# ENGR4300
# Spring 2006
# Test 1B&A

**Name________solution__________**

**Section_________________________**

Question 1 (25 points)___________

Question 2 (15 points) ___________

Question 3 (20 points)___________

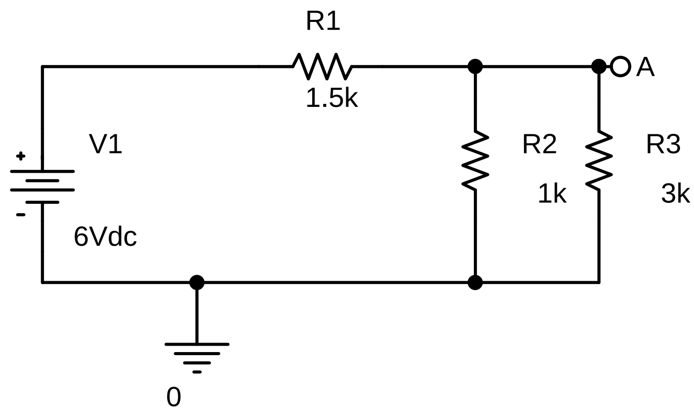
Question 4 (20 points)___________

Question 5 (20 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) (Test B)**




Part 1: Voltages and currents.

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

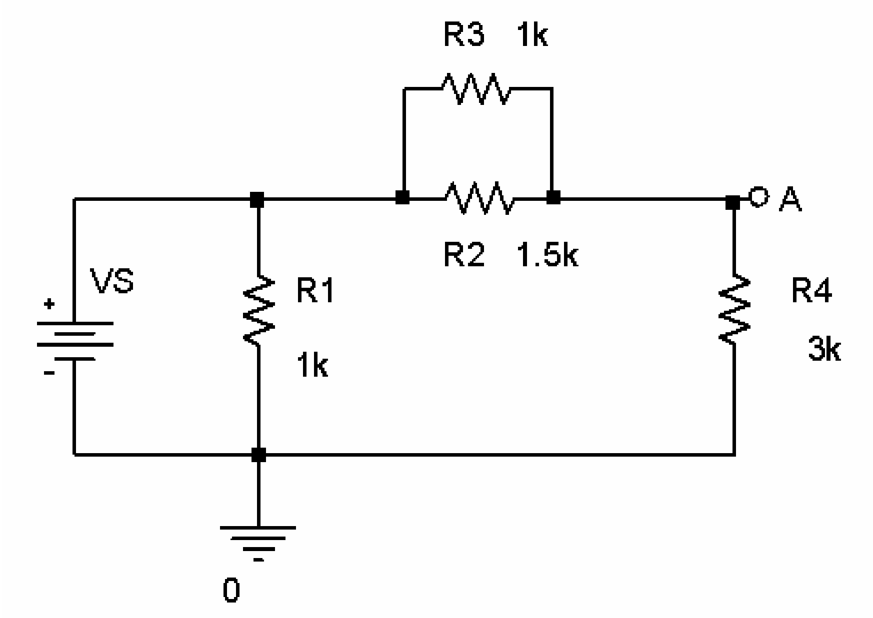
*R23 = (1k*3k)/(1k+3k) = 0.75kΩ VA = 6V(0.75k)/(0.75k+1.5k) = 2V*

$V_A = 2V$

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

*VR2 = VA = 2V IR2=2V/1K = 2mA*

$I_{R2}$ = ***2mA***




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

*R23=1k*1.5k/(1k+1.5k)=0.6k*
*R234=0.6k+3k=3.6k*
*Rt=1k*3.6k/(1k+3.6k)=0.782k*
***Rtotal = 782Ω***

2b) If VS=5V, what is the current out of this source? (2 points)

*I = 5V/782Ω = 6.4mA* ***I=6.4mA***

2c) If VS=5V, what is the voltage at point A in this circuit? (3 points)

*VA = 5(3k)/(0.6k+3k) = 4.17V* ***VA=4.167V***

2d) If VS=5V, what is the current through R2? (3 points)

*VR2 = 5V-4.167V = 0.833V IR2 = 0.833/1.5k = 0.56mA* ***IR2=0.56mA***

Question 1, Part 3: color code

3a) Resistors are found to have the color bands listed below. For each state the resistance. (4 points)

Yellow-Violet-Orange ***47k Ω***__________________________________

Brown-Red-Brown ***120 Ω***__________________________________

3b) Extra credit: If a resistor has color bands of Yellow-Violet-Yellow-Silver, what is the significance of the Silver band? (1 point)

*xtra: +/- 10% tolerance*

**<u>Answers to Test A</u>**

1a) *R12 = (2k*6k)/(2k+6k) = 1.5kΩ VA = 9V(3k)/(1.5k+3k) = 6V*
***VA = 6V***

1b) *VR2 = 9V-6V=3V IR2=3V/6K = 0.5mA* ***IR2 = 0.5mA***

2a) *R34=6k*18k/(6k+18k)=4.5k R234=6k+4.5k=10.5k Rt=21k*10.5k/(21k+10.5k)=7k*
***Rtotal = 7kΩ***

2b) *I = 10V/7kΩ = 1.43mA* ***I=1.4mA***

2c) *VA = 10(4.5k)/(4.5k+6k) = 4.28V* ***VA=4.3V***

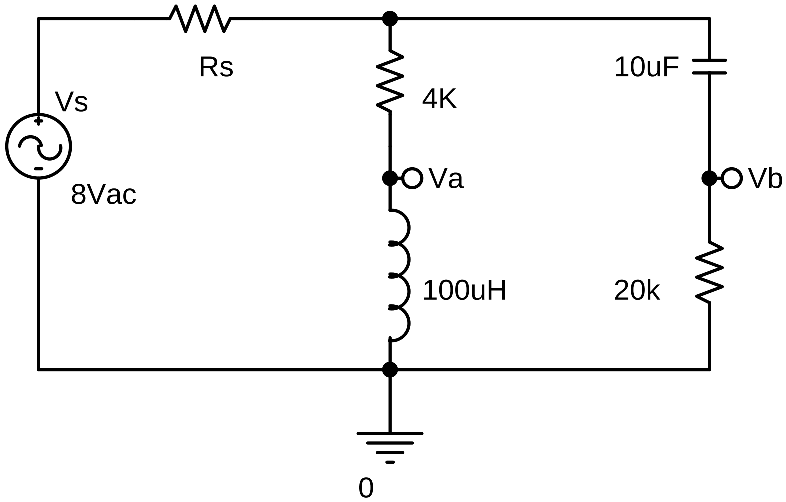
2d) *IR2 = 4.28/18k = 0.238mA* ***IR2=0.24mA***

3a) *22k Ω*

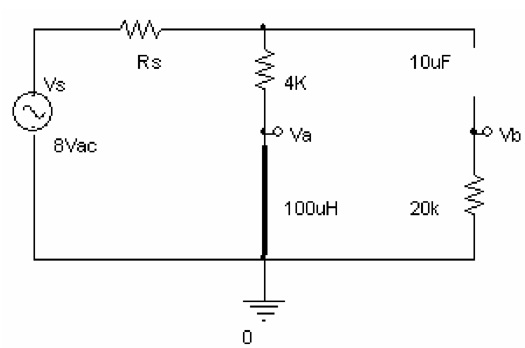
3b) *100 Ω*

*xtra: +/- 10% tolerance*

**Question 2 – Filters (15 points) (Test B)**



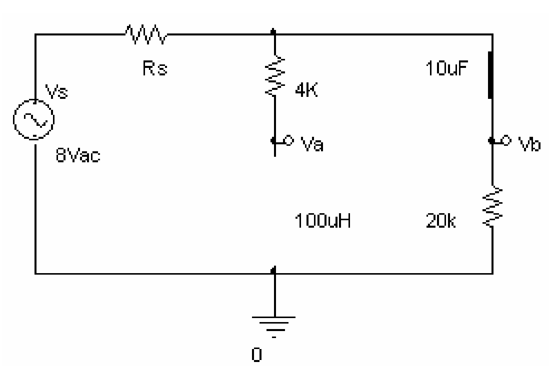

Part 1: Filters, Using Rs=0Ω
1a) Let Rs=0Ω  Redraw the circuit above for very low frequencies. Label points Va and Vb on your diagram. (3 points)




1b) Let Rs=0Ω  What is Va at very low frequencies? (2 points)

***Va = 0V***

1c) Let Rs=0Ω  Redraw the circuit above for very high frequencies. Label points Va and Vb on your diagram. (3 points)



1d) Let Rs=0Ω What is Va at very high frequencies? (2 points)

*Since Rs=0Ω,* ***Va=8V***

1e) Let Rs=0Ω If Va is considered the output, what type of filter is this? (1 point)

***High Pass Filter***

Part 2: Filters using Rs= 10kΩ
2a) Let Rs=10kΩ Referring to your picture in part 1a, what is Vb at very low frequencies? (2 points)

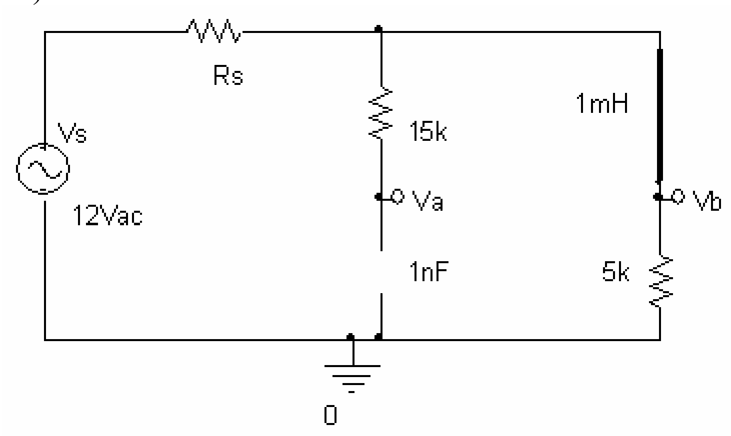
***Vb = 0V***

2b) Let Rs=10kΩ Referring to your picture in part 1c, what is Vb at very high frequencies? (2 points)

*Vb = 8(20k)/(10k+20k) = 5.33V* ***Vb=5.33V***

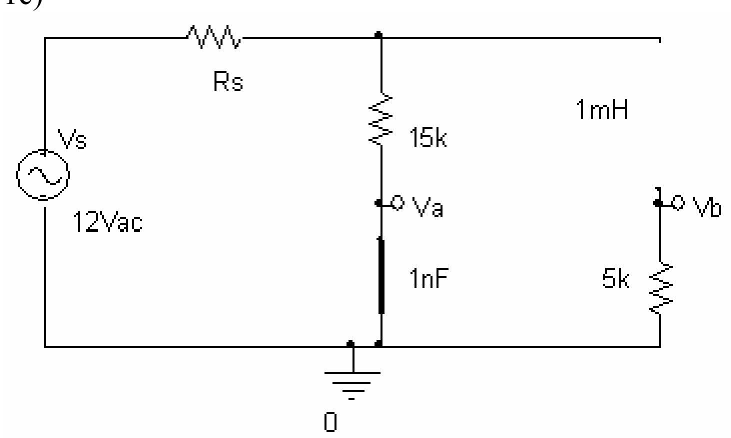
**Answers to Test A**

1a)




1b) ***Va = 12V***

1c)




1d) ***Va=0V***

1e) ***low pass filter***

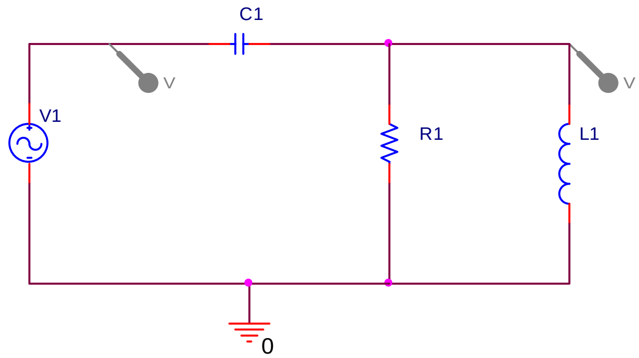
*1f) f=1/(2πRC) = 1/(2*π*15k*1n) = 10.6k Hz*

*2a) same as 1a*

2b) *Vb = 12(5k)/(10k+5k) = 4V* ***Vb=4V***

*2c)Vb=0V*

**Question 3 – Transfer Functions (20 points) (Test B)**




Part 1: Transfer Functions

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

$$Z_{out} = \frac{j\omega L1 \cdot R1}{j\omega L1 + R1} \quad H(j\omega) = \frac{Z_{out}}{Z_{in}} = \frac{\dfrac{j\omega L1 \cdot R1}{j\omega L1 + R1}}{\dfrac{1}{j\omega C1} + \dfrac{j\omega L1 \cdot R1}{j\omega L1 + R1}}$$

$$H(j\omega) = \frac{(j\omega R1L1)(j\omega C1)}{(j\omega L1 + R1) + (j\omega R1L1)(j\omega C1)}$$

$$H(j\omega) = \frac{-\omega^2 R1L1C1}{j\omega L1 + R1 - \omega^2 R1L1C1}$$

1b) What are the simplified transfer function, the magnitude, and the phase of the circuit at low frequencies? (4 points)

$$H_{LO}(j\omega) = \frac{-\omega^2 R1L1C1}{R1} = -\omega^2 L1C1$$

$$|H_{LO}| = 0 \quad \angle H_{LO} = \pi$$

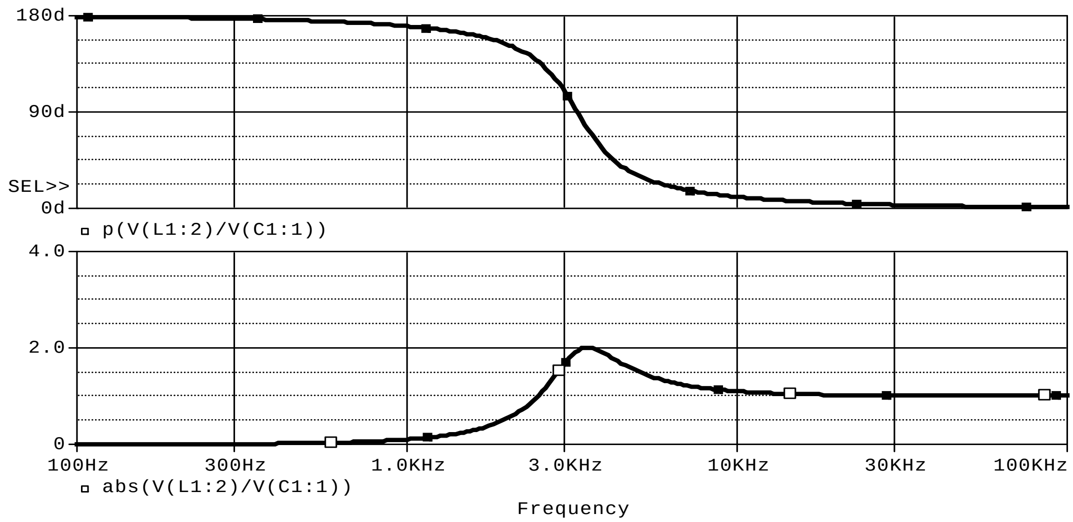
*(We know phase is positive because of the graph.)*

1c) What are the simplified transfer function, the magnitude, and the phase of the circuit at high frequencies? (4 points)

$$H_{HI}(j\omega) = \frac{-\omega^2 R1L1C1}{-\omega^2 R1L1C1} = 1$$

$$|H_{HI}| = 1 \quad \angle H_{HI} = 0$$

Part 2: The phase and magnitude of the transfer function for this circuit are pictured below:




2a) Use the graph to determine the resonant frequency of the circuit (in Hertz). Show your work. (2 points)

*from plot:* $f = 10^{3.55} = 3550Hz$

*(Answers will vary. Student must use log scale to get reasonable answer for credit.)*

2b) If the following input signal is applied to the circuit, what will be the amplitude and phase (in radians) of the output signal? [Please include all units.] (4 points)

$$v_{in}(t) = A_{in}\sin(\omega t + \phi_{in}) = 500mV\sin(18850t + 2.09\ rad)$$

*$\omega$ = 18850 rad/sec f=3000Hz*

*from plot of |H|: |H| at 3000Hz is 1.7*

*Aout = Ain×(1.7)=(500mV)(1.7) = 850mV*

*from plot of $\angle$H: $\angle$H at 3000Hz = 110 degrees = 1.92 rad*

*$\phi$out = $\phi$in + 1.92 = 2.09 + 1.92 = 4.01 rad or -2.27 rad (both ok)*

*(Answers will vary depending upon value read from plot.)*

***$A_{out}$ = 850mV*** ***$\phi_{out}$ = -2.27 rad***

**<u>Question 1A Answers</u>**

1a) $Z_{out} = \frac{j\omega L1 \cdot R1}{j\omega L1 + R1}$ $H(j\omega) = \frac{Z_{out}}{Z_{in}} = \frac{\frac{j\omega L1 \cdot R1}{j\omega L1 + R1}}{\frac{1}{j\omega C1} + \frac{j\omega L1 \cdot R1}{j\omega L1 + R1}} = \frac{(j\omega R1L1)(j\omega C1)}{(j\omega L1 + R1) + (j\omega R1L1)(j\omega C1)}$

$$H(j\omega) = \frac{-\omega^2 R1L1C1}{j\omega L1 + R1 - \omega^2 R1L1C1}$$

1b) $H_{LO}(j\omega) = \frac{-\omega^2 R1L1C1}{R1} = -\omega^2 L1C1$ *(We know it is positive because of the graph.)*

$|H_{LO}| = 0 \quad \angle H_{LO} = \pi$

1c): $H_{HI}(j\omega) = \frac{-\omega^2 R1L1C1}{-\omega^2 R1L1C1} = 1$

$|H_{HI}| = 1 \quad \angle H_{HI} = 0$

2b) *from plot:* $f = 10^{3.33} = 2140Hz$

*(Answers will vary. Student must use log scale to get reasonable answer for credit.)*

2c) *$\omega$ = 18850 rad/sec f=3000Hz*

*from plot of |H|: |H| at 3000Hz is 1.4*

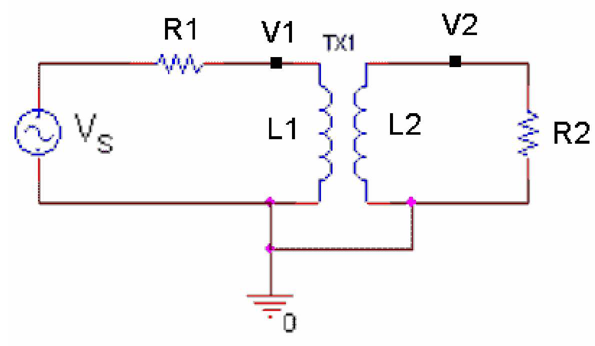
*Aout = Ain×(1.4)=(200mV)(1.4) = 280mV*

*from plot of ∠H: ∠H at 3000Hz = 33 degrees = 0.576 rad*

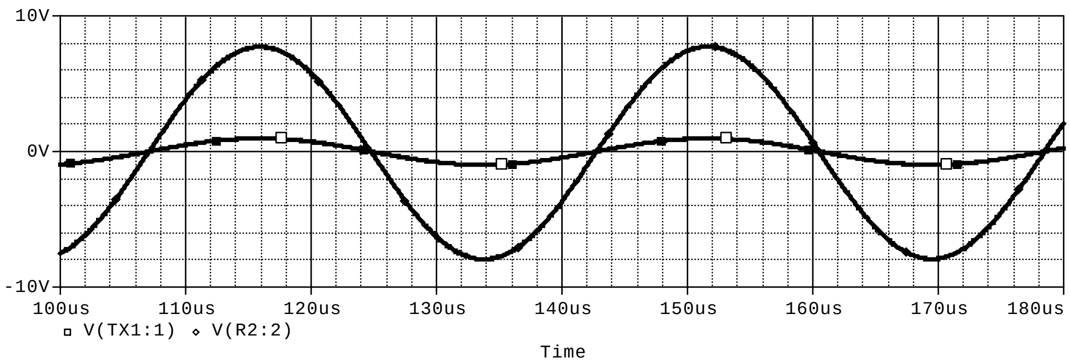
*$\phi$out = $\phi$in + .576 = 1.05 + 0.576 = 1.63 rad*

*(Answers will vary depending upon value read from plot.)*

## Question 4 – Transformers and Inductors (20 points)




You are given the above transformer. You can assume the transformer is ideal, the coupling coefficient is 1, and the resistance of R1 is negligible compared to the resistance of R2. The plot below shows the input to the transformer at V1 and the output at V2. The output is the signal with the larger amplitude.




1) Give the values of the following for the input signal (smaller amplitude) shown. Give units for each. (7 points)

Amplitude (A): ***1V***

Frequency (f): *f=1/(143us-107us)*
***f=27.8K Hz***

Angular frequency ($\omega$):
***$\omega$=2$\pi$f=175K rad/sec***

Phase ($\phi$) relative to 100us:
***$\phi = -\omega t_0$ = -(175k)(7$\mu$)= -1.22 rad***

rms voltage ($V_{rms}$):
*Vrms = 1/sqrt(2) =* ***0.707 V***

peak to peak voltage ($V_{p-p}$):
***Vp-p = 2V***

DC offset voltage ($V_{DC}$):
***$V_{DC}$ = 0V***

*(These answers will vary depending upon the numbers they get form the plot..)*

2) What is the most likely turns ratio of the transformer? (Express your answer as a whole number of turns.) (2 points)

*Turns ratio = 1V:8V =**1:8** (a=8)*

3) If the primary inductor, L1, has an inductance of 1mH, what must the inductance of the secondary inductor, L2, be? (2 points)

$$a = \sqrt{\frac{L2}{L1}} \quad 8 = \sqrt{\frac{x}{1m}} \quad L2 = 64mH$$

4) If the impedance of the input inductor L1 is 250Ω, what is the value of R2? (3 points)

$$Z_{in} = \frac{R2}{a^2} \quad 250 = \frac{R2}{8^2} \quad R2 = 16k\,\Omega$$

5) Write an expression in the form, $i(t) = I_{max}\sin(\omega t + \phi)$, that represents the current through the load resistor, R2, as a function of time. [Assume again that the phase is defined relative to 100us.] (3 points)

*$i(t) = I_{max}\sin(\omega t + \phi)$  V=IR  8V = I*(16K)  I=0.5mA  $\omega$=175K rad/s  $\phi$ = -1.22 rad*

***i(t) = 0.5mA sin(175K t – 1.22 rad)***

*( These answers will vary. If they substitute $\phi$, $\omega$, and the amplitude of the voltage correctly from part 1), then this is correct.)*

6) Assume the inductor, L1, is a long, thin coil with a length of 8.5 cm and 38 turns. If the radius of the transformer core is 0.5 cm, what material is the core most likely made of? [Assume there is no mutual inductance.] (3 points)

Some values for μ

- Air 1.257x10-6 H/m
- Ferrite U M33 9.42x10-4 H/m
- Nickel 7.54x10-4 H/m
- Iron 6.28x10-3 H/m
- Ferrite T38 1.26x10-2 H/m
- Silicon GO steel 5.03x10-2 H/m
- supermalloy 1.26 H/m

$$L = \frac{\mu N^2 \pi r_c^2}{d} \quad 1m = \frac{\mu (38)^2 \pi (0.005)^2}{(0.085)}$$

*$\mu$ =7.49EE-4H/m* ***Material = nickel***

**Answers for 4A:**

1) *A=1V f=1/((166-111)us) f=18.2K Hz*
*$\omega$=2$\pi$f=114K rad/sec $\phi$ = -$\omega t_0$ = -(114k)(11$\mu$)= -1.25 rad*
*Vrms = 1/sqrt(2) = 0.707 V Vp-p = 2V $V_{DC}$ = 0V*
*(These answers will vary, they should make sense based on values taken from the plot.)*

2) *Turns ratio = 1V:5V =1:5 (a=5)*

3) $a = \sqrt{\frac{L2}{L1}} \quad 5 = \sqrt{\frac{x}{1m}} \quad L2 = 25mH$

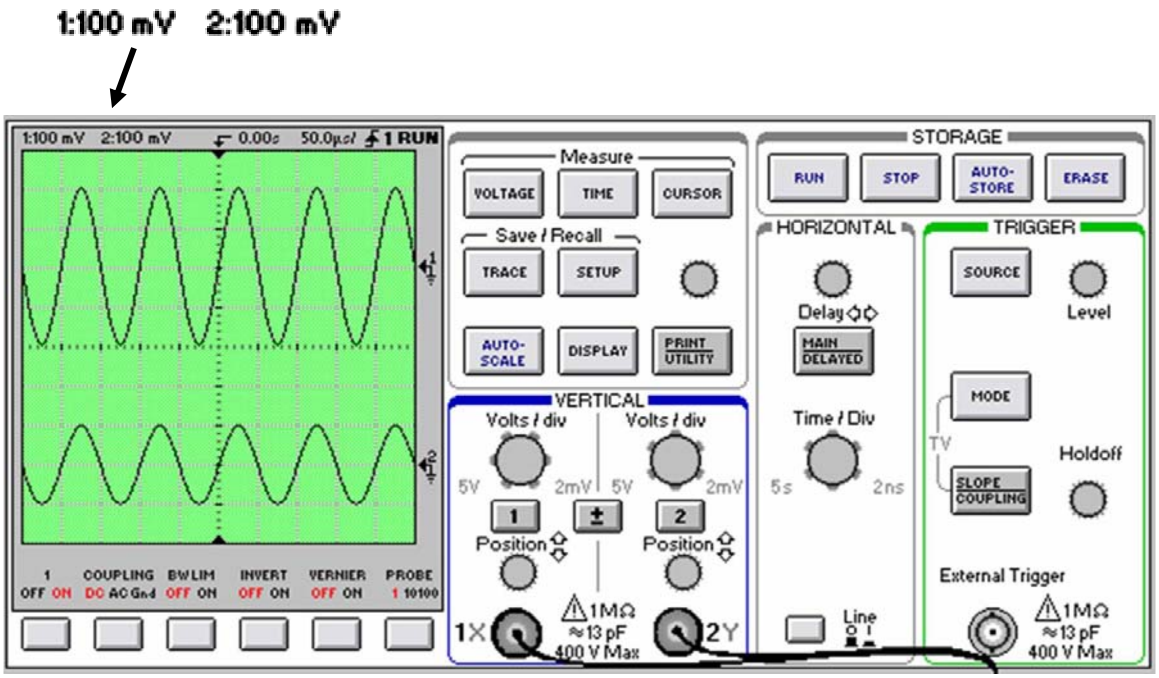
4) $Z_{in} = \frac{R2}{a^2} \quad 160 = \frac{R2}{5^2} \quad R2 = 4k\Omega$

5) *i(t) = $I_{max}$ sin($\omega$t + $\phi$) V=IR 5V = I*(4K) I=1.25mA $\omega$=114K $\phi$=-1.25 rad*
*i(t) = 1.25mA sin(114K t – 1.25 rad)*
*( These answers will vary. If they substitute $\phi$, $\omega$, and the amplitude of the voltage correctly from part 1), then this is correct.)*

6) $L = \frac{\mu N^2 \pi r_c^2}{d} \quad 1m = \frac{\mu (14)^2 \pi (0.004)^2}{(0.062)}$ *$\mu$ = 6.29EE-3H/m Material = iron*

**Question 5 – PSpice, Instrumentation and Components (20 points) Quiz B**

Part A: Given the scope setup shown below (w/ Channel 1 at 100mV/division, Channel 2 at 100mV/division and the timebase at 50μsec/div):




a) What are the peak-peak amplitudes and the frequency of the two signals shown (5 points)?

$V_{p-p}$ of the top signal (channel 1): *400mV*

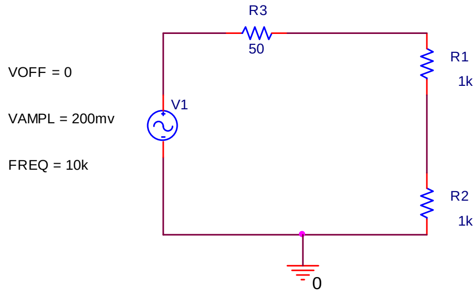
$V_{p-p}$ of the bottom signal (channel 2): *200mV*

Frequency: *Freq = 1/100μs=10k Hz*

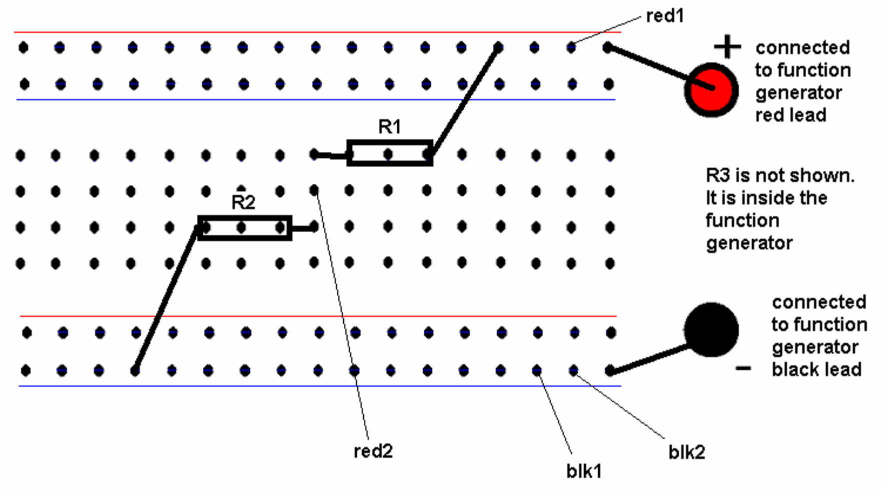
DC offset of top signal (channel 1): *0V*

DC offset of bottom signal (channel 2): *0V*

b) The two scope traces were produced using a function generator and a circuit built with up to four 1K ohm resistors. Draw a schematic for a circuit that would produce the input (ch1) and output (ch2) signals shown on the previous page. You can use all or some of the resistors. The schematic must include the function generator impedance, but you do not need to show the scope connections. (3 points)




c) Show how you would wire the circuit in part b on the protoboard below. Assume the function generator has already been connected to the board using banana plugs. (2 points)




d) On the figure above, indicate the location you would place the scope probes to get the signals shown in the scope picture for part A. Name the leads as follows: red1 (red probe channel 1), blk1 (black probe channel 1), red2 (red probe channel 2), and blk2 (black probe channel 2). (2 points)

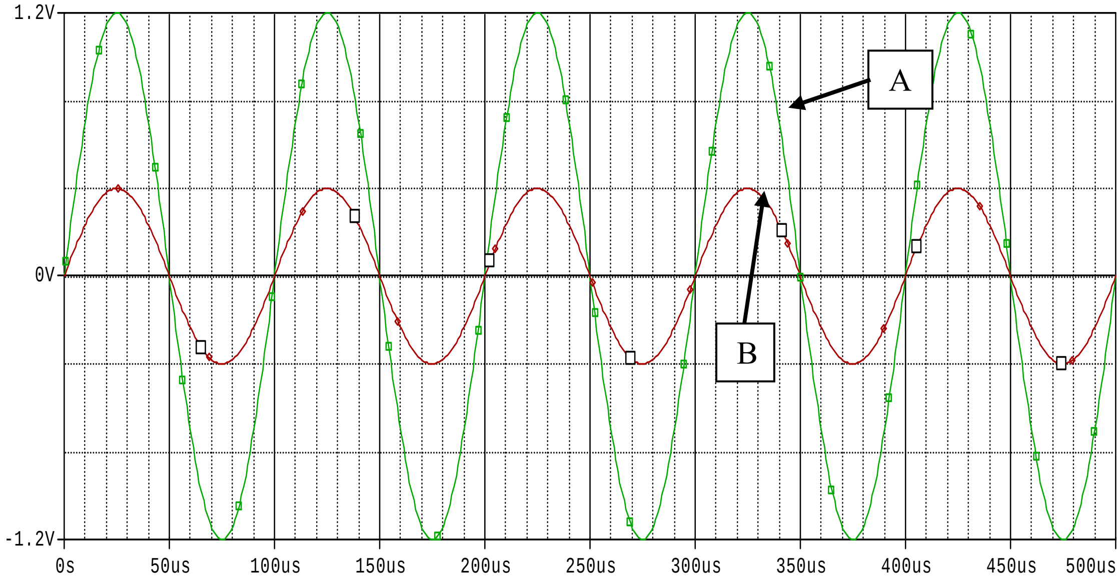
e) In the circuit you created, is the impedance of the function generator (in comparison to the value of the resistors) a significant influence on the circuit? Why or why not? (2 points)

*The impedance of the function generator is of relatively little significance. It is on the order of two orders of magnitude less than the resistors, which means that they have around 100 times more influence on the circuit. If I make a voltage divider it becomes clearer:*

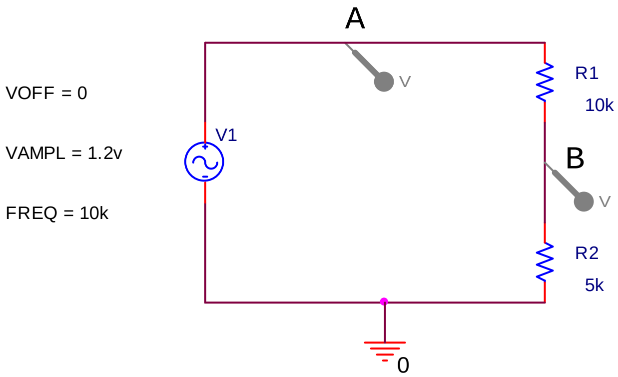
*With function generator: Vout = Vin(1k)/(1k+1k+50) = 0.49Vin*

*Without function generator: Vout = (1k)/(1k+1k) = 0.50 Vin*

Part B: You have created a circuit in PSpice to produce the following output.




a) Here is the circuit you used to create the signals. Fill in the boxes with the missing information. (4 points)



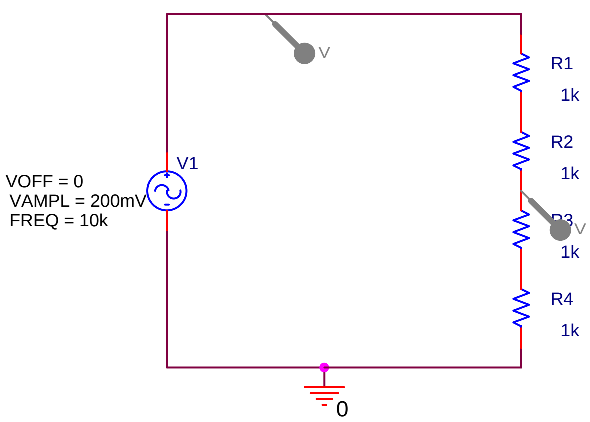

b) Indicate on the schematic above where you would place the voltage probes to produce signal A and signal B. Indicate which is which. (Do not use differential probes.) (2 points)

**5. Instrumentation and PSpice Quiz A (different sections)**

a) same as B

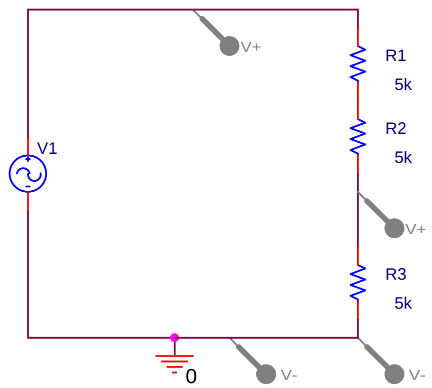
b) If the above scope traces were produced using a function generator and four 1K resistors, describe how you would use PSpice to simulate the circuit and produce an output that is similar to the scope display shown in (a).

*First I would open a new project in PSpice. I would use the "Place Part" button to add four resistors(R) in series and a sine wave source(VSIN). I would use the" place ground" button to add a ground (0). I would set the value of the resistors to 1k. I would set the source to VOFF=0, VAMPL=200mV, and FREQ=10k. Then I would put on wires using the "place wire" button to create the circuit shown below. I would place two voltage probes on the circuit (one to read the voltage from the source and the other to read the center of the two pairs of resistors), as shown. Then I would set up a transient analysis to run from 0 (start time) to 500us (run to time) in increments of 500ns (max step size). This would show 5 cycles of the wave just like the picture. (Note that this is not the only correct circuit.)*




c) Given a packet of 5K resistors, a function generator and a scope – describe how you would create a circuit that would produce the following signals. Please include the corresponding circuit diagram/schematic in your response.

*I would take my protoboard and wire three 5K resistors in series. I would attach the red lead of the function generator to one end of the three resistor series and the black lead to the other end. I would attach the red lead of channel 1 (signal A) to the same location as the red lead from the function generator. I would attach the red lead from channel 2 (signal B) of the scope between the second and third resistor (see diagram). I would attach the black lead of channel 1 and 2 from the scope to the same location as the black lead of the function generator. Then I would set the frequency of the function generator to 10k Hz and the peak-to-peak voltage to 1.2v (1/2 of desired). I would set the volts per div knob on both scope channels to 500mV (this will give me a good view of the 1.2 volt amplitude) and the time/div knob to 50us.*




d) Given the following PSpice circuit and corresponding simulation display, please identify which traces belong to the probes that are shown in the circuit schematic: