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## 1) Resistive Circuits ( 25 points)

Part A Two series connected D-cell batteries power three loads over an extension cable 1000 ' long. The cable is made using 24AWG (American Wire Gauge) wire that has a resistance of $27.3 \Omega / 1000^{\prime}$. The figure below shows this resistance as $\mathrm{R} 1=27.3 \Omega$ \& $\mathrm{R} 2=27.3 \Omega$. Loads $\mathrm{R} 3=1 \mathrm{k} \Omega, \mathrm{R} 4=800 \Omega, \mathrm{R} 5=400 \Omega$ and are configured as shown in the circuit below. All calculations should be carried to three decimal places.

$\mathrm{R} 1=27.3 \Omega \mathrm{R} 2=27.3 \Omega \mathrm{R} 3=1 \mathrm{~K} \Omega \mathrm{R} 4=800 \Omega \mathrm{R} 5=400 \Omega$
a) What is the total resistance seen by the batteries? (6 points):
b) Find the current that will be drawn from the batteries (2 points):
c) Assuming all resistors are exactly their stated value, find the voltage drop across R3 and R5. (6 points):

R3:

R5:

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d) If the last color band on all resistors is red ( $+/-2 \%$ ), what are the minimum and maximum currents R3, R4 and R5 together should draw from the batteries? (3 points):

Part B Now suppose our D-cell batteries are replaced by an ideal function generator (no 50 ohm internal impedance to worry about):

$\mathrm{V} 1: \mathrm{VOFF}=3 \mathrm{~V}$ VAMPL $=5 \mathrm{~V}$ FREQ $=1 \mathrm{KHz}$ $\mathrm{R} 1=27.3 \Omega \mathrm{R} 2=27.3 \Omega \mathrm{R} 3=1 \mathrm{~K} \Omega \mathrm{R} 4=800 \Omega \mathrm{R} 5=400 \Omega$
a) What is the maximum voltage at Vfg referenced to ground (1 point)?
b) What is the minimum voltage at Vfg referenced to ground (1 point)?
c) What is the average voltage at Vfg referenced to ground (1 point)?

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d) On the graph below, using pencil if you have one, sketch and label the voltage at Vfg. Start the drawing with Vfg = Vavg at time zero ( 5 points).


Extra Credit: On the same graph, sketch and label the voltage drop across R5 assuming the waveform drawn in (d) as the input signal. Show all calculations required below (1 extra point).

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2) Filters ( 25 points)

Part A: You want to determine what type of filter the following circuit is.

a) Redraw the circuit at very low frequencies. (2 points)
b) Redraw the circuit at very high frequencies. (2 points)
c) What is the value of Vout at very low frequencies? (1 point)
d) What is the value of Vout at very high frequencies? (1 point)
e) What type of filter is this? (1 point)

Part B: You wire the circuit in Part A of this question on your protoboard with real components.
a) Your capacitor, C, has " 683 " written on it. What is its rated value in microfarads? (2 points)
b) Your resistor, R, has an orange band, a black band, a red band, and a gold band (5\% tolerance) in that order. What is the rated value of the resistor? (2 points)
c) Your inductor, $L$, is long and thin. It has 300 turns, a core diameter of 0.5 cm , a coil length of 5 cm , a wire gauge of 26 (diameter $=0.4 \mathrm{~mm}$ ). It is wound around an air core ( $\mu=4 \pi \times 10^{-7} \mathrm{H} / \mathrm{m}$ ). Calculate an estimate for the inductance. (4 points)

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d) Based on the values of the components, give an estimate for the resonant frequency of the circuit in Hertz. (3 points)
e) If input a signal, $v(t)=2 V \sin (2 \pi \mathrm{Kt})$, is applied at the input to your circuit, will your output amplitude be less than, greater than, or about equal to the input amplitude? Explain why. (3 points)
f) You connect your circuit to a source and find that the actual resonance occurs at $f_{0}$ hertz. Assuming you now have measured values for $\mathrm{C}, \mathrm{R}$, and the resistance of the inductor, describe how you could use PSpice to get a closer estimate (than that found in part c) for the inductance of your inductor. Be specific. (4 points)
3) Transfer Functions and Phasors (25 points)

a) Find the transfer function for the above circuit. (2 points)

$$
H(\mathrm{j} \omega)=
$$

b) Find the function to describe the behavior of the circuit at very low frequencies. Also determine the magnitude and phase of this circuit at very low frequencies. (3 points)

$$
\mathrm{H}_{\mathrm{LO}}(\mathrm{j} \omega)=
$$

$$
\left|\mathrm{H}_{\mathrm{LO}}\right|=\quad \angle \mathrm{H}_{\mathrm{LO}}=
$$

c) Find the function to describe the behavior of the circuit at very high frequencies. Also determine the magnitude and phase of this circuit at very high frequencies. (3 points)

$$
\mathrm{H}_{\mathrm{HI}}(\mathrm{j} \omega)=
$$

$$
\left|\mathrm{H}_{\mathrm{HI}}\right|=\quad \angle \mathrm{H}_{\mathrm{HI}}=
$$

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d) Find the function to describe the behavior of the circuit at the resonant frequency in terms of $\mathrm{L}, \mathrm{R}$ and C . Also determine the magnitude and phase of the circuit at the resonant frequency. (6 points)

$$
\mathrm{H}_{0}\left(\mathrm{j} \omega_{0}\right)=
$$

$$
\left|\mathrm{H}_{0}\right|=
$$

$$
\angle \mathrm{H}_{0}=
$$

e) Given the input signal pictured, find the values listed Include all units. (3 points)


Time
amplitude voltage:
frequency (f):
peak-to-peak voltage:
angular frequency $(\omega)$ :
phase shift ( $\phi$ ):

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f) Assuming the input signal pictured and given values $\mathrm{C}=0.1 \mu \mathrm{~F}, \mathrm{~L}=10 \mathrm{mH}$ and $\mathrm{R}=1 \mathrm{~K}$, find a complex expression for the transfer function of the circuit at the input frequency. Also, find the magnitude and phase of the function. (6 points).
$\mathrm{H}=$
$|\mathrm{H}|=$
$\angle \mathrm{H}=$
g) For the input signal given in e), what will be the amplitude and phase of the output? (2 points)
$\mathrm{A}_{\text {out }}=$
$\phi_{\text {out }}=$

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## 4) Transformers ( 25 points)

Part A In the transformer below, the value of the input inductance (the inductance of the primary winding of the transformer) is 1 mH . You can assume that the coupling coefficient is 1 and that the resistance of R1 is negligible. Use the equations for an ideal transformer to determine the following:

$\mathrm{L} 1=1 \mathrm{mH}, \mathrm{k}=1, \mathrm{R} 1=5 \Omega, \mathrm{R} 2=5 \mathrm{~K} \Omega, \mathrm{~V} 1=200 \mathrm{mV}$
a) You would like the output voltage of the transformer to be 5 times that of the input voltage. What should the value of the constant, $a$, be? (1 point)
b) Given the value for $a$ you found in part a, what should you set the value of the output inductance (the inductance of the secondary winding of the transformer) to in order to obtain the desired voltage ratio? (3 points)
c) For the case in part b , what will be the amplitude of the output current? (3 points)
d) What is the input impedance, $\mathrm{Z}_{\mathrm{in}}$, of this transformer under the conditions given? (3 points)

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Part B Applying an input signal to your transformer.

a) Describe how you would set the function generator and manually adjust the scope to get the signal shown above. Assume that the scope is connected directly to the function generator as shown. Give specific details. (4 points)
b) Describe two ways that you could verify that the output signal has the correct peak-topeak amplitude voltage using the scope. (2 points)

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c) As you are setting up the input signal, you notice that the function generator and the scope display a different value for peak-to-peak voltage. Which is correct, the function generator or the scope? Why? (3 points)
d) Once you have set up the correct input to the circuit, you attach the transformer circuit and observe the output. Based on the ideal behavior of a transformer, sketch the expected output voltage on the scope screen below. (3 points)

e) When you observe the output on the scope, the amplitude of the output relative to the input is less than expected. How could you change the input signal to force the transformer to act more like an ideal transformer? (3 points)

