

ENGR4300
Fall 2005
Test 1A

Name:solution.....

Section_____

Question 1 (25 points)_____

Question 2 (20 points) _____

Question 3 (30 points)_____

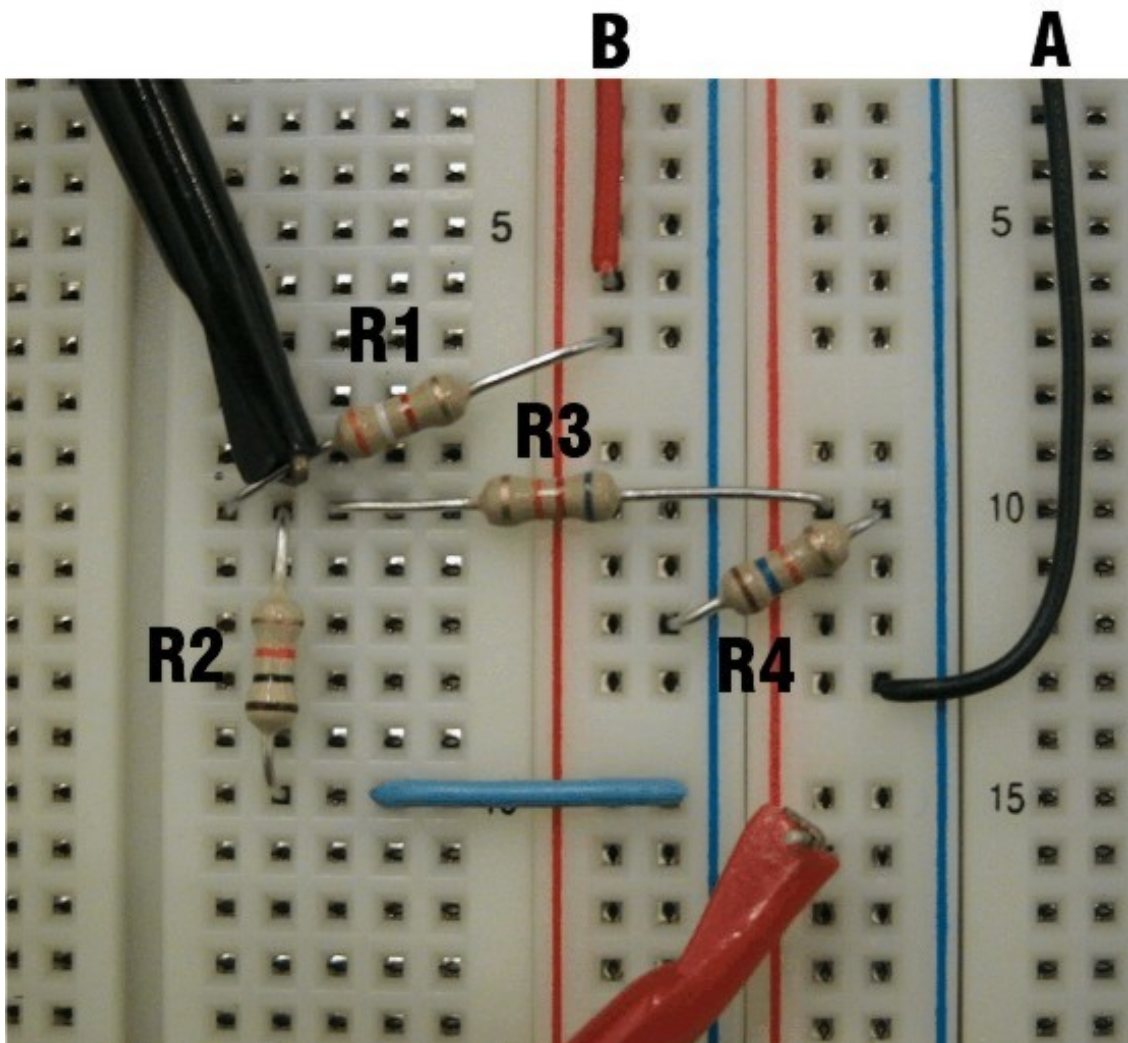
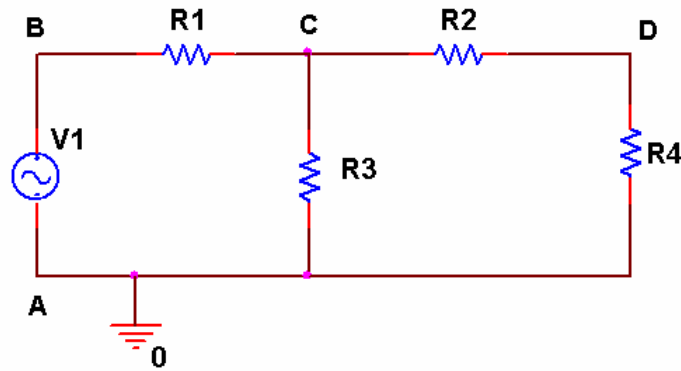
Question 4 (25 points)_____

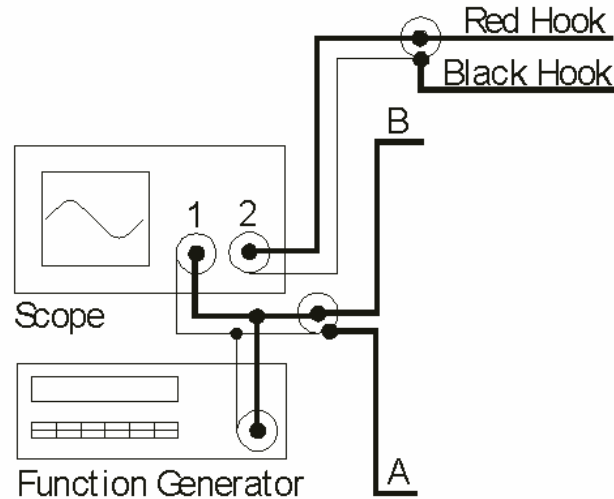
Total (100 points): _____

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

Question 1 – Resistive Circuits (25 points)

A student is given the following circuit schematic in electronics class. The student wires the circuit on his/her protoboard, hooks the circuit to the function generator, and attaches probes to measure the voltage at point C with scope channel 2. The function generator is also connected directly to scope channel 1 with a BNC “T”.





(a) The student has made three errors in wiring and connecting up the circuit. Can you find them? Also tell what you would do to correct the circuit. [Assume the signal coming in at points A and B cannot be moved.] (6 points)

R3 is not attached to ground (point A).

The red probe is not attached to anything, except the end of R3 which is floating.

The black probe must be attached to ground (point A) for the scope to function. It is not.

I would move one end of R3 from the red rail to the blue rail next to it and attach it to signal A (ground). I would place the black probe along that blue ground rail also by attaching it to the end of R3 or R4 that is connected to signal A (ground). I would move the red probe to the point where the black probe is currently located at point C (between R1, R2 and R3).

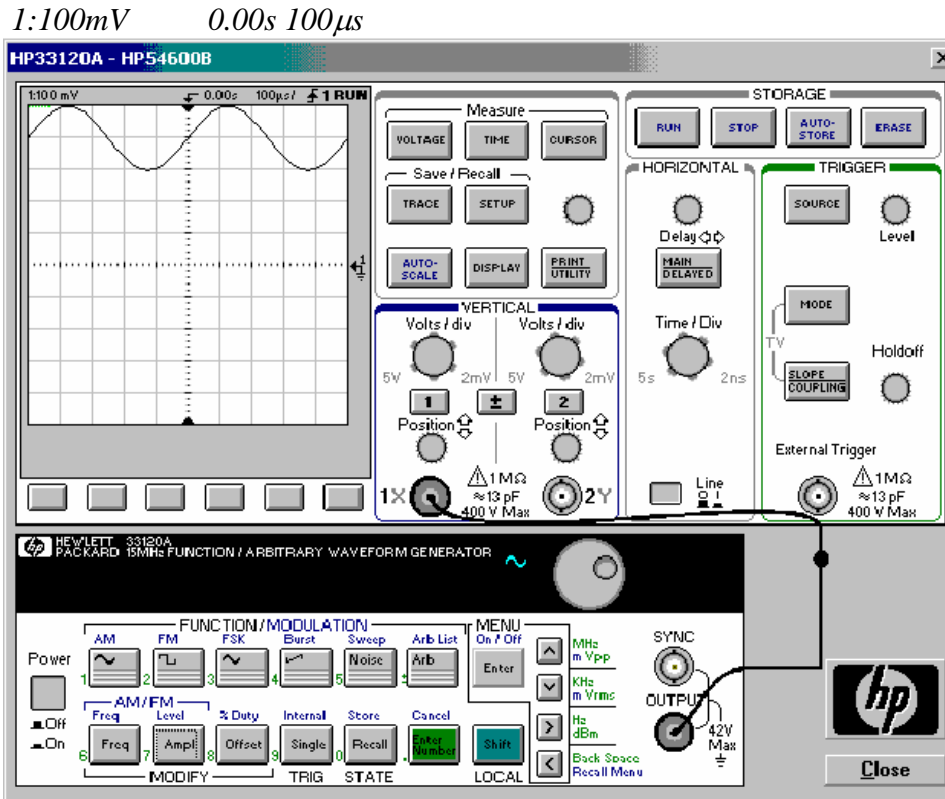
(b) The resistors have the following color codes. Write the corresponding values and tolerance to the right of each (2 points):

R1 = Orange White Red Gold = $3.9\text{kohm} \pm 5\%$ (or $3.9 \pm 0.195\text{ kohm}$)

R2 = Brown Black Orange Gold = $10\text{kohm} \pm 5\%$

R3 = Blue Red Orange Gold = $62\text{kohm} \pm 5\%$

R4 = Brown Blue Orange Gold = $16\text{kohm} \pm 5\%$



(c) The figure above shows the input signal as displayed on the scope. Given the signal above, write the expression for our input signal in the form:

_____ + _____ sin(_____ * t + _____)
 and give the units with *each* value above (4 points).

$f=1/500\mu = 2000 \quad \omega=2\pi(2000)=12566$
There is no phase because the scope triggers at 0.
 $400mV + 100mV \sin(12566 \text{ rad/sec} * t + 0 \text{ rad})$

(d) What is the frequency in Hz of the above signal? (2 points) _____

2k Hz.

(e) Given the values of the resistors you found in (b), and the signal from the scope you found in (c), and assuming you have fixed the wiring errors you found in the circuit, determine the *peak to peak voltage* of the output you are measuring with channel 2 of the scope. (4 points)

$$R_{24} = 10k + 16k = 26k \quad R_{234} = (62k * 26k) / (62k + 26k) = 18.3k$$

$$AMPL_c = (100mV)(18.3) / (18.3 + 3.9) = 82.4mV$$

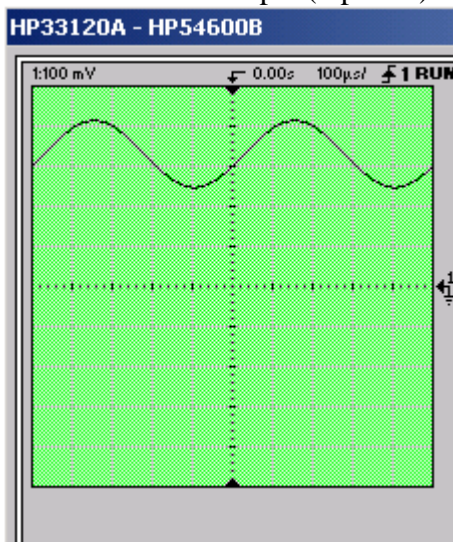
$$V_{p-p}(\text{at point C}) = 165 mV$$

(f) Now determine the *average voltage* of the output you are measuring with channel 2 of the scope. (2 points)

$$V_{ave} = 400mV(18.3) / (18.3 + 3.9)$$

$$V_{ave}(\text{at point C}) = 330mV$$

(g) On the scope display shown above, draw the voltage that would be measured on channel 2 of the scope. (3 points)



(g) Find the average current flowing in resistor R1 (2 points).

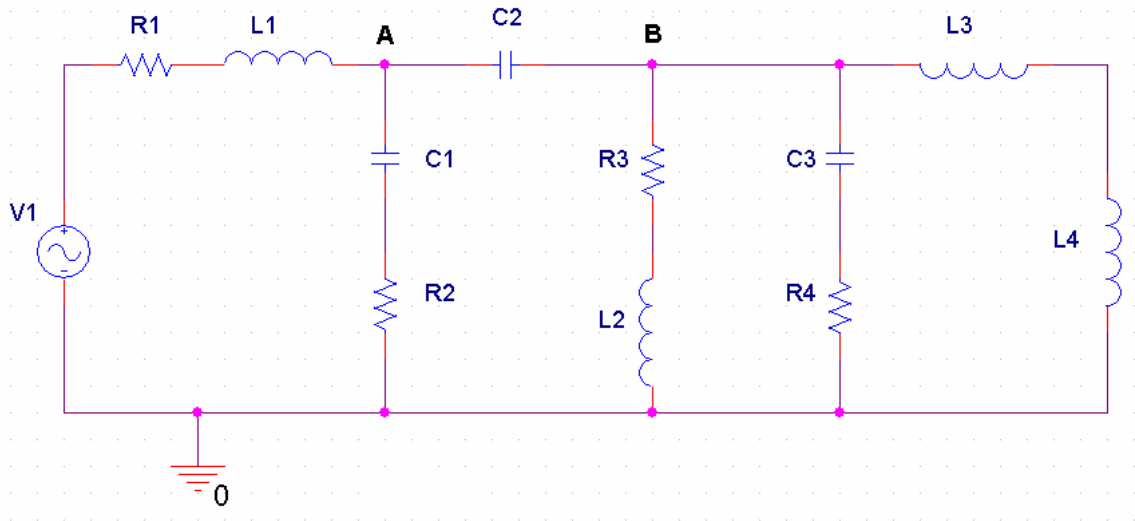
$$\text{current in } R1 \text{ is total current through circuit:}$$

$$I = (400m) / (3.9k + 18.3k) = 0.018 mA$$

$$I_{R1} = 18 \mu A$$

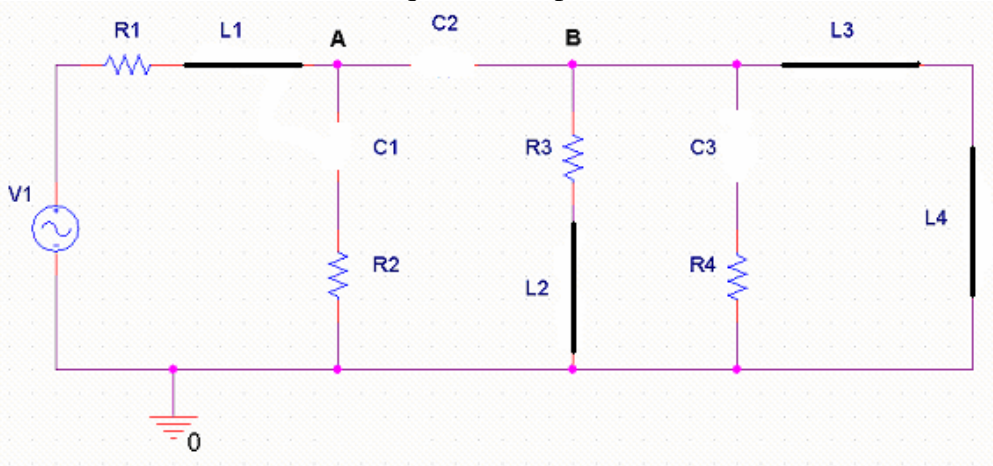
Question 2 – Filters (20 points)

You are given the following circuit. The input at V1 has the following properties:
 $V_{AMPL} = 500mV$, $FREQ = 1KHz$, $V_{OFF} = 0V$



A. The behavior of this circuit at low frequencies

1) Redraw the circuit at low frequencies (4 points)



2) What is the amplitude of the voltage at point A at low frequencies? (2 points)

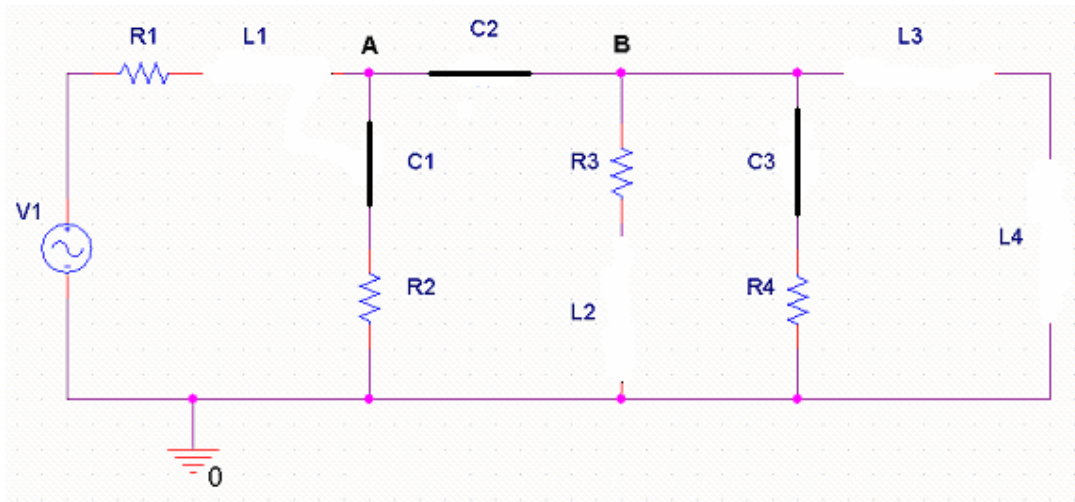
$$V_A = V_1 = 500mV$$

3) What is the amplitude of the voltage at point B at low frequencies? (2 points)

$$V_B = 0V$$

B. The behavior of the circuit at high frequencies

1) Redraw the circuit at high frequencies (4 points)



2) What is the amplitude of the voltage at point A at high frequencies? (2 points)

$$V_A = 0V$$

3) What is the amplitude of the voltage at point B at high frequencies? (2 points)

$$V_B = 0V$$

C. Is this a filter?

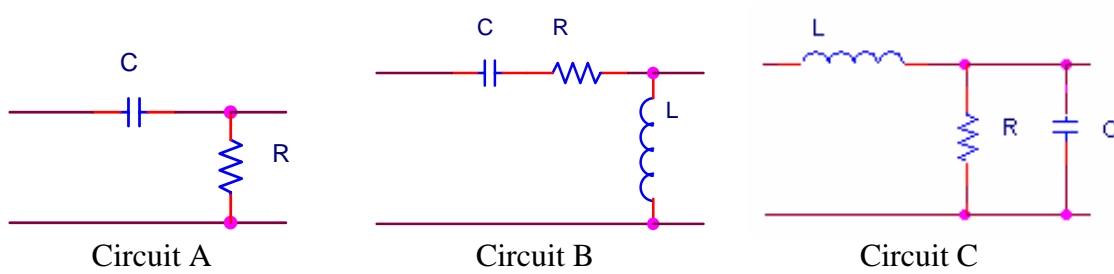
1) What type of filter could this be at point A (circle one)? (2 points)

- Low Pass*
 High Pass
 Neither

2) What type of filter could this be at point B (circle one)? (2 points)

- Low Pass
 High Pass
 Neither

Question 3 – Transfer Functions (30 points)



A. Transfer Functions

1) What is the transfer function for circuit A? You must simplify. (3 points)

$$H_A(j\omega) = \frac{R}{1/j\omega C + R} = \frac{j\omega RC}{1 + j\omega RC}$$

2) What is the transfer function for circuit B? You must simplify. (4 points)

$$H_B(j\omega) = \frac{j\omega L}{1/j\omega C + R + j\omega L} = \frac{-\omega^2 LC}{1 + j\omega RC - \omega^2 LC}$$

3) What is the transfer function for circuit C? You must simplify. (5 points)

$$H_C(j\omega) = \frac{\frac{R \times 1/j\omega C}{R + 1/j\omega C}}{j\omega L + \frac{R \times 1/j\omega C}{R + 1/j\omega C}} = \frac{\frac{R}{j\omega RC + 1}}{j\omega L + \frac{R}{j\omega RC + 1}} = \frac{R}{-\omega^2 RLC + j\omega L + R}$$

B. We want to determine what type of filter circuit B is

1) What are the simplified transfer function, the magnitude, and the phase of circuit B at low frequencies? (3 points)

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

$$|H_{\text{BLO}}| = -\omega^2 LC = 0$$

$$\angle H_{\text{BLO}} = -\pi \text{ or } +\pi \text{ radians}$$

2) What are the simplified transfer function, the magnitude, and the phase of circuit B at high frequencies? (3 points)

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

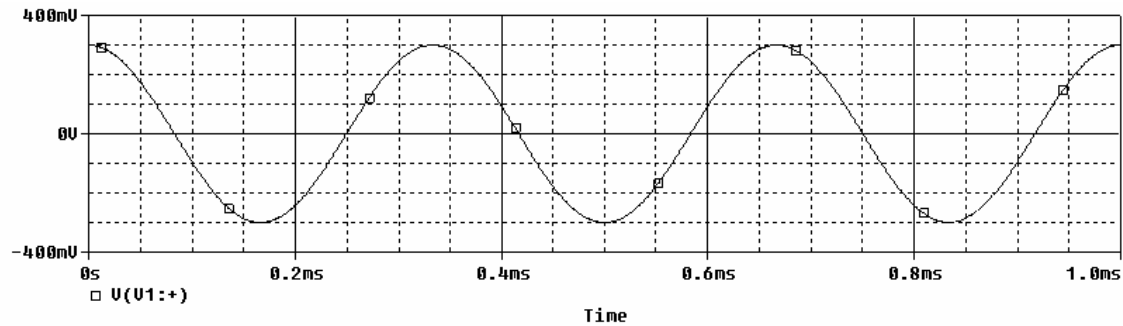
$$|H_{\text{BHI}}| = 1$$

$$\angle H_{\text{BHI}} = 0 \text{ radians}$$

3) What type of filter is circuit B? (1 point)

High Pass Filter

C. We want to know what the output of circuit A will look like for the input shown below



1) Write an equation in the form $V_{in}(t) = A_{in} \sin(\omega t + \phi_{in})$ which describes the input signal shown. (3 points)

$$V_{in}(t) = 300mV \sin(6K\pi t + \pi/2)$$

2) If $C=0.1\mu F$ and $R=1K$, what are the magnitude and phase of the transfer function of circuit A? (4 points)

$$|H_A| = 0.883$$

$$\begin{aligned} |H_A| &= \left| \frac{j\omega RC}{1 + j\omega RC} \right| = \left| \frac{j(6K\pi)(1K)(0.1\mu)}{1 + j(6K\pi)(1K)(0.1\mu)} \right| = \left| \frac{j(1.885)}{1 + j(1.885)} \right| = \\ &= \frac{1.885}{\sqrt{1 + (1.885)^2}} = \frac{1.885}{2.134} = 0.883 \end{aligned}$$

$$\angle H_A = 0.488 \text{ radians}$$

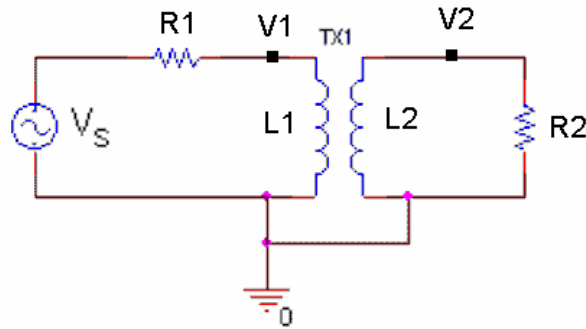
$$\angle(j(1.885)) - \angle(1 + j(1.885)) = \pi/2 - \tan^{-1}(1.885) = 1.571 - 1.083 = 0.488$$

3) What are the amplitude and phase of the output of circuit A, when the input signal from part C-1 is applied to the circuit? (4 points)

$$A_{out} = 300mV * (0.883) = 265mV$$

$$\phi_{out} = 1.571 + 0.488 = 2.059 \text{ radians}$$

Question 4 – Transformers and Inductors (25 points)



In the transformer circuit above, $R_1 = 500$ ohms, $R_2 = 10K$ ohms, and the turns ratio of the transformer is 1:4. Assume the transformer has perfect coupling. [Hint: You cannot assume that R_1 is much smaller than R_2 .]

1) What is the input impedance of the transformer? (2 points)

$$Z_{in} = R_2/a^2 = 10K/16 = 625 \text{ ohms}$$

2) Find an expression for the voltage at point V1 in terms of the input voltage, V_s . (3 points)

$$V_1 = V_s [625/(500+625)] = 0.555 V_s$$

3) Find an expression for the voltage across the load resistor, R_2 , in terms of the input voltage, V_s . (2 points)

$$V_2/V_1 = 4 \quad V_2 = 4*0.555*V_s = 2.22 V_s$$

4) What is the current through R_2 when the input voltage at V_s is 3V? (3 points)

$$I_2 = V_2/R_2 = (2.22)(3)/10K = 0.666mA$$

- 5) Find the inductance of L1, given that it has the following properties: (3 points)
- property 1: Number of turns = 50
 - property 2: Length of coil = 5cm = 0.05 m
 - property 3: Wire Gauge = 26 (wire diameter = 0.40 mm)
 - property 4: Core material = iron (permeability = $6.28\text{EE-}3$ H/m)
 - property 5: Core diameter = 0.75 cm (radius = $3.75\text{EE-}3$ m)

This is a long, thin coil. Therefore,

$$L1 = \frac{(6.28\text{EE-}3)(50)^2 \pi (3.75\text{EE-}3)^2}{(0.05)} = \frac{6.936\text{EE-}4}{0.05} = \mathbf{13.8\text{ mH}}$$

- 6) In order for the transformer to function as predicted by the transformer ratio equations, L2 must share certain properties with L1. Which three of the five properties listed above must remain the same if the two inductors are to function as an ideal transformer? [Hint: Use the equation you used to find the inductance of L1.] (3 points)

In order for the ratio $\frac{N2}{N1} = \sqrt{\frac{L2}{L1}}$ to hold, the two inductors must have the same (or similar) coil lengths (property 2), core material or permeability (property 4) and core diameter (property 5). The number of turns determines the performance of the transformer, so obviously that must be different. Since this is a long, thin, coil. The wire gauge does not enter into the equation, so it is not as important as the other three.

- 7) Assuming L2 has properties similar to L1 as discussed in question 5, what must be the inductance of L2? How many turns must it have? (3 points)

$$4 = \sqrt{\frac{L2}{L1}} \quad 16 = \frac{L2}{L1} \quad L2 = 16(L1) = 16(13.8\text{m}) = \mathbf{220.8\text{ mH}}$$

The coil must have $50(4)=200$ turns.

7) Assuming the voltage at point Vs is shown on the plot below, sketch and label the voltage at V1 and at V2. (6 points)

