ENGR4300
Fall 2006
Test 1

Name________<u>_solution</u>__________

Section_________________________

Question 1 (25 points)___________

Question 2 (20 points) ___________

Question 3 (20 points)___________

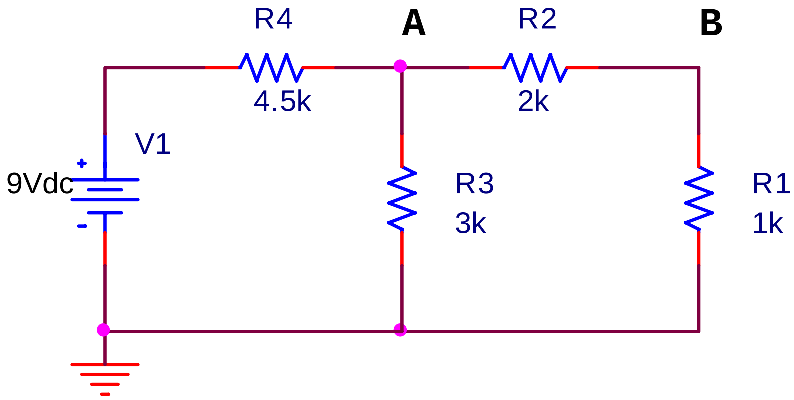
Question 4 (20 points)___________

Question 5 (15 points)___________

Total (100 points): ______________

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES <u>AND UNITS</u>. No credit will be given for numbers that appear without justification.

Question 1 – Resistive Circuits (25 points)



Part 1: Voltages and currents.

1a) What is the voltage at point A in the circuit above. (4 points)

R12 = (3k||3k) = 1.5kΩ = 6V(0.75k)/(0.75k+1.5k) = 2V

V_A = 9*1.5k/6k = 2.25V

V_A** = 9V*(3k||3k)/(3k||3k+4.5k) = **2.25V

1b) What is the current through R2 ? (3 points)

IR2=IR12 = V_A/R12 = 2.25V/3k = 0.75mA

I_{R2} = ***0.75mA***

Part 2: Equivalent circuits:
2a) What is the total resistance seen by the source VS in the circuit in Part 1?(6 points)

R12=1k+2k= 3k
R123=3k||3k=1.5k
Rt = 1.5k + 4.5k = 6k
Rtotal = 6kΩ

2b) For a 9V input, what is the current out of this source? (2 points)

I = 9V/6kΩ =1.5mA ***I=1.5mA***

2c) For a 9V input, what is the voltage at point B in this circuit? (3 points)

$V_B = V_A*(1k)/(1k+2k) = 2.25/3 = 0.75V$ $\mathbf{V_B = 0.75V}$

2d) For a 9V input, what is the current through R3? (3 points)

IR3 = VR3/3k = 2.25V/3k = 0.56mA ***IR3 = 0.75mA***

Part 3: color code

3a) You are looking for a 10k resistor. What would the color bands be for this value?. (2 points)

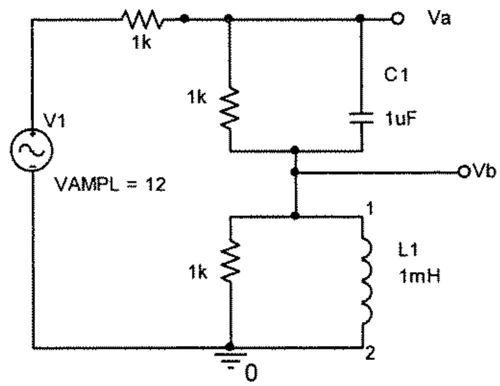
Brown-Black-Orange

3b) Your partner misreads a poorly colored 3rd band as blue instead of its correct color of green. The incorrect value you use in your calculations will be ___10____________ (insert number) times too (Large xxxxx) (circle one). (2 points)

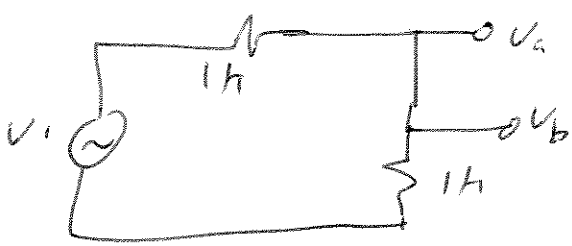
3c) Extra credit: What is the nominal tolerance of a standard resistor with no tolerance indicator band? +/-____________% (1 point)

extra: +/- 20% tolerance

Question 2 – Filters (20 points)



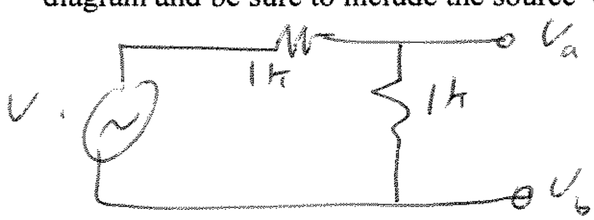
1) Redraw the circuit above for very high frequencies. Label points Va and Vb on your diagram, and be sure to include the source V1. (3 pts)



2) What are the values of Va and Vb for very high frequencies? (2 pts)

Va = 6V , Vb = 6V amplitudes

3) Redraw the circuit above for very low frequencies. Label points Va and Vb on your diagram and be sure to include the source V1. (2 pts)



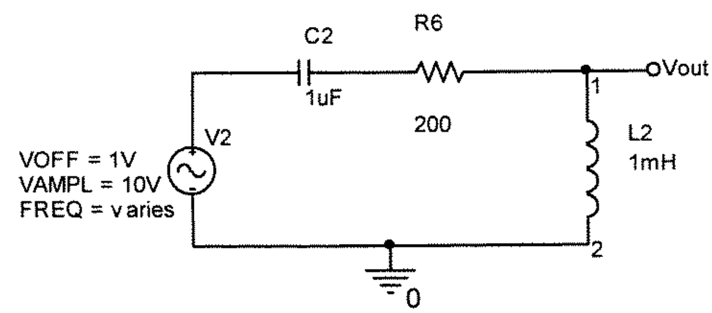
4) What are the values of Va and Vb for very low frequencies? (2 pts)

Va = 6V , Vb = 0 (amplitudes)

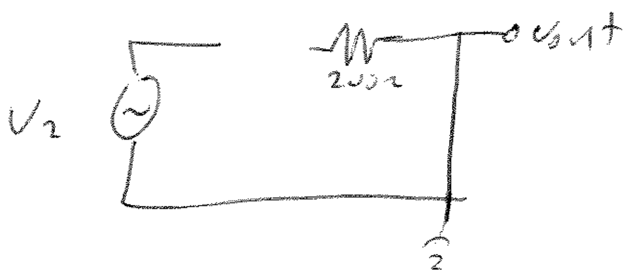
5) If Vb is the output, what type of filter is this circuit? (1 pt)

highpass

Soln.



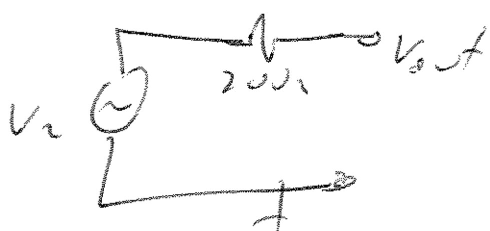
6) Redraw the circuit above for very low frequency. Label the point Vout and be sure to include V2. What is the value amplitude of Vout at very low frequencies? (3 pts)



$V_{out} = 0$

or

7) Redraw the circuit above for very high frequency. Label the point Vout and be sure to include V2. What is the value amplitude of Vout at very high frequencies? (3 pts)



$V_{out} = 10V$ amplitude

8) What is the resonant frequency for this circuit? Be sure to include units. (2 pts)

$\omega_0 = \frac{1}{\sqrt{LC}} = 3.16 \times 10^4$ radians/sec

$f = \frac{\omega_0}{2\pi} = 5.03\,kHz \approx 5\,kHz$

Either answer if units are included.

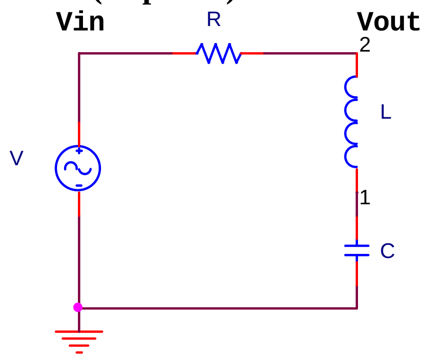
9) What is the amplitude of the current through the inductor, L2, when the signal frequency is equal to the resonant frequency? (2 pts)

$Z_c(\omega_0) = \frac{1}{j\omega_0 C} = -j\,31.6$ $\quad Z_L(\omega) = j\omega_0 L = j\,31.6$ $\quad Z_R = 200\Omega$

$Z_{total} = Z_c + Z_L + Z_R = 200\Omega$ $\quad \bar{I} = \frac{10}{200} = 0.05A = 50mA\angle 0^\circ$

$|I_L| = |I_R| = 50mA$

Question 3 – Transfer Functions (20 points)



Part 1: Transfer Functions

1a) What is the transfer function (Vout/Vin) for the circuit? You must simplify. (6 points)

$$Z_{out} = j\omega L + 1/j\omega C = \quad H(j\omega) = \frac{Z_{out}}{Z_{in}} = \frac{j\omega L + 1/j\omega C}{R + j\omega L + 1/j\omega C}$$

$$H(j\omega) = \frac{1-\omega^2 LC}{1-\omega^2 LC + j\omega RC}$$

1b) What is the simplified transfer function of the circuit at low frequencies? (3 points)

$$H_{LO}(j\omega) = \frac{1}{1} = 1$$

1c) What is the simplified transfer function of the circuit at high frequencies? (4 points)

$$H_{HI}(j\omega) = \frac{-\omega^2 LC}{-\omega^2 LC} = 1$$

Part 2: Resonance

2a) Find the frequency ω (in terms of L & C) where the impedance of the inductor and capacitor (Z_L & Z_C) have the same magnitude (but opposite signs) and cancel each other. (2 points)

$1/\omega C = \omega L$
$1/(LC) = \omega^2$
$\omega = \sqrt{\frac{1}{LC}}$

2b) How does the frequency in 2a compare to the circuit's resonant frequency? (2 points)

They are the same!

2c) What is the value of the transfer function H(jw) at this frequency? (2 points)

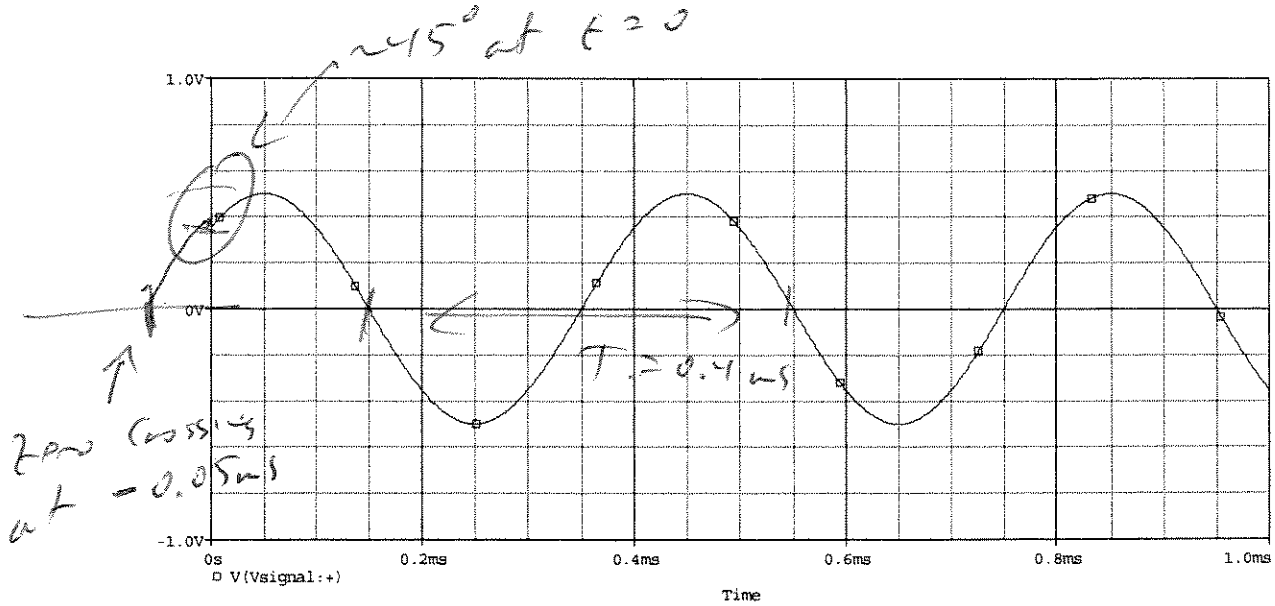
$H(j\omega) = 0$

2d) For Vin(t) = 2sin($\omega_0 t + \pi/2$) where ω_0 is the frequency found in 2a, what is Vout(t)? (2 points)

Vout(t)= 0

Question 4 – Signals, Transformers and Inductors (20 points)

Soln.



1) The voltage trace shown above is a signal measured in a circuit. Using the SIN convention, any voltage in a linear circuit can be represented by the form:

$v_x(t) = V_x \sin(\omega t + \phi_x)$

For the signal shown, determine the values of V_x, ω, and ϕ_x. Include units. (6 pts)

$V_x = 0.5V$ $T = 0.4ms$ $f = \frac{1}{T} = 2.5kHz$

$\omega = 2\pi f = 15.7 \times 10^3$ radians/sec

at $t=0$ phase ~45° $\phi_x = 45°$ $\phi_x = \pi/4$ radians

OR $t_0 = -.05ms$ $-\frac{t_0}{T} \cdot 2\pi = \frac{+0.05}{0.4} \cdot 2\pi = \pi/4$ OR 0.79 radians OR 45°

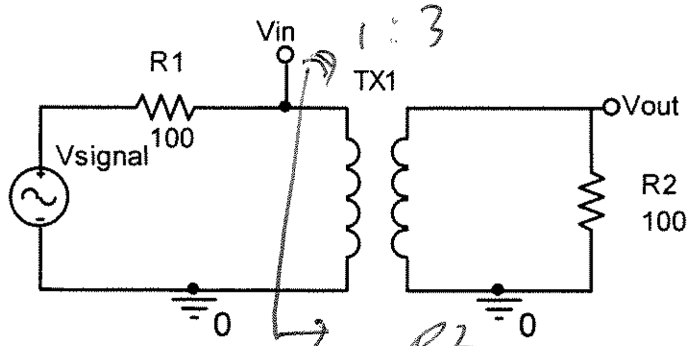
2) For the same signal, what are the a) rms value of the voltage (V_{rms}), b) peak to peak voltage (V_{p-p}), and the DC offset voltage (V_{DC})? (3 pts)

$V_{rms} = \frac{V_A}{\sqrt{2}} = \frac{0.5}{\sqrt{2}} = 0.35V$

$V_{pp} = 2V_A = 1V_{p-p}$

$V_{DC} = 0V$

Solution

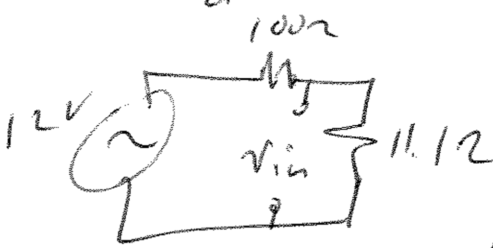


$Z_{in} = \frac{R2}{a^2}$

3) Assume the transformer in the circuit above is ideal with a turns ratio of 3:1. If Vsignal has an amplitude of 12V, what is the amplitude of Vin and Vout? Show your work for partial credit. (6 pts)

Reminder: for this part: a=3, the transformer is ideal, and Vsignal=12Vpeak.

$Z_{in} = \frac{R2}{a^2} = \frac{100}{9} = 11.1\,\Omega$



$V_{in} = \left(\frac{11.1}{100 + 11.1}\right)(12) = 1.2V = V_{in}$

$V_{out} = a \cdot V_{in} = 3.6V$

4) Still use the circuit shown above, and the transformer values listed. Now the transformer has finite self inductances of the windings, otherwise it is ideal.

a) If the self inductance of the primary is 100mHenries, what is the self inductance of the secondary? (2 pts)

$a = \sqrt{\frac{L_2}{L_1}}$ $\quad a^2 L_1 = L_2 \quad$ $L_2 = (3^2)(0.1) = 0.9H$

OR 900mH

b) Assume the primary coil is tightly wrapped around a cylindrical core made of nickel. The length of the coil is 5cm. The diameter of the nickel core is 0.6cm. For nickel $\mu = 7.54 \times 10^{-4}$H/m. The wire is 26 gauge which has a diameter of 0.4mm and a resistance of 0.123Ω/m. How many turns are there in this coil? (3 pts)

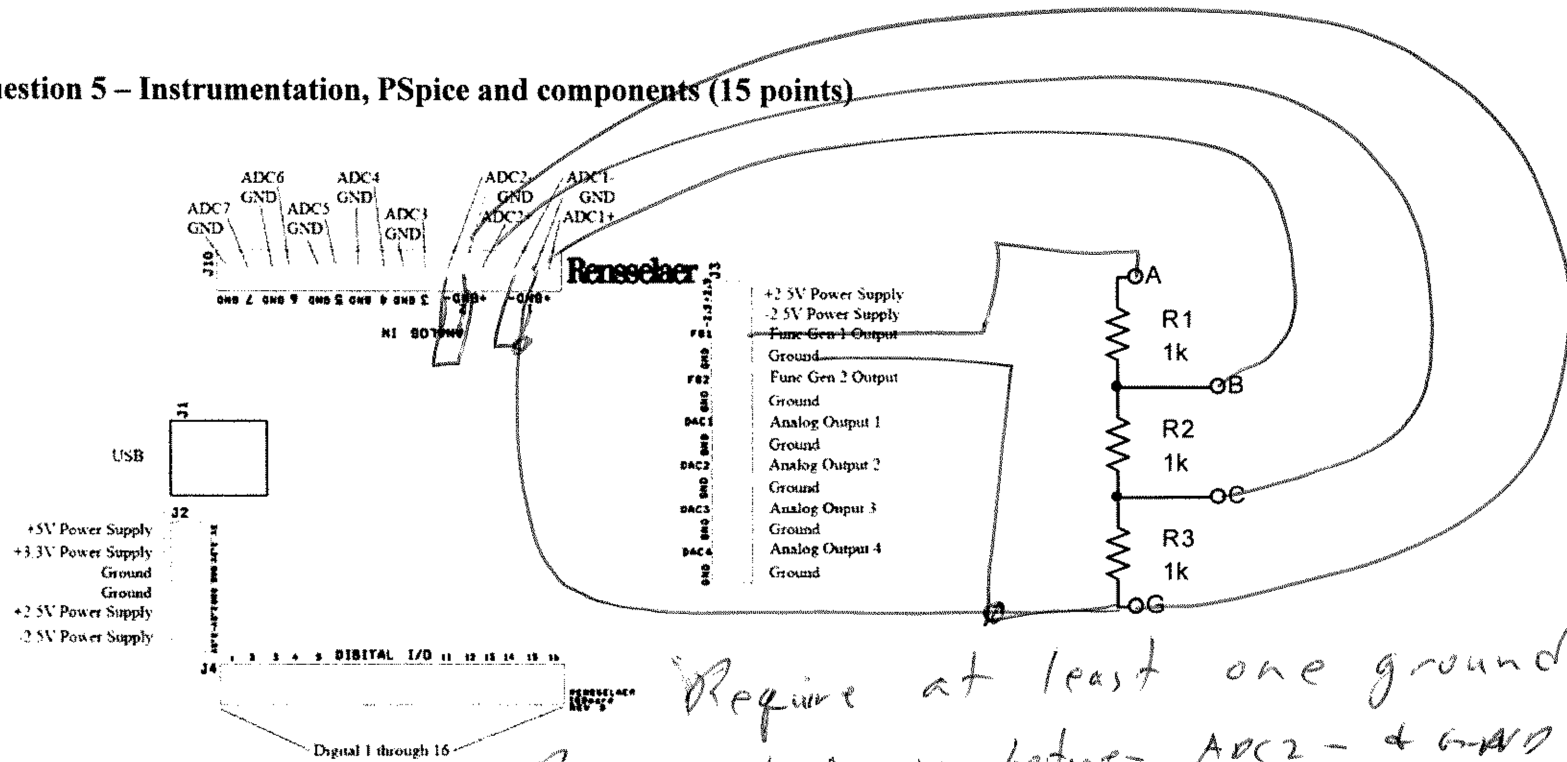
Long coil $d > r_c$

$L = \frac{\mu N^2 \pi r_c^2}{d} = \frac{(7.54 \times 10^{-4}) N^2 (3.14) \left(\frac{0.6 \times 10^{-2}}{2}\right)^2}{5 \times 10^{-2}} = 0.1$

$N^2 = 2.34 \times 10^5$ $\quad N = 484$ turns

Solu.

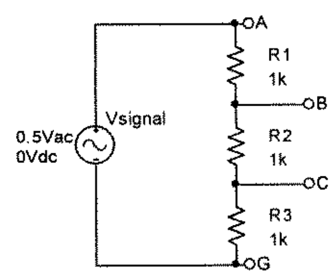
Question 5 – Instrumentation, PSpice and components (15 points)



Require at least one ground

Recommend jumper between ADC2 – & GND } Not required
ADC1 – & GND }

1) Draw lines on the figures above to represent wires needed to do the experiment represented by the schematic below. Use Function Generator 1 as the signal source. Connect ADC1 to measure the voltage at point B, and connect ADC2 to measure the voltage at point C. G is the ground reference node for the circuit. Draw all wires needed. (5 pts)



Soln.

Question 5 – continued

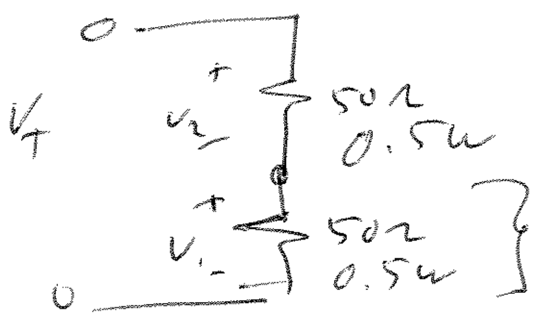
2) A 100Ω resistor has a power rating of 1/4 Watt. What is the maximum current that can be passed through the resistor without exceeding the power rating? (1 pt), Include units.

$P = I^2 R = 0.25$

$I^2 = \frac{0.25}{100} = 2.5 \times 10^{-3}$

$I = 50\,mA = 0.05\,A$

3) Two 50Ω resistors are placed in series. A voltage is applied across the two resistors. If the resistors are rated at 0.5 W each, what is the maximum voltage that can be applied across the two resistors in series without exceeding the power rating of the resistors? (1 pts) Include units.



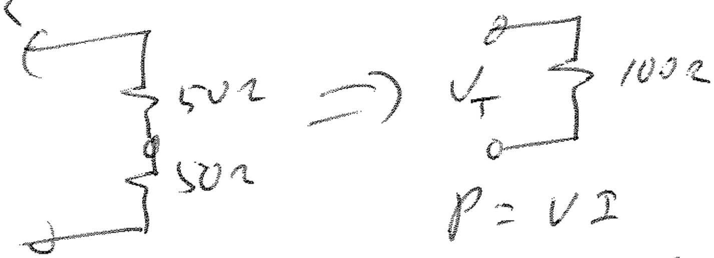
$P = V_1^2/R \quad 0.5 = \frac{V^2}{50}$

$V_1 = 5v$

$V_1 = V_2 = 5$

$V_T = V_1 + V_2 = 10v$

OR



100Ω, 1w total

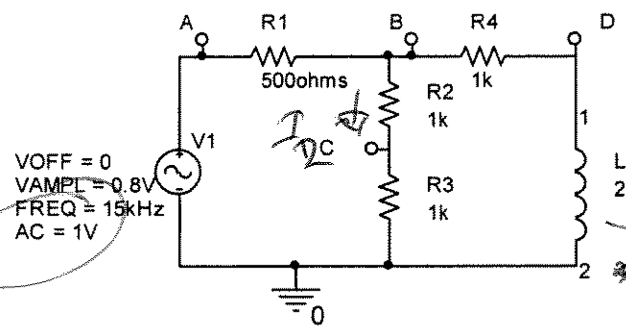
$I = V_T/R$

$P = VI$

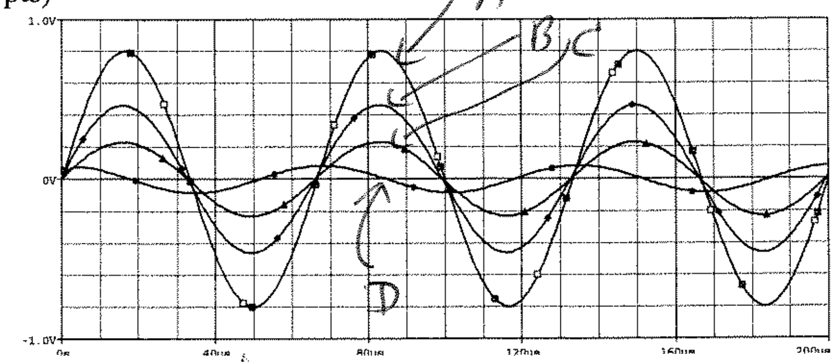
$P = (V_T)\left(\frac{V_T}{R}\right) = \frac{V_T^2}{R}$

$1 = \frac{V_T^2}{100} \quad V_T^2 = 100$

$V_T = 10v$



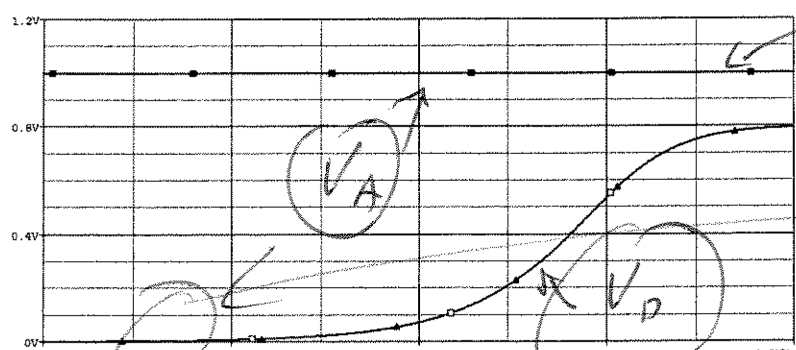
4a) The schematic shown above was simulated using Capture and PSpice. Voltage traces were plotted for nodes labeled A, B, C and D. These are shown below. Label the traces with the letters A, B, C and D to indicate which trace is for which node in the circuit. (4 pts)



4b) What type of analysis is shown in the plot above? Circle one of the following: (1 pt)

Time Domain (Transient) DC Sweep AC Sweep Bias Point

4c) Below is another possible output plot for the schematic at the top of the page. There are only two traces on this plot. Again label the traces with the appropriate letters: A, B, C or D. (2 pts)



4d) What type of analysis is shown in the plot for question 4c) ? Circle one of the following: (1 pt)

Time Domain (Transient) DC Sweep AC Sweep Bias Point