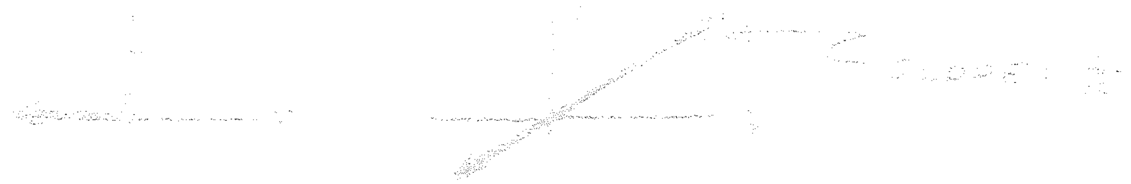
(b) IN THE FOURIER SERIES:

$$v(t) = \sum_{n=-\infty}^{\infty} a_n e^{j2\pi nt/T}$$

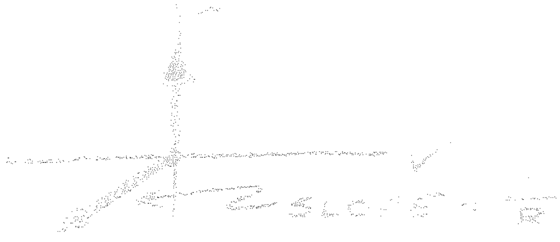
DETERMINE $a_n$. (IF YOU ARE CLEVER, NO INTEGRATION IS REQUIRED.)

(HINT: USE $\cos\theta = \frac{1}{2}[e^{j\theta} + e^{-j\theta}]$, $\sin\theta = \frac{1}{2j}[e^{j\theta} - e^{-j\theta}]$)

[illegible] FOR [illegible] THE RESISTOR

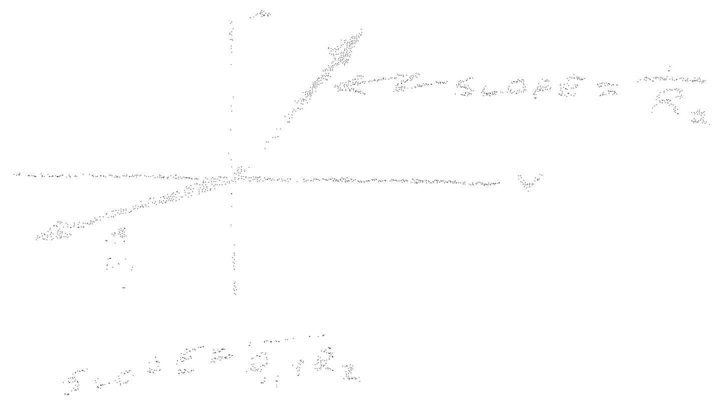


(a) WHEN WE TRY TO MAKE V POSITIVE, THE DIODE IS FORWARD BIASED AND THUS A SHORT. WHEN THE DIODE IS REVERSED BIASED (AN OPEN CIRCUIT), THE COMBINATION ACTS LIKE A RESISTOR.

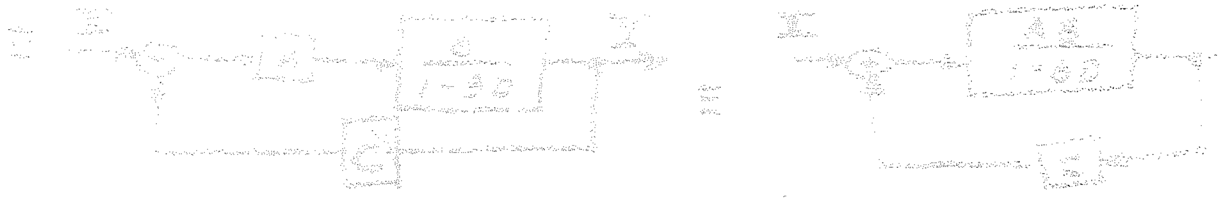


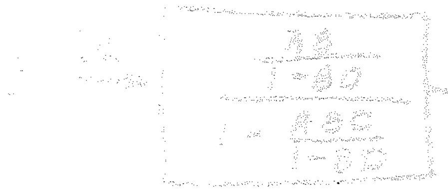
(b) WHEN DIODE IS FORWARD BIASED THE COMBINATION ACTS LIKE A RESISTOR. A REVERSE BIAS GIVES AN OPEN CIRCUIT

(c) WHEN FORWARD BIASED, THIS COMBINATION ACTS LIKE $R_1$, WHEN REVERSE BIASED, LIKE $R_1 + R_2$



[illegible] [illegible] the [illegible]
[illegible] a [illegible] [illegible]
[illegible], see soln.





$$\Rightarrow T(s) = \frac{\frac{AB}{1-BD}}{1-\frac{ABC}{1-BD}} = \frac{AB}{1-BD-ABC}$$

(3)

(a) By voltage division, $T(s) = \frac{V_o}{V_i} = \frac{sL_2}{s(L_1+L_2)+R}$

$$= \frac{s\frac{L_2}{L_1+L_2}}{s+\frac{R}{L_1+L_2}}$$

(b)

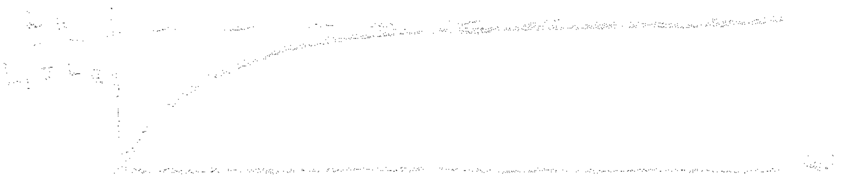
Input: $v_i(t) = V_0 u(t) \Rightarrow V_i(s) = \frac{V_0}{s}$

$V_o(s) = T(s)V_i(s) = \left(\frac{L_2}{L_1+L_2}\right)\frac{V_0}{s+\frac{R}{L_1+L_2}}$

$v_o(t) = \mathcal{L}^{-1}[V_o(s)] = \frac{V_0 L_2}{L_1+L_2} e^{-(Rt/(L_1+L_2))}$

(c)

$|T(j\omega)| = \frac{L_2}{L_1+L_2} \frac{\omega}{\sqrt{\omega^2+\frac{R^2}{(L_1+L_2)^2}}}$, $|T(j0)| = 0$
$|T(j\infty)| = \frac{L_2}{L_1+L_2}$



(d) This is a hi pass filter.

[illegible]

[illegible] = 0.80

ACCORDING TO OUR DEFINITION OF [illegible] THE SYSTEM WAS OPERATIONAL FOR [illegible] 8 HRS. IT TOOK 2 [illegible] REPAIR, AND RAN FOR [illegible] TO THE TESTS [illegible] WAS ONLY ONE [illegible]

$$MTBF = \frac{8\ HRS}{1\ FAILURE} = 8\ HRS$$

$$MTTR = \frac{2\ HRS}{1\ FAILURE} = 2\ HRS$$

$$A = \frac{MTBF}{MTBF + MTTR} = \frac{8}{10} = 0.80$$

[illegible]

$$X_k = \sum_{n=0}^{N-1} x_n e^{-j2\pi nk/(N)}$$

[illegible]

$$x_n = \begin{cases} 2 & ; n = 0 \\ 1 & ; n = 1 \\ 0 & ; \text{FOR ALL OTHER } n. \end{cases}$$

(NAME)

# TEST 2

EE 234
BOB MARKS
3/31/77

INSTRUCTIONS:

- WORK ALL 5 PROBLEMS. DO YOUR WORK ON THE BLANK PAGES PROVIDED IN THIS BOOKLET. BUDGET YOUR TIME CAREFULLY.
- EACH OF THE 5 PROBLEMS IS WORTH 20PTS FOR A TOTAL OF 100 PTS.
- THIS TEST IS OPEN BOOK, OPEN NOTES, AND CLOSED NEIGHBOR.

-BEST OF LUCK-

| PROBLEM | SCORE | OUT OF |
|---|---|---|
| 1 | | 20 |
| 2 | | 20 |
| 3 | | 20 |
| 4 | | 20 |
| 5 | | 20 |
| | | 100 |
| | TOTAL | |

"WHEN LIFE HANDS
YOU A LEMON...
MAKE LEMONAIDE"

DALE CARNEGIE

(1) 20

TRUE-FALSE: MARK T OR F AFTER EACH OF THE FOLLOWING STATEMENTS. MARKS SUCH AS "T" WILL NOT BE GRADED. DO NOT GUESS. THERE WILL BE A PENALTY FOR WRONG ANSWERS

1. THE OUTPUT IMPEDANCE OF AN IDEAL OP AMP IS THE SAME AS THAT OF A SHORT CIRCUIT WHICH HAS AN IMPEDANCE OF ZERO......

2. THE EQUIVALENT CIRCUIT FOR A BJT WHICH CONTAINS IDEAL CURRENT SOURCES, IS A GOOD MODEL FOR THE ENTIRE OPERATING RANGE OF THE TRANSISTOR.............

3. THE THREE TERMINALS OF A MOSFET ARE THE COLLECTOR, BASE, AND EMITTER.....

4. ANALOG COMPUTERS ARE LESS EXACT IN GENERAL THAN DIGITAL COMPUTERS....

5. AN AMPLITUDE MODULATED SINUSOID CONTAINS ONLY TWO FREQUENCIES....................

6. WE MAY SEND, AT MOST, 10 VOICES OF MAXIMUM FREQUENCY 3000 HZ OVER A 60,000 HZ CAPACITY CHANNEL..........

7. SELF BIASING CIRCUITRY REDUCES THE EFFECTS OF TEMPERATURE CHANGE ON BJT TRANSISTOR'S PARAMETERS........

8. THE UNKNOWN RESISTANCE ON A BALANCED WHEATSTONE BRIDGE IS A FUNCTION OF THE APPLIED VOLTAGE....................

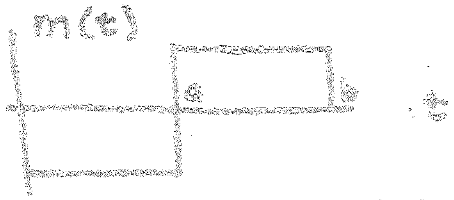
9. SHORTCIRCUITING THE VOLTAGE SUPPLY TO A BALANCED WHEATSTONE BRIDGE WILL HAVE NO EFFECT ON THE VOLTAGES AND CURRENTS WITHIN THE CIRCUIT...

10. IF WE EXCEED 100% MODULATION IN AM, WE DISTORT OUR SIGNAL.........

11. EE IS GOOD FOR YOU..................

2) 2%

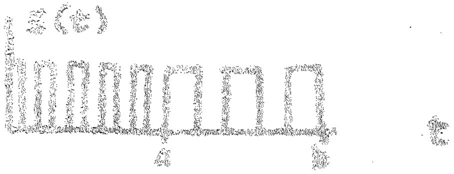
WE WISH TO MODULATE THE SIGNAL:



IN EACH OF THE FOLLOWING, STATE WHAT TYPE OF MODULATION IS USED

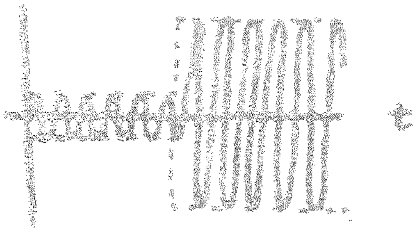
[CHOICES: AM, FM, PM, PAM, PDM, PPM]

(a)



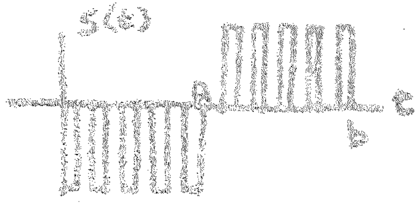
TYPE ________________

(b)



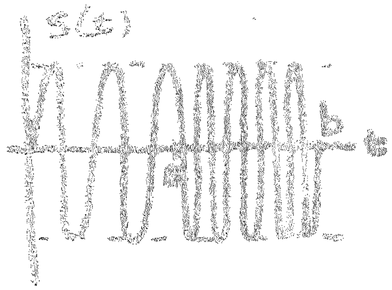
TYPE ________________

(c)



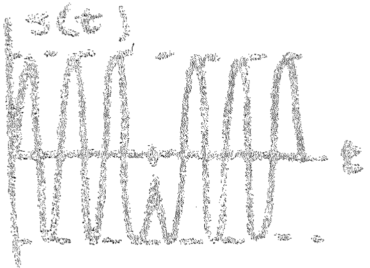
TYPE ________________

(d)



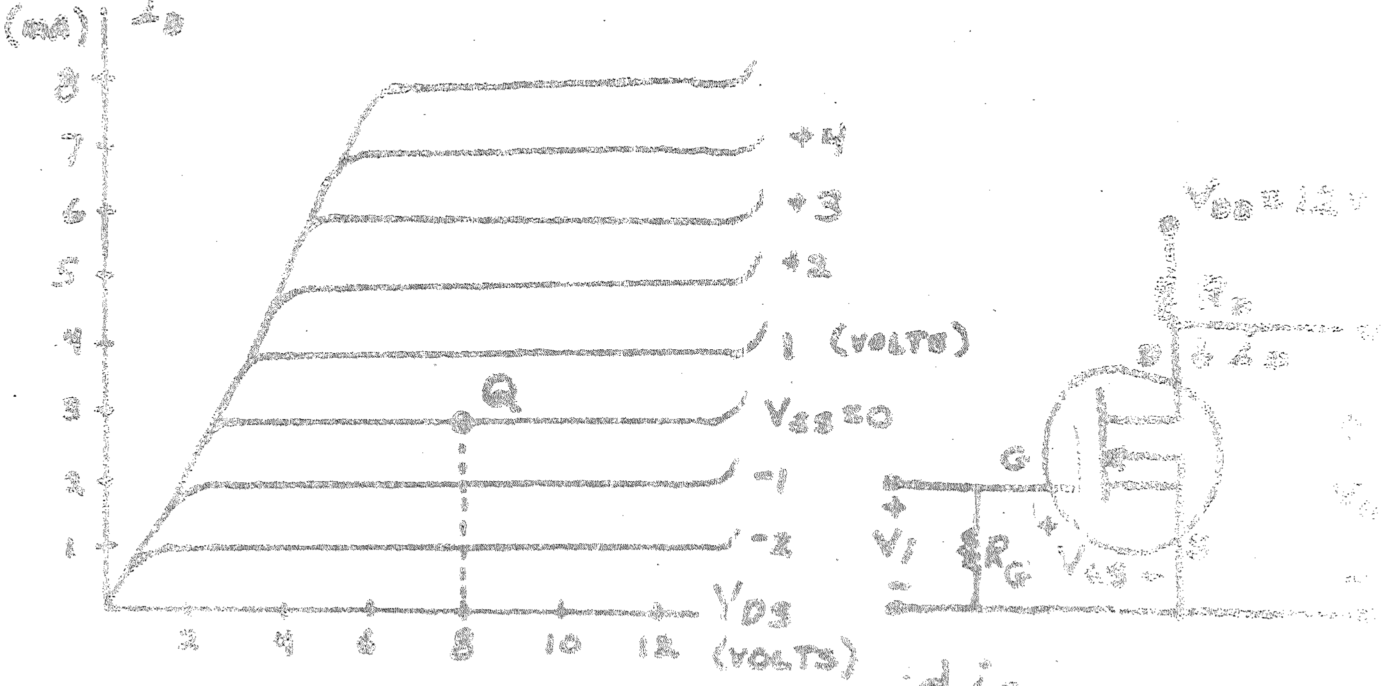
TYPE ________________

(e)



TYPE ________________

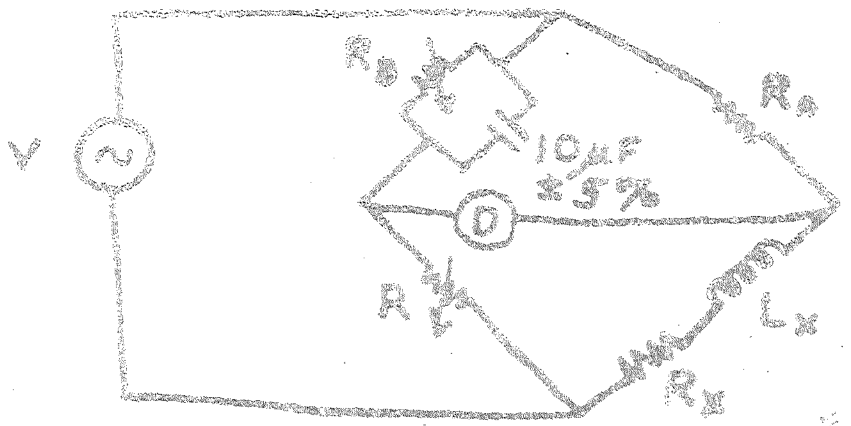
(3) 20%



(a) DETERMINE THE GAIN $G = \frac{di_D}{dV_{GS}}$, IN MHOS, OF THIS DE MOSFET CIRCUIT. [USE ONLY TWO POINTS TO DETERMINE THE LINE ON THE $i_D$ VS. $V_{GS}$ CURVE. CONFINE ANALYSIS TO THE LINEAR PORTION OF THE TRANSISTOR CURVE.]

(b) SKETCH THE LOAD LINE ON THE ABOVE $i_D$ VS $V_{DS}$ CURVE USING THE QUIESCENT POINT SHOWN.

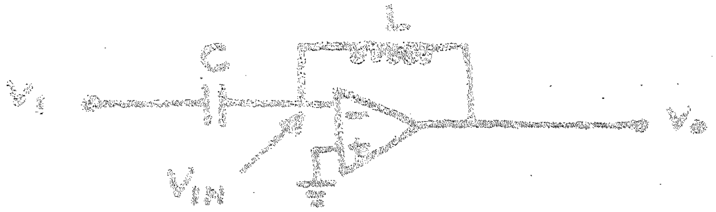
(4) 20/1



THIS MAXWELL BRIDGE BALANCES WHEN $R_B = 100\,\Omega$ ±2% AND $R = 1000\,\Omega$ ±2%, IF WE KNOW THAT $R_A$ LIES SOMEWHERE BETWEEN 99. AND 101 Ω, FIND $L_x$ AND $R_x$ AND THEIR CORRESPONDING TOLERENCES IN ±( )%. USE THE USUAL APPROXIMATIONS.

(5) 20/2

DETERMINE $V_o(t)$ AS A FUNCTION OF $V_i(t)$ IN THE FOLLOWING OP-AMP CIRCUIT:



ASSUME THE OP AMP HAS INFINATE INPUT IMPEDANCE (i.e., ZERO INPUT CURRENT) AND THAT

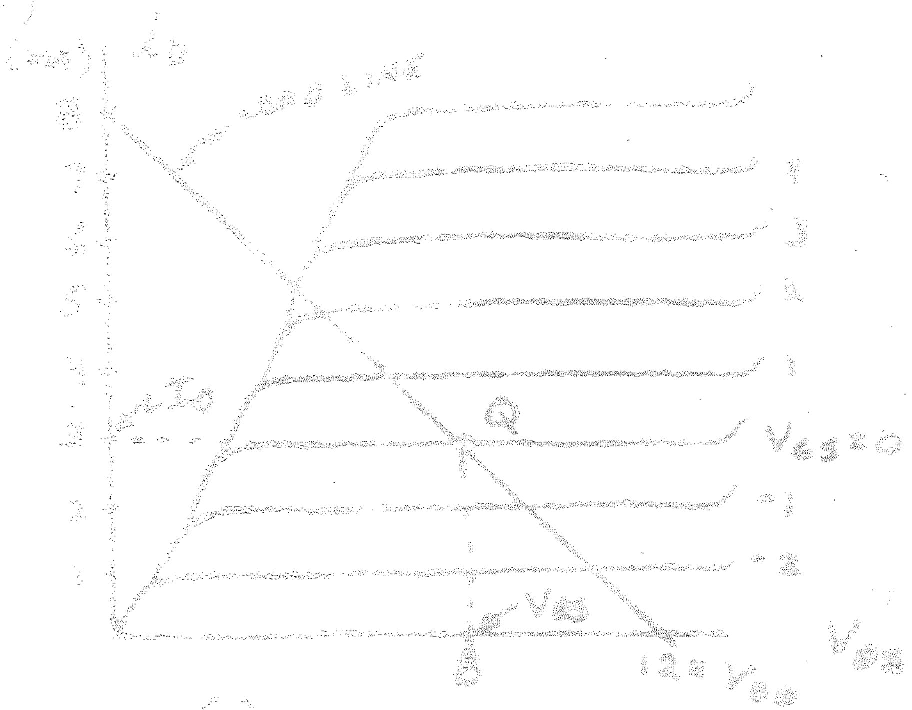
$$\frac{d^2 V_{IN}}{dt^2} \approx V_{IN} \approx 0$$

EE 204 TEST #2 SOLUTIONS (Dog [illegible]

1) 1 T, 2 F, 3 F, 4 T, 5 F, 6 T, 7 T, 8 F, 9 F, 10 T

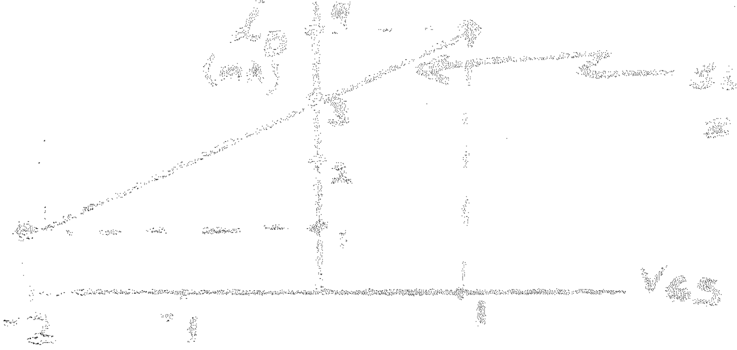
(2) (a) PDM, (b) AM, (c) PAM, (d) FM, (e) PM

(3)



(a) $V_{DD}$ = 12 V AND Q DETERMINE LOAD LI

(b) @ $V_{GS}$ = 1, $i_D$ = 4 mA ; @ $V_{GS}$ = −2, $i_D$ =



SLOPE = GAIN = $\frac{3 mA}{3 V}$ = 1.0 mƱ

0.001 Ʊ

4) $R_A$ : 99Ω < $R_A$ < 101Ω ⇒ $R_A$ = 100Ω ± 1% ...

WE SHOWED IN HOMEWORK #5, PROBLEM 2, THA

$R_x = R R_B / R_A$ AND $L_x = C_B R R_A$

THUS

$$R_x = \frac{(10^3)(10^2)}{(10^2)} \cdot \frac{(1 \pm 0.02)(0 \pm 0.02)}{(1 \pm 0.01)}$$

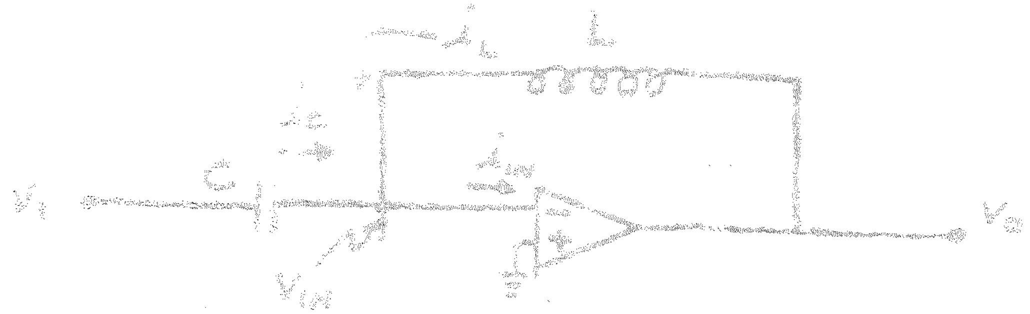
$$= 1000\Omega \cdot [(1 \pm 0.02)(1 \pm 0.02)(1 \pm 0.01)]$$

$$= 1000\Omega \cdot (1 \pm 0.05) = 1000\Omega \pm 5\%$$

$$L_x = (10^{-8})(10^3)(10^2)[(1 \pm 0.05)(1 \pm 0.02)(1 \pm 0.0$$

$= 1$ H ± 8%

(5)



SUMMING CURRENTS AT $V_{IN}$ WITH $i_{IN} = 0$:

$$i_C - i_L = 0 = C\frac{d(V_1 - V_{IN})}{dt} + \frac{1}{L}\int^t (V_0 - V_{IN})dt$$

OR

$$\int^t (V_0 - V_{IN})dt = -LC\frac{d(V_1 - V_{IN})}{dt}$$

DIFFERENTIATING:

$$V_0 - V_{IN} = -LC\left[\frac{d^2V_1}{dt^2} - \frac{d^2V_{IN}}{dt^2}\right]$$

ASSUMING $V_{IN}$ & $d^2V_{IN}/dt^2 \approx 0$ GIVES

$$V_0 = -LC\frac{d^2V_1}{dt^2} \Leftarrow \text{"DOUBLE DIFFERENTI}$$

(NAME)

# TEST 3

EE 33
Bob Ma
4/26/7

INSTRUCTIONS

- WORK ALL 5 PROBLEMS. DO YOUR WORK ON THE PAGES IN THIS BOOKL BUDGET YOUR TIME CAREFULLY
- EACH PROBLEM IS WORTH 20 PTS. (TOTAL = 100 POINTS)
- TEST IS OPEN BOOK, OPEN NOTE

-BEST OF LUCK

| PROB | TOTAL | OUT OF |
|---|---|---|
| 1 | | 20 |
| 2 | | 20 |
| 3 | | 20 |
| 4 | | 20 |
| 5 | | 20 |
| | TOTAL | 100 |

"WISDOM IS T
PRINCIPAL TH
THEREFORE, GE
WISDOM, AND W
ALL THY GETT
GET UNDERSTA

PROV. 4-

(1) YOU RUN A FIELD WITH OILWELLS A, B, AND C.
EACH WELL IS FITTED WITH A SMOKE DETE
WHICH PUTS OUT A LOGIC "1" IF THE WEL
ON FIRE. OTHERWISE, IT'S LOGIC ZERO.

(a) SUPPOSE YOU WANTED A SINGLE RED "IDIO
LIGHT" TO GO ON WHEN TWO OR MORE O
YOUR WELLS IS ON FIRE. ASSIGNING A
TO THIS LIGHT BEING ON, COMPUTE THE
CORRESPONDING TRUTH TABLE.

(b) FROM YOUR TRUTH TABLE, DESIGN A LOG
CIRCUIT TO LITE YOUR LITE USING THE
SMOKE DETECTOR SIGNAL LEVELS AS INP

| A | B | C | L |
|---|---|---|---|
| 0 | 0 | 0 | |
| 0 | 0 | 1 | |
| 0 | 1 | 0 | |
| 0 | 1 | 1 | |
| 1 | 0 | 0 | |
| 1 | 0 | 1 | |
| 1 | 1 | 0 | |
| 1 | 1 | 1 | |

(2)(a) USING THE "AMERICAN STANDARD CODE FOR INFORMATION EXCHANGE" ON PAGES 5-8 TO 5-11 OF VINE'S BOOK, WRITE THE CODE FOR THE MESSAGE:

I_LIKE_LEE

AFTER EACH LETTER (OR SPACE), PUT AN EVEN ONES PARITY BIT FOR THAT CODED LETTER (OR SPACE). USE THE SPACES BELOW FOR YOUR CODE:

(b) LET $P_c$ BE THE PROBABILITY OF RECEIVING THE CODE EXACTLY AS IT WAS SENT AND $P$ BE THE PROBABILITY A BIT IS SENT OVER THE CHANNEL WITH NO ERROR. WHAT IS $P_c$ FOR $P=0.9$? FOR $P=0.99$? FOR $P=0.999$?

(c) WHAT MUST $P$ BE IF $P_c=0.95$? (CARRY $P$ TO AT LEAST FIVE PLACES).

(3) IN CLASS, WE DEVELOPED THE BOOLEAN LOGIC FOR A TWO AND A THREE WAY LIGHT SWITCH. HERE, WE CONSIDER A FOUR WAY LIGHT SWITCH WITH SWITCHES A, B, C, & D, AND LIGHT, L.

(a) DETERMINE THE TRUTH TABLE FOR THIS SYSTEM. ASSUME, AS A STARTING POINT, THAT IF (ABCD) = (0, 0, 0, 0), THEN OUR LIGHT IS OFF (L = 0).

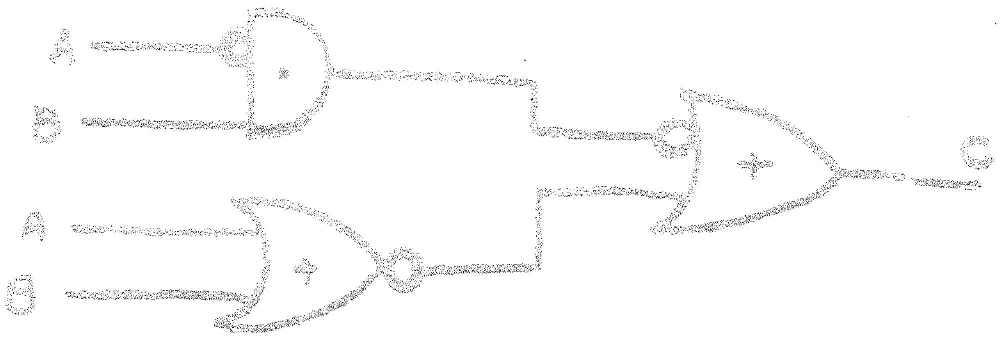
(b) FROM (a), WRITE THE BOOLEAN FUNCTION FOR L (YOU NEED NOT SIMLIFY NOR IMPLEMENT).

TRUTH TABLE:

| A | B | C | D | L |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | |
| 0 | 0 | 1 | 0 | |
| 0 | 0 | 1 | 1 | |
| 0 | 1 | 0 | 0 | |
| 0 | 1 | 0 | 1 | |
| 0 | 1 | 1 | 0 | |
| 0 | 1 | 1 | 1 | |

| A | B | C | D | L |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | |
| 1 | 0 | 0 | 1 | |
| 1 | 0 | 1 | 0 | |
| 1 | 0 | 1 | 1 | |
| 1 | 1 | 0 | 0 | |
| 1 | 1 | 0 | 1 | |
| 1 | 1 | 1 | 0 | |
| 1 | 1 | 1 | 1 | |

(4) CONSIDER THE FOLLOWING LOGIC CIRCUIT



(a) COMPUTE THE TRUTH TABLE FOR THE OUTPUT, C; GIVEN THE INPUT A,B

(b) WRITE THE BOOLEAN FUNCTION FOR C IN TERMS OF A AND B.

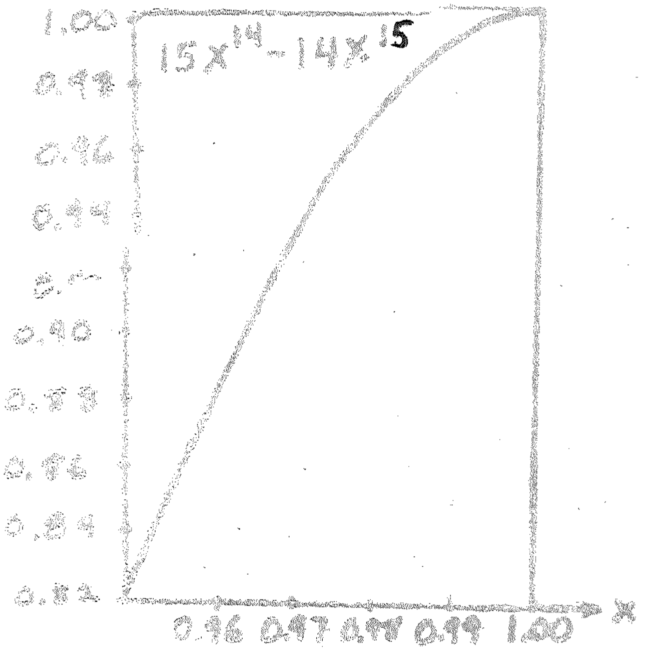
| A | B | C |
|---|---|---|
| 0 | 0 | |
| 0 | 1 | |
| 1 | 0 | |
| 1 | 1 | |

(5) WE WISH TO SEND AN ARBITRARY ELEVEN BIT WORD OVER A BINARY SYMMETRIC CHANNEL (p WITH $p_0 = p_1 = 1/2$. WE WISH TO HAVE A PROBABILITY OF CORRECT DETECTION OF 90%. COMPUTE THE REQUIRED VALLE OF CORRECTLY SENDING AN INDIVIDUAL BIT, $p$, FOR THE FOLLOWING TWO CASES.

(a) WE SEND THE ELEVEN BIT MESSAGE DIRECTL WITH NO CODING.

(b) WE SEND THE ELEVEN BIT MESSAGE IN A SINGLE BIT ERROR CORRECTION HAMMING CODE. (FOUR PARITY BITS FOR A TOTAL OF FIFTEEN BITS). YOU MAY FIND THE FOLLOWI GRAPH HELPFUL SHOW YOUR WORK.

(c) WHICH OF THE TWO SCHEMES REQUIRES THE LESS NOISY CHANNEL?



TEST # 3 (SOLUTIONS) by Marky

(1)(a) ANY TIME THERE ARE TWO OR MORE "1"'S, IN A, B, & C, WE WANT OUR LIGHT TO GO ON:

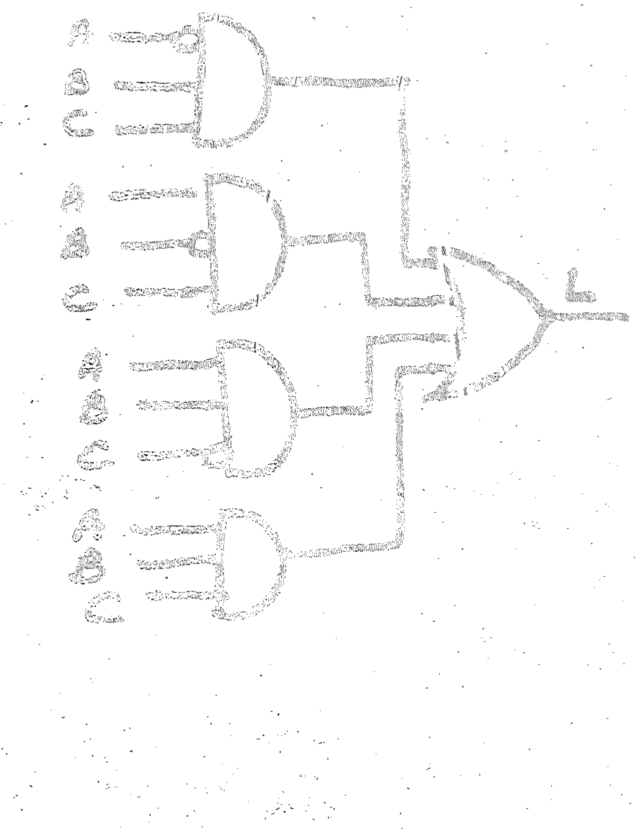
| A | B | C | L |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

← TRUTH TABLE

(b) FROM OUR TRUTH TABLE:

$L = \bar{A}BC + A\bar{B}C + AB\bar{C} + ABC$

THUS, A SCHEME WOULD BE:



NOTE: IN NO WAY IS THIS THE OPTIMAL IMPLEMENTATION SCHEME. CAN YOU REDUCE THE NUMBER OF REQUIRED GATES?

(b) THERE ARE 72 BINITS IN THE ABOVE

THUS $P_c = p^{72}$

$p = 0.9 \Rightarrow P_c = (0.9)^{72} = 0.00051$

$p = 0.99 \Rightarrow P_c = (0.99)^{72} = 0.48$

$p = 0.999 \Rightarrow P_c = (0.999)^{72} = 0.93$

(c) $P_c = p^{72} \Rightarrow p = P_c^{1/72} = (0.95)^{1/72}$

$= 0.99929$

(3)(a)

| A | B | C | D | L |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 |

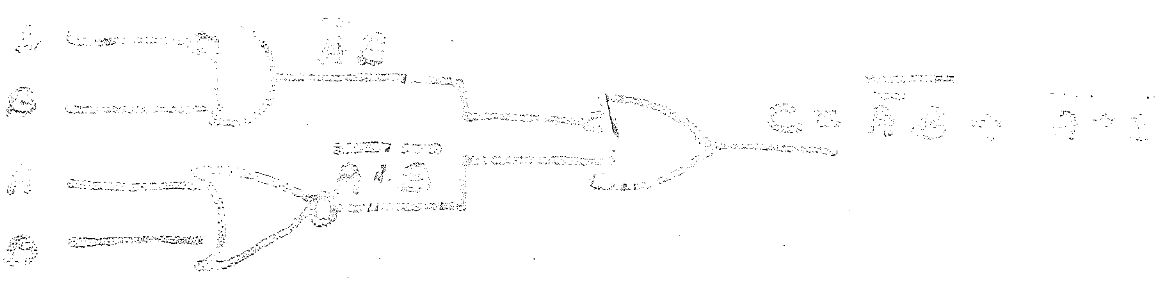
| A | B | C | D |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 |

(b) FROM TRUTH TABLE:

$L = \bar{A}\bar{B}\bar{C}D + \bar{A}\bar{B}C\bar{D} + \bar{A}B\bar{C}\bar{D} + \bar{A}BCD$

$+ A\bar{B}\bar{C}\bar{D} + A\bar{B}CD + AB\bar{C}D + ABC\bar{D}$

(4)



(a) $A=0, B=0 \Rightarrow \bar{A}B = 1 \cdot 0 = 0$

$\overline{A+B} = \overline{0+0} = 1$

$C = 1 + 0 = 1$

$A=0, B=1 \Rightarrow \bar{A}B = 1 \cdot 1 = 1$

$\overline{A+B} = \overline{0+1} = \bar{1} = 0$

$C = 0 + 0 = 0$

$A=1, B=0 \Rightarrow \bar{A}B = 0 \cdot 0 = 0$

$\overline{A+B} = \overline{1+0} = \bar{1} = 0$

$C = 1 + 0 = 1$

$A=1, B=1 \Rightarrow \bar{A}B = 0 \cdot 1 = 0$

$\overline{A+B} = \overline{1+1} = \bar{1} = 0$

$C = 1 + 0 = 1$

TRUTH TABLE IS

| A | B | C |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

(b) FROM FIGURE, $C = \overline{\bar{A}B} + \overline{A+B}$

OR, FROM TRUTH TABLE:

$\bar{C} = \bar{A}B \Rightarrow C = \overline{\bar{A}B} = A + \bar{B}$

OR $C = \bar{A}\bar{B} + A\bar{B} + AB$

(ALL OF THESE ARE CORRECT ANSW

(b) [illegible]

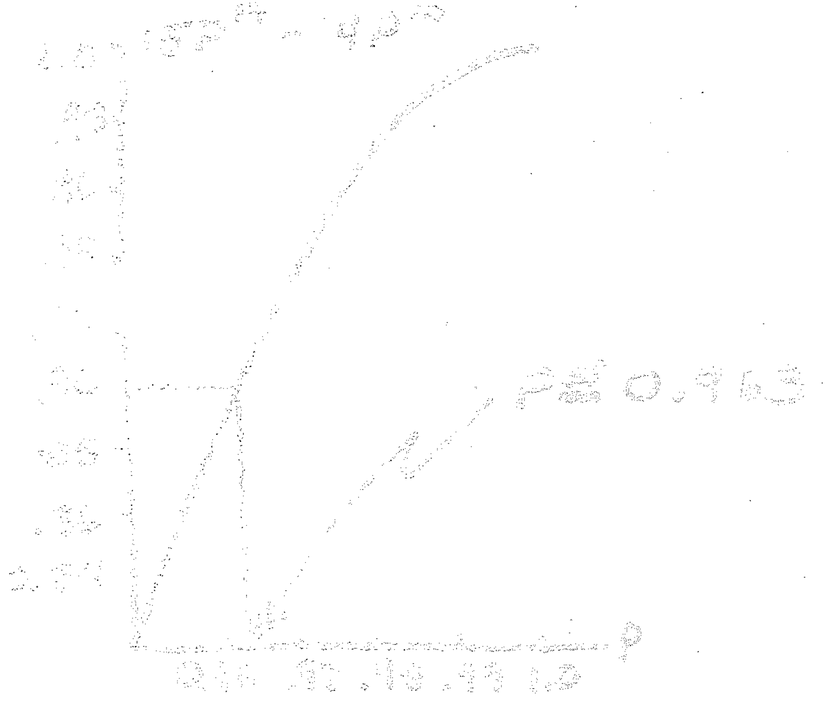
(c) [illegible] 18 AND

[illegible] ACCEPT] [illegible]

$= p^{18} + 18 p^{17}(1-p)$

$= p^{18} + 18 p^{17} - 18 p^{18} + 153 p^{16}$ [illegible]

[illegible] THE GRAPH:



(c) THE CUSUM SCHEME DOES [illegible]

0.923 < 0.963

NAME

# FINAL

EE 234
BOB MARKS
MAY 6, 1977

INSTRUCTIONS:

THIS TEST IS DIVIDED IN TO TWO SECTIONS:

I. 100 TRUE-FALSE QUESTIONS (200 POINTS)
II. FOUR PROBLEMS (200 POINTS EACH)
THE TOTAL # OF POINTS IS 400.

"ALL WISDOM OF THIS WORLD
IS FOOLISHNESS WITH GOD"
1 COR 3:19

SOME RELATIONS:

$e^{j\theta} = \cos\theta + j\sin\theta$ ⟸ EULER

$R(t) = e^{-\lambda t}$ ⟸ CONSTANT FAILURE RATE RELIABILITY

$\frac{1}{(s+a)(s+b)} = \frac{1}{(s+a)(b-a)} + \frac{1}{(s+b)(a-b)}$ ⟸ PARTIAL FRACTIONS

$\mathcal{L}[u(t)] = 1/s$

$\mathcal{L}[e^{-at}] = \frac{1}{s+a}$

$P_r[k$ ERRORS IN $n$ TRIALS EACH WITH PROBABILITY $p] = \binom{n}{k}(1-p)^k p^{n-k}$

| | | |
|---|---|---|
| TRUE FALSE | | 200 |
| 1 | | 150 |
| 2 | | 50 |
| 3 | | 50 |
| 4 | | 50 |
| | | |

# PART I

ANSWER EACH OF THE FOLLOWING QUESTIONS WITH A "T" OR AN "F". AMBIGUOUS MARKS, LIKE "Ŧ" WILL NOT BE GRADED. DO NOT GUESS. THERE WILL BE A PENALTY FOR WRONG ANSWERS. IF YOU DO NOT KNOW AN ANSWER, IT IS BEST TO LEAVE THE SPACE BLANK. (NO ANSWER IS -2, WRONG ANSWER IS -3, CORRECT ANSWER IS +3).

1. A DIODE IS A NONLINEAR DEVICE. . . . . . . . . . ______
2. THEVININ'S THEOREM CANNOT BE APPLIED TO DIODE TYPE CIRCUIT ELEMENTS. . . . ______
3. KIRCHHOFF'S VOLTAGE AND CURRENT LAWS CANNOT BE APPLIED TO A DIODE-TYPE CIRCUIT. . . . ______
4. A REVERSE BIASED DIODE CONDUCTS. . . . . . . . ______
5. A RECTIFIER CAN TAKE A PERIODIC WAVEFORM OF ZERO AVERAGE VALUE & RECTIFY IT TO GIVE ANOTHER PERIODIC WAVEFORM WITH NON-ZERO AVERAGE POWER. . . . . . . . . . . . ______
6. RECTIFIER TYPES INCLUDE FULL AND HALF WAVE RECTIFIERS. . . . . . . . . . . . . ______
7. A LOW RIPPLE FACTOR DENOTES A MORE "BUMPY" WAVEFORM. . . . . . . . . . . . ______
8. CAPACITIVE FILTERS ARE USED TO INCREASE THE RIPPLE FACTOR OF A RECTIFIED WAVEFORM. . ______
9: THE TERMINALS OF A FET ARE GATE, SOURCE, & DRAIN. ______
10: THE FET IS MODULATED BY CONTROLLING THE SIZE OF THE CONDUCTING CHANNEL. . . . . . . ______
11. DE MOSFET MEANS "DEPLETION EFFECT METAL OXIDE SEMICONDUCTOR FIELD EFFECT TRANSISTOR". . . ______
12. IN NORMAL BJT USE, THE EMITTER JUNCTION IS REVERSE BIASED. . . . . . . . . . . . ______
13. THE LAPLACE TRANSFORM IS A LINEAR OPERATION ______
14. ALL LINEAR NON-CAUSAL SYSTEMS ARE LINEAR. . . ______
15. ALL KNOWN SYSTEMS ARE CAUSAL IN THE PHYSICAL WORLD. . . . . . . . . . . . . . . . ______
16. A LINEAR TIME-INVARIANT SYSTEM'S TRANSFER FUNCTION IS DEPENDENT ON THE SYSTEM INPUT. ______
17. A BANDLIMITED SIGNAL HAS INFINITE BANDWIDTH. ______
18. A SIGNAL OF BANDWIDTH 200 HZ MUST BE SAMPLED AT LEAST AT A RATE OF 400 SAMPLES PER SECOND IF WE WISH TO LOSE NO INFORMATION ______
19. A FOURIER SERIES DECOMPOSES A PERIODIC WAVE FORM INTO ITS COMPONENT HARMONICS
20. "MTBF" DENOTES "MEDIAN TIME BETWEEN FAILURES" ______
21. THE TOTAL MTBF OF A SYSTEM COMPOSED OF A NUMBER OF ELEMENTS CONNECTED IN SERIES IS SIMPLY THE SUM OF THE ELEMENTS' MTBF'S ______
22. THE RECIPRICAL OF MTBF IS FAILURE RATE
23. THE BATHTUB CURVE IS A PLOT OF FAILURE RATE VS. TIME . . . . . . . . . . . . ______

24. MAINTAINABILITY IS NOT A PROBABALISTIC MEASURE ______

25. AVAILABILITY IS THE RATIO BETWEEN MTBF & MTTR. ______

26. MTTR IS A MEASURE OF MAINTAINABILITY . . . . . ______

27. QUIESCENCE DENOTES THE NO SIGNAL OPERATING POINT OF A TRANSISTOR CIRCUIT . . . . . . . . . ______

28. KIRCHHOFF'S LAWS CANNOT BE USED WHEN ANALYZING NONLINEAR TRANSISTOR CIRCUITS . . ______

29. THE PARAMETERS OF A BJT ARE RELATIVELY INSENSITIVE TO AMBIENT TEMPERATURE . . . ______

30. BJT'S CAN EITHER BE npn OR pnp . . . . . . . . ______

31. A CRUDE BJT CAN BE MADE FROM TWO DIODES . . ______

32. WHEATSTONE BRIDGES ARE USED FOR MEASURING RESISTANCES TO HI PERCISION . . ______

33. A MAXWELL BRIDGE IS CAPABLE OF MEASURING TWO UNKNOWN COMPONENTS IN A SINGLE BALANCE OF THE BRIDGE . . . . . . ______

34. AN IDEAL OP AMP HAS AN INPUT IMPEDANCE OF 0 ______

35. ANALOG COMPUTERS IN GENERAL ARE MORE EXACT THAN DIGITAL COMPUTERS . . . . . . . ______

36. OP AMPS CAN BE USED TO SUM VOLTAGES AND PERFORM VOLTAGE WAVEFORM INTEGRATION . . . ______

37. OP AMPS ARE GENERALLY SEMICONDUCTOR DEVICES . . . . . . . . . . . . . . . . . . . . . ______

38. AN UNMODULATED AM CARRIER IS SIMPLY A UNIFORM SQUARE WAVE . . . . . . . . . . . . ______

39. THE AMPLITUDE ENVELOPE OF A MODULATED FM CARRIER VARIES WITH THE APPLIED SIGNAL . . ______

40. WHEN WE SELECT AN AM OR FM STATION ON OUR RADIOS, WE ARE SIMPLY SELECTING THE CARRIER FREQUENCY OF THAT STATION . . . ______

41. PAM IS THE DIGITAL EQUIVALENT OF AM . . . . . . ______

42. PAM DENOTES "PHASE AMPLITUDE MODULATION". ______

43. PDM DENOTES "PHASE DURATION MODULATION". ______

44. MULTIPLEXING MEANS THE ACT OF SENDING TWO OR MORE SIGNALS OVER THE SAME CHANNEL . . ______

45. PPM DENOTES "PULSE POSITION MODULATION". . ______

46. ONLY ANALOG SIGNALS CAN BE MULTIPLEXED. ______

47. AN "APRIORI" PROBABILITY MEANS A "BEFOREHAND" PROBABILITY . . . . . . . . ______

48. THE PHRASE "I WILL BE HERE OR THERE" CONTAINS AN EXCLUSIVE OR. . . . . . . . . ______

49. EVENTS "A" AND "$\bar{A}$" PLACED AS INPUTS TO AN (INCLUSIVE) OR GATE WILL ALWAYS GIVE A LOGIC ZERO AS OUTPUT. . . . . . . . . . . ______

50. WITH A SINUSOID INPUT, THE OUTPUT OF A DIODE CLAMPER CIRCUIT HAS A ZERO D-C VALUE. . . . . . . . . . . . . . . ______

51. THE EXISTANCE OF A FEEDBACK CIRCUIT ASSURES THAT THE OUTPUT WILL NOT OSCILLATE. . . . . . . . ______

52. LAPLACE TRANSFORMS CAN BE USED TO REDUCE THE CONVOLUTION OPERATION TO MULTIPICATION. . . . . ______

53. THE FREQUENCY RESPONSE OF A LINEAR TIME INVARIANT SYSTEM CAN BE OBTAINED FROM THE SYSTEM'S TRANSFER FUNCTION. . . . . . . . . . . ______

54. THE BALANCING POINT OF ALL IMPEDANCE BRIDGES IS INDEPENDENT OF THE SOURCE FREQUENCY. . . . ______

55. IN ORDER TO DOUBLE THE db GAIN OF AN AMP, WE MUST MULTIPLY THE ACTUAL AMP GAIN BY 20. . . . ______

56. A BALANCED MAXWELL BRIDGE IS INDEPENDENT OF BOTH THE SOURCE FREQUENCY AND AMPLITUDE. ______

57. ALL IMPEDANCE BRIDGES CAN BE BALANCED. . . . ______

58. A POSITIVE REACTANCE IS AN INDUCTIVE REACTANCE. ______

59. A GAIN OF 1 IS THE SAME THING AS A db GAIN OF ZERO. . . . . . . . . . . . . . . . . . . . . . . . . . ______

60. AN EIGHT-WAY LIGHT SWITCH CANNOT BE IMPLEMENTED USING ANY KNOWN TECHNIQUE. . . . . . . . . . . . . ______

61. AN EVEN ONES PARITY CODE IS AN ERROR DETECTION CODE AND NOT A CORRECTION CODE. . . . . . . . . . ______

62. A HAMMING CODE IS AN ERROR CORRECTION CODE. . ______

63. A HALF ADDER PERFORMS BINARY ADDITION AND DIVIDES THE RESULT BY TWO (IN BINARY). . . . . . ______

64. TWO SWITCHES IN PARALLEL CAN BE USED AS AN AND GATE. . . . . . . . . . . . . . . . . . . . . . . ______

65. IF MASS IS TAKEN AS THE MECHANICAL DUAL OF CAPACITANCE, THEN COMPLIANCE IS THE MECHANICAL DUAL OF INDUCTANCE. . . . . . . . . . . . . . . . . ______

66. IF THE VELOCITY OF A CHARGE MOVING IN A UNIFORM MAGNETIC ($\vec{B}$) FIELD IS PARALLEL TO THAT FIELD, THERE IS NO RESULTING FORCE ON THE CHARGE. . . . ______

67. THERE IS FORCE ON A CURRENT CARRYING WIRE IN A $\vec{B}$ FIELD. . . . . . . . . . . . . . . . . . . . . . . . . ______

68. HAMMING, THE ORIGINATOR OF THE HAMMING CODE, ALSO ORIGINATED HAMMIN' EGGS. . . . . . . . . . . . . . . . ______

69. A BIASED TRANSISTOR IS A BIGOTE[illegible] TRANSISTOR. . . ______

70. AN ELECTROMAGNET PRODUCES A [illegible] FIELD. . . . . . . . ______

71. THE FORCE RESULTING FROM MOTION OF A CHARGE IN A $\vec{B}$ FIELD IS PERPENDICULAR TO THE PLANE DEFINED BY THE VELOCITY DIRECTION AND THE UNIFORM $\vec{B}$ FIELD DIRECTION. . . . . . . . . . . . . . . . . . ______

72. ONE CAN MAKE A MOTOR BY APPROPRIATELY USING THE PROPERTIES OF A MAGNETIC FIELD. SUCH IS NOT THE CASE FOR AN ELECTRIC FIELD. . . . ______

73. IN d'ARSONVAL MOVEMENT, THE RESULTING TORQUE ON THE NEEDLE IS PROPORTIONAL TO THE APPLIED INDUCTANCE . . . . . . . . . . . . . . . . . . . . . . ______

74. IF WE PASS A SQUARE WAVE OF FREQUENCY 50KHZ THRU
A LOW PASS FILTER THAT ONLY PASSES FREQUENCIES
UP TO 75KHZ, OUR OUTPUT WILL BE A SINUSOID
RIDING ON A D-C BIAS TERM. . . . . . . . . . . . . ______

75. FOR THE ABOVE, IF THE CUT OFF IS AT 25KHZ, WE WILL
HAVE ONLY A D-C TERM IN THE OUTPUT. . . . . . . . . ______

76. THE FOURIER SERIES OF THE SIGNAL V(t) = 4 VOLTS HAS
NO TERMS. . . . . . . . . . . . . . . . ______

77. ONLY WAY TO COMBAT CHANNEL NOISE IS TO CHANGE ALL
ONE'S TO ZERO'S IN OUR CODE. . . . . . . . . . . . ______

78. IF A SIGNAL IS UNDERSAMPLED, THEN, ACCORDING TO THE
SAMPLING THEOREM, HIGH FREQUENCIES ARE DISTORTED. . ______

79. ONE WAY TO INCREASE RELIABILITY IS REDUNDANCY . . . ______

80. CHANNEL NOISE IS A PRODUCT OF NATURE THE EFFECTS
OF WHICH CANNOT BE REDUCED BY MAN'S CLEVERNESS . . . ______

81. ALL TRANSISTOR'S ARE FET'S . . . . . . . . . . . . . ______

82. ALL FET'S ARE TRANSISTORS. . . . . . . . . . . . . . ______

83. AN INDUCTOR IS A DIFFICULT COMPONENT TO INCLUDE
ON AN INTEGRATED CIRCUIT CHIP. . . . . . . . . . . . ______

84. WHEN WE MODEL A MECHANICAL CIRCUIT, LAPLACE TRANS-
FORMS CANNOT BE USED IN THE SOLUTION. . . . . . . . . ______

85. A DIODE IS A TIME-VARIANT ELECTRONIC COMPONENT. . . . ______

86. A SMOKE DETECTOR IS A TIME-VARIANT SYSTEM. . . . . . ______

87. A HAMMING CODE CAN DETECT AN ERROR IN A PARITY BIT. ______

88. LOGIC CIRCUITS CAN BE DESIGNED DIRECTLY FROM
TRUTH TABLE. . . . . . . . . . . . . . . . . . . . . . ______

89. TWO TYPES OF "OR" GATES ARE IRON AND COPPER. . . . . ______

90. WE MAY FABRICATE A "NOT" GATE BY CONNECTING THE
TWO INPUT TERMINALS OF AN "AND" GATE. . . . . . . . . ______

91. EXCEEDING 100% MODULATION IN AM CAUSES DISTORTION. . ______

92. AN IDEAL DIODE IS EITHER A SHORT OR AN OPEN CIRCUIT. ______

93. ALTHOUGH NECESSARY FOR OPERATION, BRUSHES ON A
DC MACHINE DO NOT CONDUCT ANY CURRENT. . . . . . . . ______

94. ONE WAY TO INCREASE THE FREQUENCY ON AN INDUCTION
MACHINE IS TO INCREASE THE NUMBER OF POLES. ______

95. A D/A CONVERTER CONVERTS A DIGITAL INPUT INTO
AN AM MODULATED SIGNAL . . . . . . . . . . . . . . . ______

96. SLIP RINGS ROTATE . . . . . . . . . . . . . . . . . . ______

97. SPLIT SLIP RINGS CAN RECTIFY. . . . . . . . . . . . . ______

98. SLIPPING SPLIT SLIP RINGS SLURP SLOP ON SPLITTING SLIPS. ______

99. WATER FLOATS ON OIL . . . . . . . . . . . . . . . . . ______

100. THIS IS THE LAST TRUE-FALSE QUESTION ON THIS TEST . . . ______

EXTRA CREDIT:

101. THE ANSWER TO THIS QUESTION IS FALSE. . . . . . . . . ______

# PART II

5%

1. A SINGLE PROTOTYPE MACHINE IS PUT ON TEST FOR 1100 HRS. IN THAT TIME, THERE WERE 2 FAILURES. THE TIMES TO REPAIR THE MACHINE FROM THESE TWO FAILURES WERE 60 HRS AND 40 HRS. WE ASSUME THAT, WHILE OPERATING, THE MACHINE EXPERIENCES A CONSTANT FAILURE RATE.

(a) WHAT IS THE MACHINE'S MTBF?
(b) " " " " FAILURE RATE?
(c) " " " " MTTR?
(d) WHAT IS THE PROBABILITY THE MACHINE WILL HAVE NO FAILURES IN 200 HRS. OF USE?
IN 500 HRS OF USE?
(e) WHAT LENGTH OF TIME COULD WE USE THE MACHINE AND HAVE A 50-50 (ie 50%) CHANCE OF IT'S NOT FAILING?

2. AT A RECEIVER, YOU RECEIVE THE FOLLOWING 15 BIT STRING OF BINITS WHICH YOU KNOW IS AN 11 BIT HAMMING CODE WITH FOUR PARITY BITS. (ASSUME EVEN ONES PARITY).

50

(a) HAS THERE BEEN AN ERROR IN TRANSMITTING THE CODE? HOW DO YOU KNOW?

(b) ASSUMING ONLY ONE BINIT ERROR WAS MADE, CORRECT THIS CODE.

RECEIVED CODE:

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

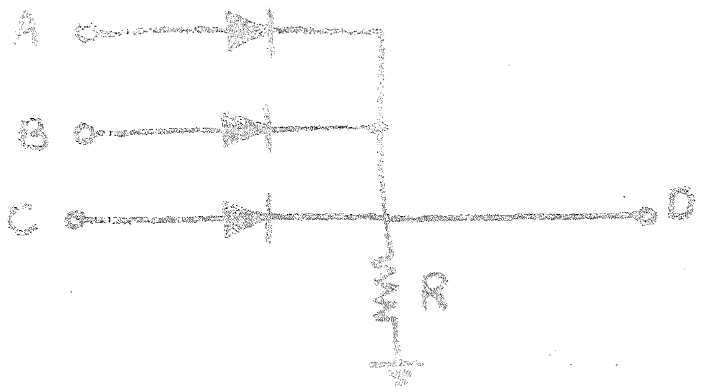
(c): ASSUME WE RECEIVED THIS CODE OVER A BINARY SYMMETRIC CHANNEL, BEARING IN MIND YOUR ANSWER IN (B), WHAT IS THE PROBABILITY OUR CORRECTED CODE IS THE CODE SENT? THAT IS, COMPUTE:

$$P_r[1 \text{ BINIT ERROR} / \text{AN ERROR HAS OCCURED}]$$

ASSUME $P_1 = P_0 = 1/2$ AND $p = q = 0.99$.

3.

50/4



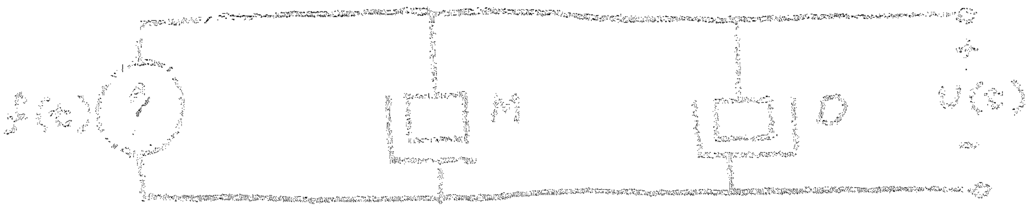
IN THE ABOVE LOGIC CIRCUIT, A, B, AND C ARE AT A LOGIC ZERO WHEN THERE IS NO APPLIED VOLTAGE AND AT A LOGIC ONE WHEN 5 VOLTS IS APPLIED. THE SAME IS TRUE FOR THE GATE OUTPUT, D.

(a) IN THE SPACE PROVIDED BELOW, DETERMINE THE TRUTH TABLE FOR THIS GATE.

(b) WHAT TYPE OF LOGIC GATE IS THIS?

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | |
| 0 | 0 | 1 | |
| 0 | 1 | 0 | |
| 0 | 1 | 1 | |
| 1 | 0 | 0 | |
| 1 | 0 | 1 | |
| 1 | 1 | 0 | |
| 1 | 1 | 1 | |

4.



50%

CONSIDER THE ABOVE MECHANICAL CIRCUIT. A MASS M, IS SUBJECTED TO AN APPLIED FORCE, $f(t)$. D DENOTES MECHANICAL RESISTANCE. ASSUME $f(t) = f_0 \mu(t)$ WHERE $\mu(t)$ IS THE UNIT STEP FUNCTION AND $f_0$ IS CONSTANT. FURTHER ASSUME ZERO INITIAL CONDITIONS (i.e., THE INITIAL VELOCITY IS ZERO).

(a) FIND THE RELATIONSHIP FOR THE VELOCITY, $U(t)$, (IN TERMS OF M, D, AND $f_0$) AS A FUNCTION OF TIME.

(b) GIVEN $M = 5$ kg, $D = 1 \frac{\text{NT-SEC}}{\text{M}}$, AND $f_0 = 30$ NT., HOW LONG WILL IT TAKE THE MASS TO ACHEIVE A VELOCITY OF 10 METERS/SEC?

(c) ① IN TERMS OF $f_0$ AND D AND M, WHAT IS THE SPEED, $U(t)$, IN STEADY STATE (AFTER A "LONG TIME")

② WHAT IS THE STEADY STATE VALUE OF $U(t)$ FOR THE PARAMETERS GIVEN IN (b)?

(d) DETERMINE THE REQUIRED FORCE, $f_0$, THAT IS REQUIRED TO ACHEIVE A VELOCITY OF 100 METER/SEC IN 10 SECONDS. USE

$D = 1 \frac{\text{NT-SEC}}{\text{M}}$ AND $M = 5$ kg.

EE 334 FINAL SOLUTIONS by MARKS! (MAY [illegible])

1. T
2. T
3. F
4. F
5. T
6. T
7. F
8. F
9. T
10. T
11. F
12. F
13. T
14. T
15. T
16. F
17. F
18. T
19. T
20. F
21. [illegible]
22. T
23. T
24. F
25. F
26. T
27. T
28. F
29. F
30. T
31. T
32. T
33. T
34. F
35. F
36. T
37. T
38. F
39. F
40. T
41. T
42. F
43. F
44. T
45. T
46. F
47. T
48. T
49. T
50. F
51. F
52. T
53. T
54. F
55. F
56. T
57. F
58. T
59. T
60. F
61. T
62. T
63. F
64. F
65. T
66. T
67. T
68. F (NG)
69. F (NG)
70. T
71. T
72. F
73. F
74. T
75. T
76. F
77. F
78. T
79. T
80. F
81. F
82. T
83. T
84. F
85. F
86. T
87. T
88. T
89. F (NG)
90. F
91. T
92. T
93. F
94. F
95. F
96. T
97. F
98. F (NG)
99. F
100. F (NG)

(NG) NOT GRADED – AUTOMATIC CREDIT.

1. MACHINE ON TIME = 1000 HRS
MACHINE REPAIR TIME = 100 HRS
# FAILURES = 2
(a) MTBF = $\frac{1000\text{ HRS}}{2\text{ FAILURES}}$ = 500 HRS
(b) $\lambda = \frac{1}{MTBF}$ = 0.002 FAILURES/HR
(c) MTTR = $\frac{100}{2}$ = 50 HRS
(d) $R = e^{-t/MTBF} \Rightarrow R(200) = e^{-\frac{200}{500}} \approx 0.67 \Rightarrow 67\%$
$R(500) = e^{-500/500} = \frac{1}{e} \Rightarrow 37\%$

e. $0.5 = e^{-t/500}$
$\frac{t}{500} = \ln 2$
$t = 500 \ln 2$
$= 347$ HRS

2.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| | | | | | | | $P_3$ | | | | $P_2$ | | $P_1$ | $P_0$ |

(b) OUR RECEIVED PARITY BITS ARE
$P_3P_2P_1P_0 = 1001$
ASSUMING CORRECT CODE, OUR $P_0$ PARITY BIT SHOULD BE

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 |
| $P_0$ | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

7 ONES ⇒ $P_0 = 1$

FOR $P_1$:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | 3 | 6 | 7 | 10 | 11 | 14 | 15 |
| $P_1$ | 1 | 0 | 1 | 0 | 1 | 0 | 1 |

4 ONES ⇒ $P_1 = 0$

FOR $P_2$:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | 5 | 6 | 7 | 12 | 13 | 14 | 15 |
| $P_2$ | 1 | 0 | 1 | 0 | 1 | 0 | 1 |

4 ONES ⇒ $P_2 = 0$

FOR $P_3$:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| $P_3$ | 1 | 0 | 1 | 0 | 1 | 0 | 1 |

4 ONES ⇒ $P_3 = 0$

RECEIVED: $P_3P_2P_1P_0$ = 1001
SHOUD BE $\Longrightarrow$ 0001
DIFFERENCE: 1000 ⇒ ERROR IN BIN 8.

(a) THE CODE HAD TO BE WRONG SOMEWHERE BECAUSE THE PARITY BITS DIDN'T CHECK.

(c) $P_r$[1 BINIT ERROR/ AN ERROR HAS OCCURED]

$$= \frac{P_r\text{[1 BINIT ERROR AND AN ERROR HAS OCCURED]}}{P_r\text{[AN ERROR HAS OCCURED]}}$$

$P_r$[1 BINIT ERROR AND AN ERROR] =

= $P_r$[1 BINIT ERROR] = $15 p^{14}(1-p)$

= 0.1303

$P_r$[AN ERROR HAS OCCURED]

= 1 − $P_r$[NO ERROR HAS OCCURED]

= $1 - p^{15}$ = 0.1399

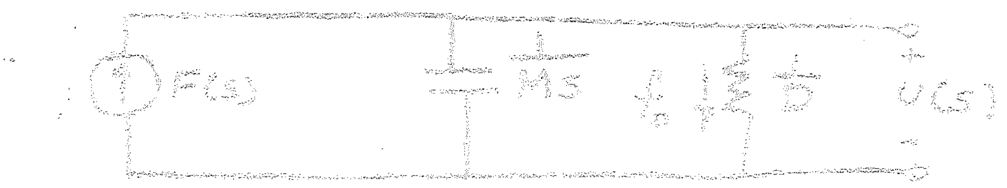
⇒ $P_r$[1 BINIT ER/ AN ERROR] = $\frac{0.1303}{0.1399}$ = 0.9312

4. THIS IS AN "OR" GATE SINCE ANY TIME A, B OR [illegible] ARE FORWARD BIASED BY THE APPLIED [illegible] ALL OF THE VOLTAGE APPEARS ACROSS THE RESISTOR R. (SEE P.366 OF SMITH, FIG. [illegible]) OUR TRUTH TABLE IS:

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

| YOUR LAB GRADE | TOTAL % FINAL | RANK IN CLASS | YOUR FINAL GRADE IN EE 321 |
|---|---|---|---|
| | | | |

4, FIRST, TRANSLATE CIRCUIT INTO LAPLACE DOMAIN



(a) BY CURRENT DIVIDER:

$$f_D = \frac{1/MS}{1/D + 1/MS} F(s) = \frac{D F(s)}{D + MS}$$

AND $U(s) = \frac{1}{D} f_D = \frac{F(s)}{D + MS}$

NOW $f(t) = f_0 \mu(t) \Rightarrow F(s) = \frac{f_0}{s} \Rightarrow U(s) = \frac{f_0}{s(D+MS)}$

$$U(s) = \frac{f_0/M}{s(D/M + s)} = \frac{f_0}{M}\left(\frac{M/D}{s} - \frac{M/D}{(s + D/M)}\right)$$ (⟸ FACT HINT (PARTIAL FRACTION))

$$= \frac{f_0}{D}\frac{1}{s} - \frac{f_0}{D}\frac{1}{s + D/M}$$

INVERSE LAPLACING:

$$U(t) = \frac{f_0}{D}\mu(t) - \frac{f_0}{D} e^{-t/M/D}\mu(t)$$

$$= \frac{f_0}{D}\left(1 - e^{-t/M/D}\right)\mu(t)$$

(b) $10 = \frac{30}{1}\left(1 - e^{-t/30}\right)$

$e^{-t/30} = 2/3 \Rightarrow t = 30 \ln\frac{3}{2} = 12.16$

(c) $U(t) = \frac{f_0}{D}\left(1 - e^{-t/M/D}\right)\mu(t)$

$\Rightarrow U(\infty) = f_0/D = \frac{30}{1} = 30$ m/sec

(d) $U = \frac{f_0}{D}\left(1 - e^{-tD/M}\right)$

$$\Rightarrow f_0 = \frac{UD}{1 - e^{-t/M/D}} = \frac{(100)(1)}{1 - e^{-10/30}}$$

$= 352.8$ NEWTONS

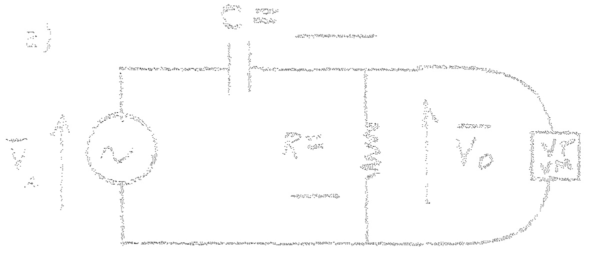
Marks

# EE 334 Lab Session

Frequency Response time constant and Fourier series.

1. Frequency response. For the circuits shown, measure $v_o$ using a sinusoidal input signal set at 2 volts, and vary the frequency from 20 Hz to 5 KHz. Be sure to include the half power point (cut-off frequency) as one of the measurements.

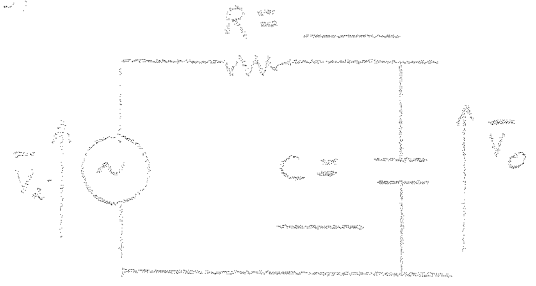
a)



| f | $v_o$ |
|---|---|
| | |

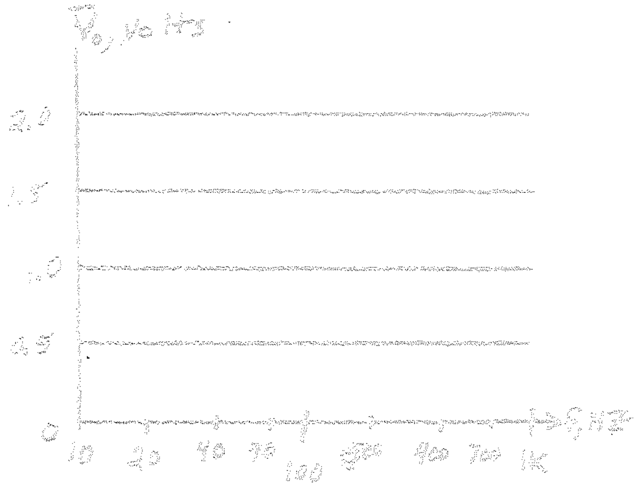
cut-off frequency ($w_{co}$) = ______ rad/s.

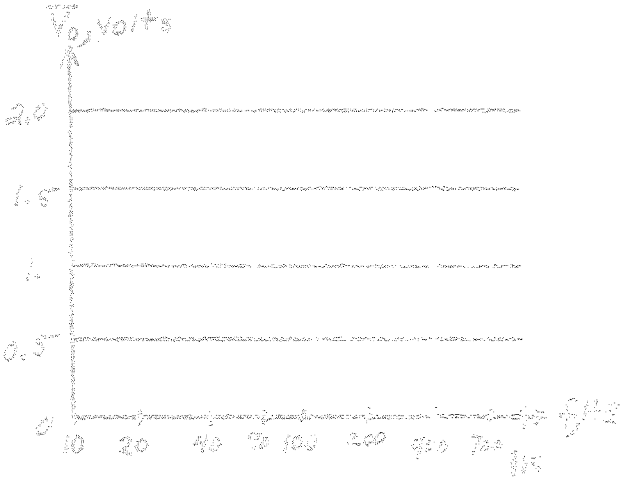
b)



| f | $v_c$ |
|---|---|
| | |

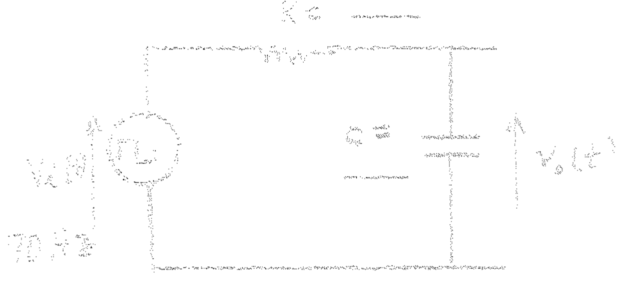
cut-off frequency ($w_{co}$) = ______ rad/sec

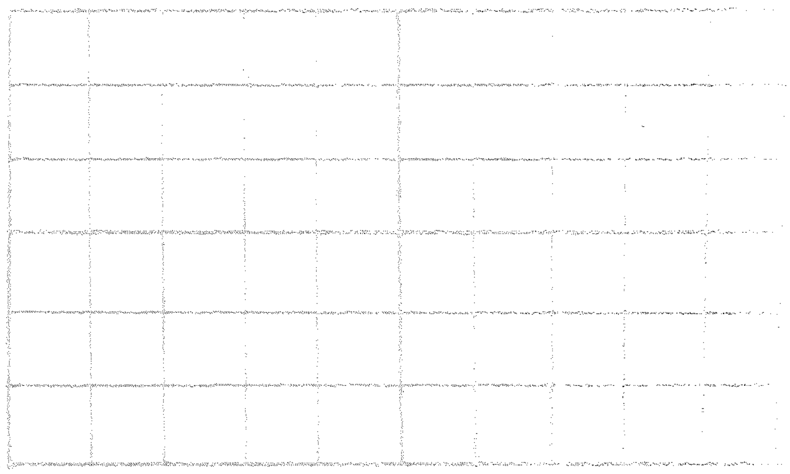




[illegible] CIRCUIT

Apply a square wave input signal with the amplitude [illegible] at [illegible] and a frequency input of 70 Hz. Use the circuit of part 1(a) [illegible] observe $v_o$ with a CRO. Set the horizontal sweep so only one cycle appears on the screen. Then switch the horizontal display knob from "Normal" to "Mag". Record the waveform below and calculate the time constant.



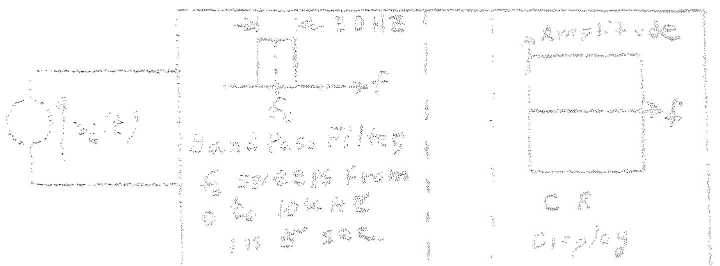


Time constant ($\tau_c$) = ______

RC = ______

$\frac{1}{f_{co}}$ (from part 1(a)) = ______

3) Fourier Series



Spectrum Analyzer

A 1 KHZ square wave signal is applied to the input of an HP 3580A Spectrum Analyzer, which displays the harmonics of the signal vs. frequency.

Record the amplitude and frequency of each harmonic. Repeat for the triangular and sinusoidal waves.

Wave

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| square | amplitude | | | | | | | |
| | frequency | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| triangular | amplitude | | | | | | | |
| | frequency | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| sinusoidal | amplitude | | | | | | | |
| | frequency | | | | | | | |

Marks

Exp. No. $6^3$ [illegible]

Transistor (BJT) and JFET Amplifiers

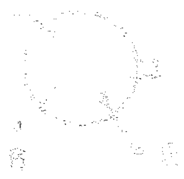
The purpose of this experiment is to measure the current and voltage gains of a transistor amplifier, and the voltage gain of a JFET amplifier. The [illegible] connection [illegible] shown below

[illegible]

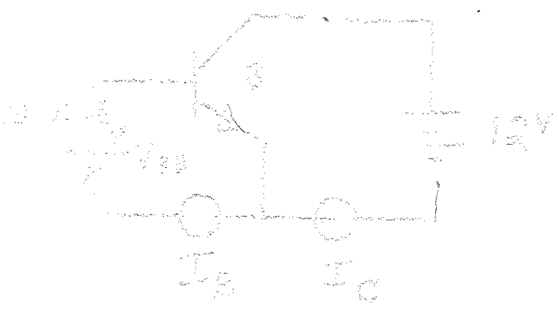
npn

JEDEC TO-[illegible]

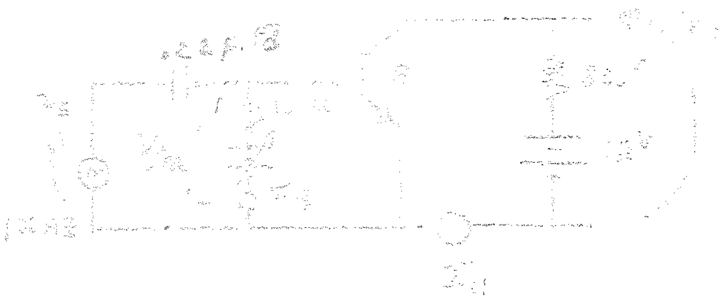
p channel



A. BJT amplifier



(a)



(b)

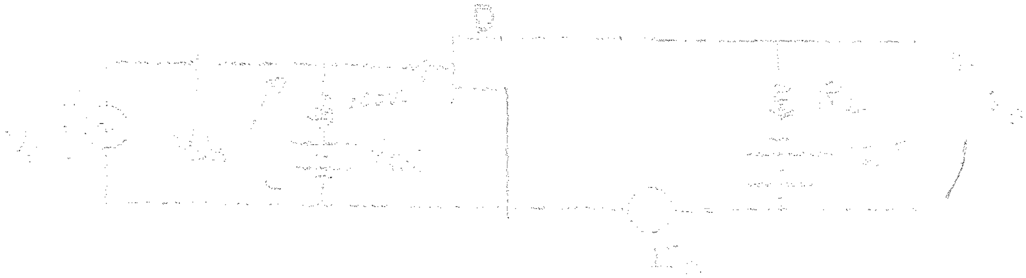
(1) Connect the circuit of Fig. (a), and [illegible] for each of the following [illegible]

[illegible]

(2) [illegible] the circuit of Fig. (b) and adjust [illegible] the output and gradually increase [illegible] distortion [illegible] $V_o$ and [illegible]

[illegible]

B. JFET amplifier



1. Connect the above circuit with the following values: $V_s = 0$, $R_L = 0$. Measure $I_D$ for each of the following values of $V_{GG}$ (volts): 3, 2, 1, 0.5, .1, 0.

2. Set $V_{GG}$ to 2 volts and $R_L$ to 3 k ohms. Connect a CRO to the output and gradually increase $V_s$ until $V_o$ appears distorted. Reduce the input until distortion is eliminated. Measure $V_o$ and $V_{in}$ (peak to peak) with the CRO.

## Report

Part A (1). a) Calculate the d.c. beta (current gain) for $I_B$ = 0.2 ma.

b) Calculate the a.c. current gain (a.c. beta) as follows:

$$\beta = \frac{\Delta I_c}{\Delta I_B} \quad (V_{CE} \text{ constant}).$$

use the .2 to .3 change for $\Delta I_B$.

A (2). Calculate the voltage gain.

B (1). The amount or control that the gate voltage has over the drain current is measured by the change in $I_D$ per volt change in $V_{GG}$. This is called $g_m$(mhos) and is expressed as

$$g_m = \frac{\Delta I_D}{\Delta V_{GG}} \quad (\text{constant } V_{DS}).$$

Calculate $g_m$ using data for $V_{GG}$ change from 0.5 to 1 volt.

B (2). Calculate the voltage gain.

Marks

# EE 234 (4)

## Recording Instruments

The purpose of the laboratory is to demonstrate:

1. The basic ideas of operation of the most commonly used recording instruments,
2. Ways to calibrate recording instruments,
3. Frequency limitations of instruments,
4. Sensitivity of the instruments and noise effects at high sensitivity positions of the instruments.

Equipment:

|  |  |
|---|---|
| 1. Strip chart recording | 2. X-Y plotter |
| 3. Function generator | 4. D.C. Power Supply |

## Lab Procedure

### A. X-Y plotter

Connect the function generation (sine wave) to the X-Y plotter. Set the function generator frequency to 0.1 HZ, and the plotter sensitivity to 1 volt/division. Increase the generator output until the recorder output produces 5 inches of deflection (peak to peak).

1. Keep the generator voltage constant (use a CRO or a digital voltmeter to measure it). Plot a curve of deflection vs. frequency (frequency response curve), using frequencies of 0.1, 1, 2, 3, 4, and 5 HZ, or until the half power point is found.
2. Replace the generator with d.c. source. Increase the d.c. voltage to get 1 inch of deflection. Calibrate the recorder. (Note that this is a d.c. amplifier). Use this reading for calculating sensitivity.
3. Remove the source from the input to the plotter. Set the sensitivity to maximum. Touch the input terminals with the fingers. Not the results.
4. Set the function generator to produce a ramp at .1 HZ. Use the plotter to get a graph of this voltage vs. time. Use a 1 V/division sensitivity setting.
5. Repeat for triangle and square wave.

Strip Chart Recorder

1. Set the input of the recorder to the 5 volt range. Connect the function generator to the recorder and set the generator amplitude to produce a peak-to-peak deflection of 3 inches. Set the chart speed to 8 inches/minute. Note the type of marking pen used. How does it differ from the X-Y plotter pen?

2. Repeat steps 1 through 5 of part A, for the strip chart recorder

Report:

1. Describe a galvanometer type recorder.

2. For the X-Y plotter, describe the mechanism and associated circuits used to move the pen in the X direction. What is the maximum speed that the pen will move?

3. Plot a curve of maximum deflection vs. frequency for the X-Y plotter and strip-chart recorder.

4. Describe a capillary ink writing system and a heated stylus system.

5. Define sensitivity and calculate it for the strip-chart recorder and X-Y plotter.

References:

Principles of Modern Instrumentation - Spitzer, Howarth

Guide to Electronic Measurements and Laboratory - Stanley Wolf

Electrical Measurements and Instrumentation - Oliver and Page

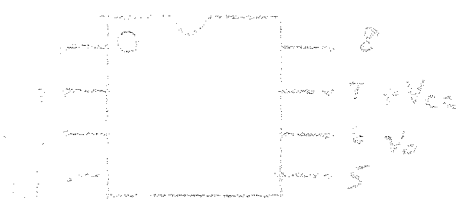
Marks

# [illegible]

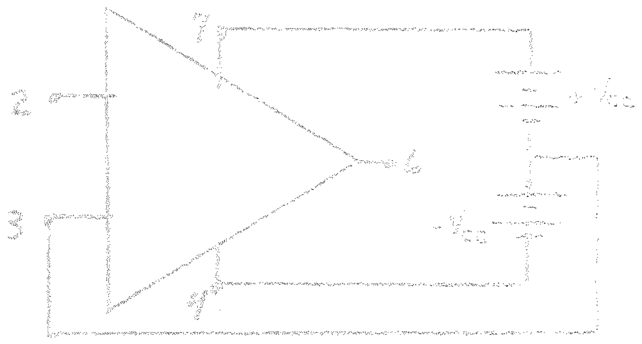
[illegible]

[illegible] experiment will provide an introduction to integrated [illegible] operational amplifiers (IC op-amps). Today op-amps [illegible] used in a wide range of analog signal processing including [illegible] amplification, wave shaping, servo and process control, [illegible] and also in many non-linear applications such [illegible] comparators, analog to digital and digital to analog convert- [illegible] non-linear function operators. We will be concerned [illegible] the use of an op-amp as an amplifier, a summer, and an [illegible].

In this experiment you will be using type 741 op-amps. [illegible] have a gain of about 200,000 open circuited and a band- [illegible] of about 1 MHz for unity gain. The 741 is an integrated [illegible], meaning that the op-amp is implemented by transistors [illegible] resistors grown or deposited on a single chip of semicon- [illegible] material (in this instance it is silicon).



[illegible] view 741-8 pin)



[illegible] the inverting input
[illegible] non-inverting input)

## [illegible] Supplies

In order to achieve the ability to produce both positive [illegible] negative voltages the op-amp requires both $+V_{cc}$ and $-V_{cc}$ sup- [illegible]. The 741 will operate on supply voltages of from ±3V to ±22V [illegible] ±15V for our work. The two power supplies are connected [illegible] above and need not be disconnected (though they should be [illegible] off while changing circuits) during the experiment. Thus the [illegible] connections will not be shown on subsequent diagrams.

Scope Triggering

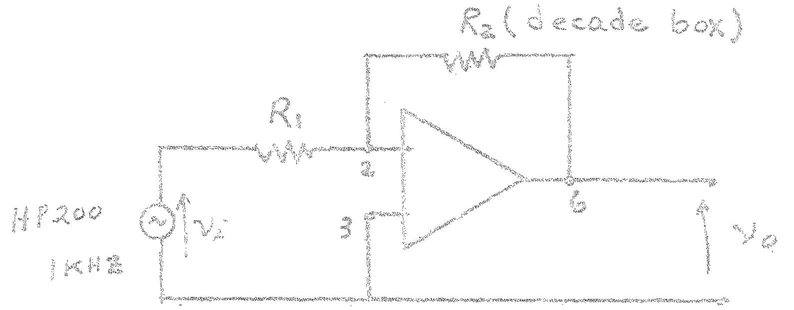
To observe the inversion of the input signal by the op-amp it will be necessary (on a one channel scope) to synchronize the scope trigger from some reference - usually the output of the signal generator. This is done by connecting the scope trigger input to the ungrounded side of the signal generator and putting the scope trigger source control on ext + or - and the trigger coupling control on AC or DC - and then adjusting the trigger level control. The lab instructor will review this with the class before beginning the experiment.

If a two channel scope is available, connect the amplifier input to one channel, and the output to the other, and observe the inversion.

Amplifiers

A. Inverting Amplifier

Connect the op-amp as shown below:



a) Use 5K ohms for $R_1$, and set $R_2$ to give theoretical gains of 10, 20, 40 and 80. Set the input signal to give about 12 volts peak-to-peak for $v_o$. Adjust the input to eliminate distortion. Measure the gain in each case, using the CRO as a voltmeter.

Q1 How does the measured gain compare with the theoretical gain?

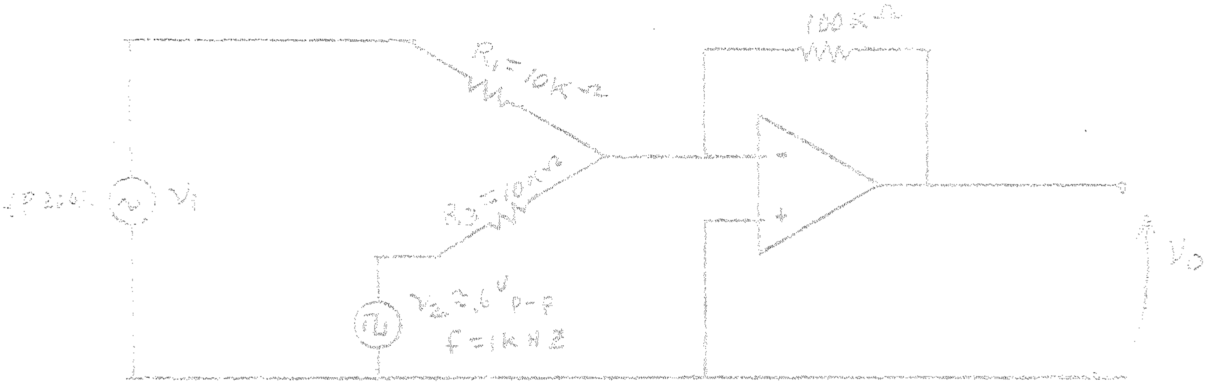
b) With the x80 theoretical gain setting, increase the signal input until you observe clipping on both the upper and lower portions of the output. Measure the voltage difference between the upper and lower clipping points on the output. The clipping is caused by the op-amp reaching its maximum and minimum output voltages (the saturation voltages), which are determined by the power supply voltages. A gain of x100 does not mean that the output will be 100 times the input [illegible] since the amplifier may reach its saturation [illegible]

[illegible] = 100 and $v_{in}$ = 1v our op-amp would not give 100v out value.

$V_{sat}$ – because it inverts).

[illegible] Summer

With the op-amp connected as a x10 amplifier ($R_1$ = 10K, $R_2$ = 100K), connect $R_3$ to the – input terminal (also known as the "summing point") and connect the output of the square wave generator to it as shown.

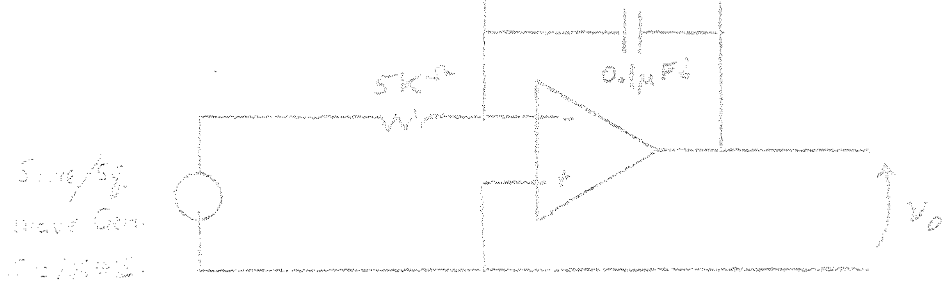


Adjust the square wave generator so $v_2$ is 0.6 v p to p. Observe $v_2$ with the scope synched to the square wave and sketch the waveform. Now connect the H-P oscillator, set its freq. to 4KHz and slowly increase its amplitude to about 1/2 the amplitude of $v_2$, and sketch $v_1$. Slowly change the frequency of $v_1$ until a steady pattern results in $v_o$.

(1) Sketch the output with both generators connected. Is it the sum of the two inputs?

[illegible] Integrator

For integration a capacitor is added in the feedback loop, as shown below. The 100K resistor is present for d.c. stabilization of the op-amp and is not considered, here, as a part of the feedback loop.



1) Connect the circuit as shown. Set the generator for a square wave output, f = 1KHz, $V_{in}$ = 5V. p to p. Observe the output.

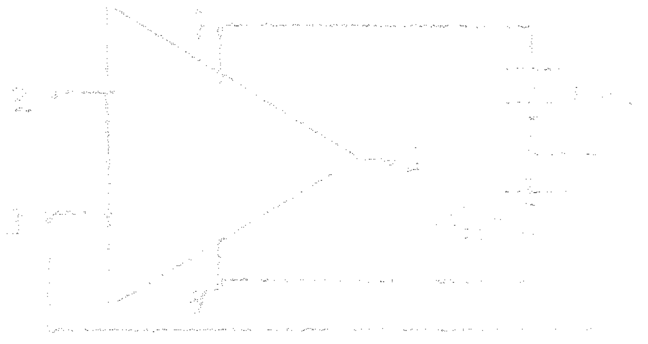
2) Sketch output waveform - what sort of wave is this? Is it the integral of the input? Explain?

3) Switch the generator to sine wave output, increase the output to maximum. Observe the output $v_o$. Use ext. trigger for the

4) What output does an integrator produce if the input is a sine wave? Did this circuit really integrate? Explain.

[illegible] functions operators. [illegible] of op-amps, as [illegible]

[illegible] should be [illegible] type [illegible] op-amps [illegible] of about 200,000 [illegible] described [illegible] the unity gain [illegible] that the op-amp [illegible] implemented [illegible] on a single chip [illegible] it is [illegible] to its [illegible]



inverting input
non-inverting input

[illegible] provides the ability to produce both positive [illegible] the op-amp requires both $+V_{cc}$ and $-V_{cc}$ [illegible] supply voltages of [illegible] two power supplies are [illegible] not be disconnected [illegible] should [illegible] during the experiment [illegible] will [illegible] be shown on subsequent drawings.

[illegible]

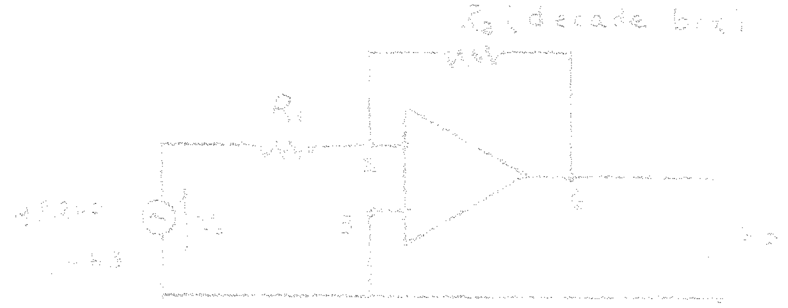
[illegible] by triggering the [illegible] of the signal generator and [illegible] the trigger [illegible] and then adjusting the trigger level [illegible] review this with the class before beginning [illegible]

If a dual channel scope is available, connect the amplifier input to one channel, and the output to the other, and observe the [illegible]

[illegible]

Inverting Amplifier

Connect the op-amp as shown below:

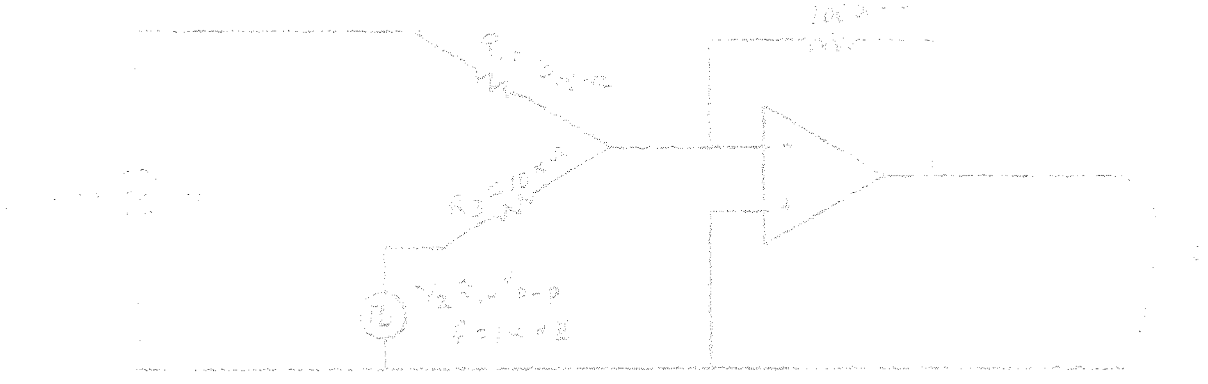


a. Use [illegible] for $R_i$, and set $R_f$ to give theoretical gains of [illegible] 40 and 80. Set the input signal to give about [illegible] volts peak-to-peak for $v_i$. Check the [illegible] distortion. Measure the gain at each [illegible] using the [illegible] indicated.

How does the measured gain compare with the theoretical value? [illegible] the 80 theoretical gain setting, increase the [illegible] until you observe clipping on both the upper and lower portions of the output. Measure the voltage difference between the upper and lower clipping points on the output. The clipping is caused by the op-amp reaching its maximum and minimum output voltages (the saturation voltages) which are determined by the power supply voltages. A gain of 100 does not mean that the output will be 100 times the input

[illegible]

[illegible] connected as a [illegible] amplifier [illegible] input terminal [illegible] the output of the square wave generator [illegible]

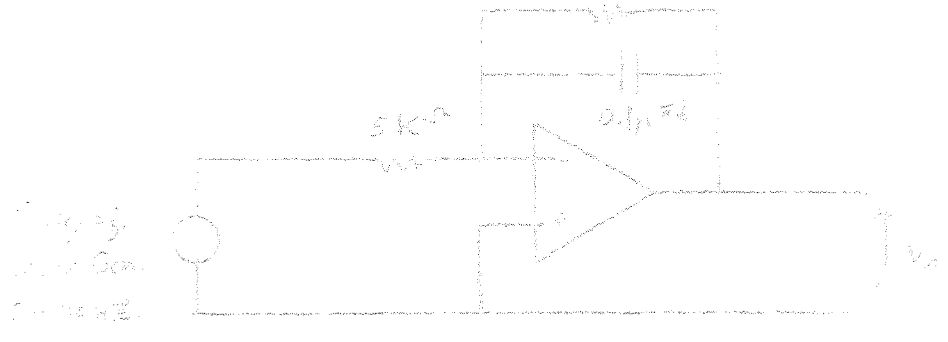


Adjust the square wave generator so $v_2$ is [illegible]. Observe $v_o$ with the scope synched to the square wave and sketch the [illegible]. Now connect the H-P oscillator, set its freq. [illegible] and increase its amplitude to about 1/2 the amplitude [illegible] as shown $v_1$. Slowly change the frequency of $v_1$ until a [illegible] pattern results in $v_o$.

Sketch the output with both generators connected. Is it the sum of the two inputs?

[illegible] Integrator

For integration a capacitor is added in the feedback loop as shown below. The 100K resistor is present for [illegible] stabilization of the op-amp and is not considered, here, as a part of the feedback loop.



# OILFIELD AUTOMATION SIMULATION

May 9, 1975

By Mark Carpenter

# OILFIELD AUTOMATION SIMULATION

This program is a dynamic simulation of an oilfield to be utilized as a teaching aid in the understanding of digital control systems. The complete systems dynamics are incorporated in the program so that the user may write a control program for the field.

## Designation of Program Variables

The following is a list of matrix variables, their dimensions, and usage in the program.

| | | |
|---|---|---|
| Q(4) | Well | |
| | Q(K)=J | |
| P(4) | Well Status | P(K)=1 then Well K is on<br>0(K)=0 then Well K is off |
| X(4) | [illegible] of well in a fractional number | |
| Y(4) | [illegible] of a well in a fractional number | |
| W(4) | Manifold Status | W(K)=1 means Well K feeds Separator 1<br>W(K)=2 means Well K feeds Separator 2 |
| Z(4) | Complement of W(K)-1 | |
| B(6) | Total tank capacities for the two separators, two oil holding tanks, and two water holding tanks | |
| L(14) | Various valves in the oilfield | |

| | |
|---|---|
| C(14) | Pump capacities of the pumps |
| E(2) | Water outlet levels in the two separators |
| F(2) | Oil outlet levels in the two separators |
| T(6) | Total fluid volume in the six tanks |
| O(2) | Oil volume in the two separators |
| I(2) | Water volume in the two separators |

The letter T designates the sample time in hours, and T9 is a counter to keep up with the total time period accumulated. Also used in the program are O1, O2, O3, O4, I1, I2, I3, I4, S5, S6, S7, S8, W1, W2, K, and K6. Care should be taken in the writing of the control program to prevent an overlapping of variables.

The Oilfield

The oilfield (Figure 1) has four wells, two separators, two oil holding tanks, and two water holding tanks. The valves are designated by X and are numbered. The pump locations are marked with a V and have the same subscript number as the valves at that location. For instance, C(6), or pump number 6, is located at valve L(6), where at valve number 9, L(9), there is no pump.

T(1) and T(2) are Separator 1 and Separator 2, T(3) and T(4) are the water holding tanks, and T(5) and T(6) are the oil holding tanks.

The entire control scheme centers around the two separators. Figure 2 shows a separator and various outlet locations.

Since the tanks are cylindrical, the volume is directly proportional to the height of the fluid. The main program sets F(K) at 50% and E(K) at 33.3% of the total tank height or volume. I(K) is the water level of the tank and T(K) is the total fluid level in the tank.

The control program will contain E(K), F(K), T(K), I(K), and O(K) as fractional portions of the total tank capacity, S(K).

## The Control Program

The control program will be interfaced with the main program so that the main program will record accumulations in the tank and the control program will control the flows into and out of these tanks. Figure 3 shows a flow chart of the relationship between the main and control programs.

When the program is initially started, it goes through the dynamics first and then to the control program. The control program should monitor the tanks and make appropriate valve status changes. After the control operations are completed, the main program will transfer to the system dynamics, and the tank accumulations will again be calculated with the new valve statuses.

## Inputs by the Operator

The following questions will be asked to the operator when the program is initially started:

1. Is Well 1-4 ON or OFF
2. Does Well 1-4 feed Separator 1 or Separator 2
3. What are the tank capacities in barrels
4. What are the Pump Capacities in GPM (the program will convert it to barrels/hour)
5. What is the valve status of L(9) and L(10) (water holding tank manifold)
6. What is your sample time in minutes (the program will convert it to hours)

These values will be asked only once during the program. The sample time will determine how often the control loop will monitor the various tank and interface levels.

## The System Dynamics

The system dynamics are simple rate and accumulation equations whose dimensions are barrels and hours. The change in accumulation is calculated by multiplying the difference of the input and output by the sample time. A number of IF statements are used to prevent the mathematical equations from exceeding the system's physical limitations. For instance, the total fluid volume cannot exceed a tank volume. The program will terminate anytime a tank overflows, water gets in the oil tank, or oil gets in the water tank.

## Print Out

The main program will print once each sample time. The total accumulated time, the volumes of fluid in all the tanks, and the interface level [illegible]. The separation [illegible] be printed. Any other information needed by the operator should be printed from the control program.

Some Guides for Writing the Control Program

1. The variables W(K) and L(K) are the only variables that the control program should alter. All other variables can be compared with a control variable, but they should not be changed.
2. The control program will see the sample time in hours, not minutes.
3. The fluid volumes T(K), interface levels I(K), and volume O(K), will be given as a fractional part of the total tank capacities B(K).
4. The water outlet level and oil outlet level E(K) and F(K) respectively, are also in a fractional form of the total tank size.
5. The control program should be written from statement 7000 to 8999. Statements 1-10 can be used to [illegible] time counters.
6. The last statement in a control program should be a Remark Statement. Any time the program needs to be transferred to the main program, send it to your last statement. The main program will pick it up at this point.

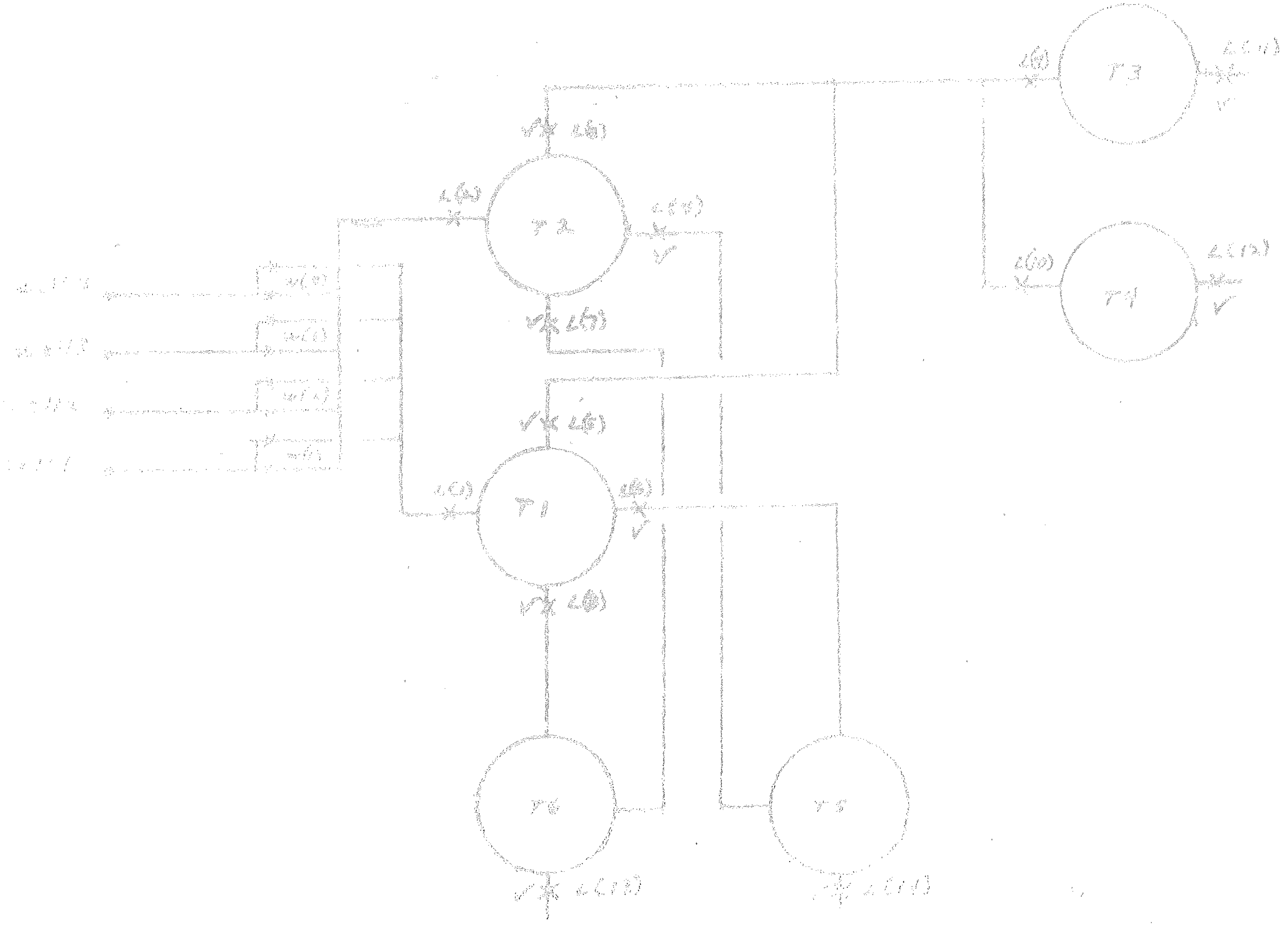


FIGURE 1. [illegible] MODEL

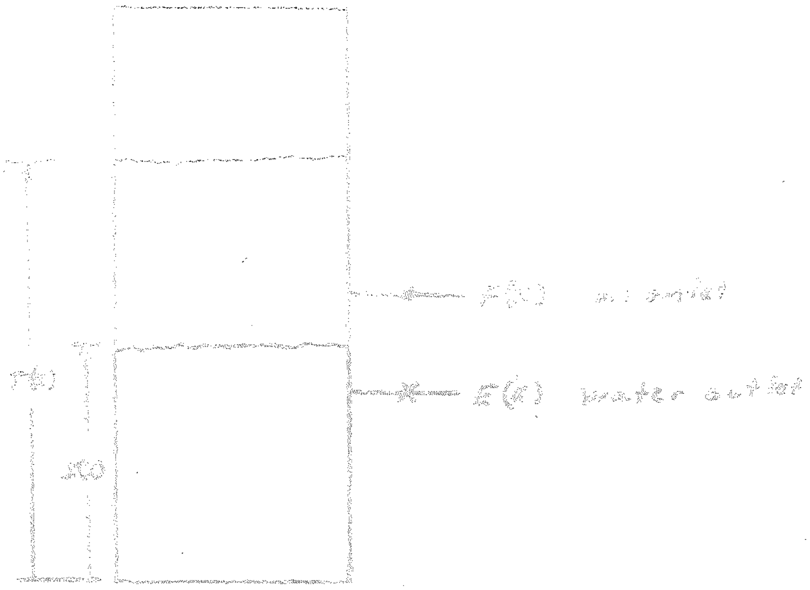


FIGURE 2
A SEPARATOR

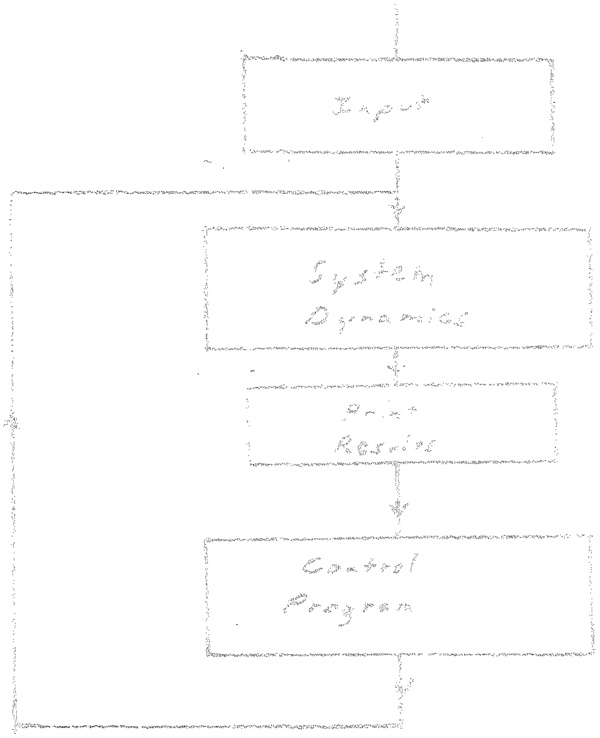


FIGURE 3
PROGRAM FLOW CHART

4 A's
5 B's
10 C's
5 D's
4 W's
1 I

..........SEMESTER SESSION 19..........19.......... SPRING 1977

SUBJECT EE 234

SECTION..........CLASS PERIOD..........ROOM..........

ASSISTANT..........

HW = 10%
ΣT = 40%
F = 30%
L = 20%

| | NAMES | TESTS | | | | HOMEWORK | | | | | | | | | .1 | .4 | .3 | .2 | FINAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MONTH DATE | #1 | #2 | #3 | ΣT | #1 | #2 | #3 | #4 | ~~#5~~ | #6 | #7 | #8 | #9 | ΣHW | ΣT | F | L | GRADES | | |
| 1 | [redacted] | 41 | 90 | 100 | 231 | 10 | - | - | 11E | 25 | 27 | 29 | 80 | 52 | 234 | 231 | 294 | 91 | 79 | B | 10 |
| 2 | [redacted] | 85 | 91 | 100 | 276 | 12 | - | 33 | 28 | 30 | - | 1 | 80 | 50 | 233 +20 | 276 | 339 | 94 | 89 | A | 4 |
| 3 | [redacted] | 69 | 94 | 98 | 261 | 10 | - | 27 | 23 | 30 | 26 | 20 | 80 | 48 | 264 | 261 | 284 | 87 | 82 | B | 8 |
| 4 | [redacted] | 78 | 83 88 90 | 100 | 273 | 14 | 27 | 33 | 18E | 28 | 23 | 21 | 80 | 47 | 291 | 273 | 350 | 89 | 90 | A | 2 |
| 5 | [redacted] | 38 | DROPPED | | — | 13 | 10 | 32 | - | DROPPED | | — | — | | — | — | — | 25— | — | W | — |
| 6 | [redacted] | 83 | 91 | 100 | 274 | 9 | 29 | 40 | 29E | 27 | 15 | 21 | 80 | 47 | 297 | 274 | 293 | 87 | 86 | B | 6 |
| 7 | [redacted] | 64 | 52 | 37 | | 10 | 12 | 14 | - | 26 | - | - | 42 | 50 | 154+20+50 | 153 | 208 | 87 | 61 | D | 20 |
| 8 | [redacted] | 75 | 96 | 92 | 263 | 7 | 21 | 25 | 23 | 23 | 25 | 25 | 80 | 44 | 273 | 263 | 343 | 89 | 88 | B | 5 |
| 9 | [redacted] | 53 | 81 | 95 | 229 | 12 | - | 23 | 22E | 23 | 15 | 22 | 40 | 50 | 207+20 | 229 | 245 | 88 | 74 | C | 17 |
| 10 | [redacted] | 58 | DROPPED | | — | 17 | 23 | 34 | - | DROPPE | | - | — | — | — | — | — | 25— | — | W | — |
| 11 | [redacted] | 68 | 97 | 94 | 259 | 10 | 8 | - | - | - | 24 | - | — | — | 42 +20 | 259 | 292 | 86 | 76 | C | 16 |
| 12 | [redacted] | 66 | 88 | 100 | 254 | 12 | 23 | 29 | 23 | 27 | 23 | 10 | 80 | 37 | 264 | 254 | 221 | 92 | 78 | C | 12 |
| 13 | [redacted] | 82 | 92 100 | 100 | 294 | - | 23 | 33 | 24 | 23 | 24 | 26 | 60 | 50 | 263 + 20 | 294 | 370 | 81 | 93 | A | 1 |
| 14 | [redacted] | 54 | 94 | 76 | 224 | 18 | 13 | 32 | 29 | 24 | 29 | 25 | 80 | 47 | 297 | 224 | 296 | 88 | 80 | C | 9 |
| 15 | [redacted] | 65 | 90 | 95 | 250 | 7 | 11 | 30 | 22 | 28 | 8 | 15 | 75 | 45 | 241 +20 | 250 | 255 | 85 | 78 | C | 12 |
| 16 | [redacted] | 37 | 63 | 84 | 184 | - | - | 23 | - | 26 | - | - | 40 | 40 | 129 | 184 | 184 | 80 | 59 | D | 23 |
| 17 | [redacted] | 32 | 77 | 79 | 188 | 7 | - | 19 | - | - | - | - | 42 | 38 | 106 +20 | 188 | 201 | 74 | 59 | D | 23 |
| 18 | [redacted] | 47 | 72 | (95) | ○ | 11 | 6 | 34 | 19 | - | 24 | 23 | (80) | (50) | (117) I 247 | I 214 | I 360 | I 68 | I 81 | I | — |
| 19 | [redacted] | 44 | DROPPED | | — | 14 | 23 | 27 | - | DROPPED | | - | — | — | — | — | — | 25 - | — | W | — |
| 20 | [redacted] | 43 | 73 | 86 | | 6 | - | - | - | 25 | 10 | 13 | 80 | 48 | 182+20 | 202 | 289 | 70 | 69 | C | 19 |
| 21 | [redacted] | 54 | 95 | 100 | 249 | 10 | 16 | 28 | 23E | 27 | 20 | - | 20 | 48 | 192 | 249 | 301 | 83 | 79 | C | 10 |
| 22 | [redacted] | 61 | 63 | 39 | | 7 | - | 12 | - | 26 | - | - | 42 | 40 | 127 +20 | 163 | 241 | 74 | 60 | D | 20 |
| 23 | [redacted] | 81 | 91 | 92 | 264 | 16 | - | - | 10 | - | 21 | 7 | 1 | — | 55+20 | 264 | 310 | 85 | 78 | C | 12 |
| 24 | [redacted] | 69 | 84 | 64 | 217 | 12 | 25 | 34 | 23 | 30 | 29 | 22 | 80 | 44 | 299 | 217 | 311 | 78 | 78 | C | 12 |
| 25 | [redacted] | 72 | 97 | 100 | 269 | 14 | 12 | 25 | 28E | 30 | 28 | - | 80 | 48 | 265 | 269 | 369 | 89 | 90 | A | 2 |
| 26 | [redacted] | DROPPED | | | — | 5 | DROPPED | | | DROPPE | | - | — | — | — | — | — | -15 | — | W | — |
| 27 | [redacted] | 57 | 69 | 72 | 198 | 2 | - | - | 15 | - | - | - | — | — | 17+20 | 198 | 226 | 79 | 60 | D | 20 |
| 28 | [redacted] | 69 | 83 | 74 | 226 | - | - | 31 | 17 | 26 | 29 | 23 | — | 45 | 171 | 226 | 265 | 73 | 70 | C | 18 |
| 29 | [redacted] | 78 | 84 | 9888 | 260 | 16 | 14 | 33 | 18 | 19 | 28 | 22 | 60 | 50 | 260 | 260 | 306 | 92 | 85 | B | 7 |
| | MAXIMUM → | 100 | 100 | 100 | 300 | 20 | 30 | 40 | 30 | 30 | 30 | 30 | 60 | 50 | 320 | 300 | 400 | 100 | | | /24 |

90-100 : 11
80-90 : 7
70-80 : 2
60-70 : 3

100's : 9
90-100 : 15
80-90 : 3
70-80 : 4
60-70 : 1
50-60 : 0
40-50 : 0
30-40 : 2

0.450-0.500 → 1
0.4 - 0.45 → 5
0.35 - 0.4 → 10
0.3 - 0.35 → 1
<0.3 → 5

FINAL GRADE HP-25 PROGRAM

```
(ΣH.W.)  .1     (ΣT)  .4     STO0  400  RCL0  (L)   X
ENT.     X      ENT   X      R/S   ÷    +     ENT   RCL0
                                                100
300      STO0   300   RCL0   (F)   .3   STO0  ÷     +
÷        R/S    ÷     +      ENT   X    R/S   .2    100
                                                    X
                                                    STO 00
```

1. THE GRADE I EXPECT TO RECEIVE IN THIS COURSE: A B C D F
2. THE GRADE I FEEL I SHOULD GET IN THIS COURSE: A B C D F
3. THE THING I LIKED BEST ABOUT THIS COURSE:

---

4. THE THING I LIKED LEAST ABOUT THIS COURSE:

---

5. THE NEATEST THING I LEARNED IN THIS COURSE:

---

6. THE TOPIC COVERED IN THIS COURSE WHICH I STILL DON'T QUITE UNDERSTAND:

---

7. IF I HAD IT ALL TO DO OVER, I WOULD (a) STILL REMAIN IN THIS SECTION (b) SWITCH TO AN OTHER SECTION (c) PUT OFF TAKING THE COURSE (d) DROP OUT OF SCHOOL AND SELL VACUUM CLEANERS.
8. THE COORDINATION BETWEEN LAB AND LECTURES WAS (a) EXCELLENT (b) GOOD (c) FAIR (d) POOR (e) NONEXISTANT
(9.) THE LECTURES WERE PRESENTED (a) EXCELLENTLY (b) PRETTY GOOD (c) FAIR (d) POOR
10. MY GRADE FOR THE INSTRUCTOR IS: A B C D F
11. THE QUIZES GIVEN WERE REPRESENTATIVE OF THE MATERIAL COVERED (a) AGREE (b) DISAGREE
12. THE HOMEWORK HELPED ME TO BETTER UNDERSTAND THE MATERIAL (a) AGREED (b) DISAGREE.
13. BOB MARKS IS A SWELL FELLOW AND AN ALL-AROUND NICE GUY (a) AGREE (b) AGREE.
14. I FEEL THIS COURSE WILL HELP ME IN MY CARREER (a) A LOT (b) A LITTLE (c) NOT AT ALL (d) IN A NEGATIVE SENSE

---

COMMENTS:

1.

1. A
2. A
3. EASY
4. LAB
5. OP Amps
6. Fourier SERies
7. A
8. E
9. A
10. A
11. A
12. A
13. A
14. A

1 C

2 C

3 NOT MUCH (Easy [illegible]

4 LAB

5.

6. [illegible]

7. a.

8. D

9. A.

10. A.

11 A

12 A

13. A

14. C

1) A

2) B

3) The instructor and that's about all

4) The lab

5) None

6) Linear system theory

7) a

8) b

9) b

10) A

11) a

12) a

13) a

14) C

1- C

2- C

3- it is not my majer

4- LAb

5-

6- FOURiR - SAMPling

7- D

8- B

9- A

10- A

11- A

12- A

13- A

14- B

1. A
2. A
3. BOOLEAN STUFF & CODING
4. ABSTRACTS OF EE
5. HAMMING CODE
6. ELECTRO-MECHANICS
7. A
8. D
9. B
10. B (on spelling)
11. A
12. A
13. A
14. B
15. HOUR TESTS SHOULD BE LIMITED TO 1 HOUR

1. C
2. C
3. It only meets twice a week.
4. Too many topics and I really don't know much about anything.
5. Discussion of far out wild EE material
6. Electro mechanics
7. A
8. D
9. B
10. B
11. A
12. A
13. A
14. C

1. A
2. A
3. Subject covered are general enough
4. (except Fourier Xform & series I'll never see anywhere else) not even in math. Probably same with electromech. systems
5. hamming codes, modulation
6. Fourier series, transforms
7. A
8. E
9. C
10. B
11. A
12. A
13. A
14. ~~A~~ A or B

① A

② A

③ Sampling theorem and Multiplexing, Modulation

④ Fourier Series, <u>Lab</u>

☆ should count first test more than 2nd and 3rd tests.

⑤ Binary channels and coding

⑥ Fourier series

⑦ stay in this section A)

⑧ E) non existent

⑨ A)

⑩ A)

⑪ A)

⑫ A)

⑬ A)

⑭ C)

1. C
2. C
3. Modulation
4. Homework
5. Boolean Logic
6. OP-AMPS
7. a
8. c
9. b
10. A
11. a
12. b
13. a
14. b

1. B
2. A-B
3. DON'T HAVE TO STUDY ALL THE TIME
4. LAB
5. HOW LUCKY I AM TO NOT BE AN EE MAJOR
6. ELECTO-MECHANICS & DIODES & RECTIFIERS
7. STAY IN THIS SECTION
8. PIS-POOR
9. PRETTY GOOD
10. $B^+$
11. Agree
12. Agree
13. C
14. a little (b)

COMPUTER PROGRAM ASSIGNMENT WAS STUPID & A LOT OF NEEDLESS WORK & WORRY.

1) A
2) A
3) informal atmoosphere
4) Lab & tests
5) Impedance bridge
6) Fourier Series
7) remain in this section
8) nonexistant
9) B) Pretty good
10) $B^+$
11) A
12) A
13) A
14) ~~very little~~ C

① B
② B
③ Boolean logic
④ laplace Xform , fourier series
⑤ modulation
⑥ Impedance bridges
⑦ A
⑧ C
⑨ B
⑩ A
⑪ A
⑫ B
⑬ A
⑭ B

1 C—B
2 B
3 fun
4 $\angle_{AB}$
5
6 Linear System
7 B
8 B
9 C
10 B
11 A
12 A
13 A
14 B

1. A
2. A
3. lectures are interesting
4. –
5. Sampling theorem
6. FOURIER SERIES
7. A
8. B
9. A
10. A
11. A
12. A
13. A
14. B

# TEACHER EVALUATION

1. A
2. A
3. NOT TOO MUCH Homework
4. Lab
5. small idea of how computers work
6. FET & BJT circuits
7. (a)
8. (d)
9. (a)
10. A
11. A
12. YES (A)
13. A
14. (B)
15. NO PROGRAM

① C

② B —

③ Linear system theory, coding & binary channels

Op. amps

④ SAMPLING THEOREM FOURIER SERIES

⑤ Everything

⑥ Electro - mechanics

⑦ a)

8) C) FAIR.

9) B) GOOD.

10) B —

11) A) agree to a certain ~~extent~~

12) A) agree

13) A)

14) A) a lot.

1. C
2. B
3. NO TRICKS ON EXAMS OR H.W.
4. LAB
5. USE OF BASIC PROGRAMMING
6. SAMPLING THEORY
7. a) REMAIN
8. c) POOR
9. b) GOOD
10.
11. a) AGREE
12. a) AGREE
13. ONLY STEVE MARTIN CAN SAY THAT
14. C)

1. D
2. F
3. MANNER TAUGHT
4. DON'T ENJOY STUDYING EE
5. BOOLEAN ALGEBRA
6. SAMPLING
7. A
8. [redacted] D
9. B
10. A
11. A
12. A
13. A
14. C

[redacted]

HELP!

EVALUATION

1. C
2. D
3, trip to Power Plant
4, Lab
5. how a three way light switch work
pathway to hell is paved with good intentions)
6. Fourier series
7. A
8. E
9 A
10. A
11. A agree
12. agree when I get the solution
13. well maybe but then maybe not
14. B

1) C
2) C
3) Last 2 tests
4) Lab
5) Hamming code & how it works.
6) Electro Mechanics & fourier series, Laplace tranforms
7) (A)
8) (E) and below
9) (B) → a little fast
10) (A)
11) (A)
12) ~~FES~~ (A)
13) (A)
14) (B) → teaches dicipline (only kidding)

1. B

2. B

3. It's nothing like anything I've ever seen Before
I enjoyed the last part Best — for the 3rd test binary #'s ect

4. lab

5. ~~theory that I don't understand~~ Coding —

6. laplas & fourier theory

7. A

8 E

9 A

10. A

11. A

12. A

13. A.

14. C