Physics 313 assignment for Thursday, Sept 10, 2019:

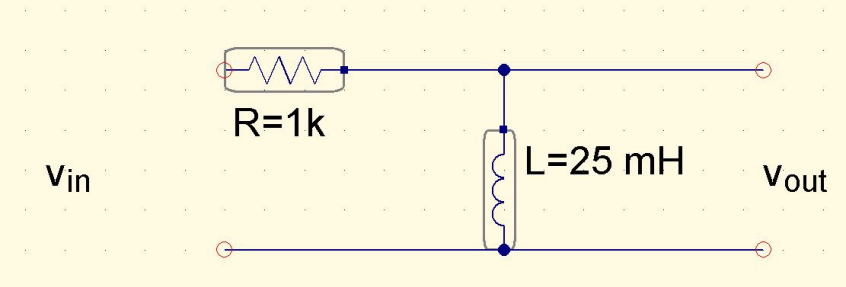
New topics: RC integrators and differentiators; frequency decomposition

To receive full credit, **clearly show your reasoning** (including any necessary calculations), and **indicate your final answer in an unambiguous way** (such as by circling or underlining it). If you have any questions about the interpretation of any problem, please ask!

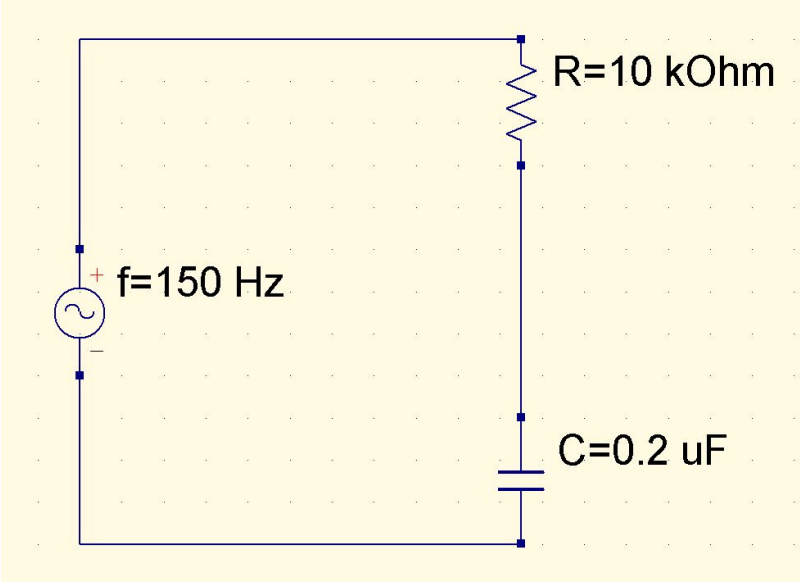
Round your answers appropriately (remember that 1, 5, and 10% are typical resistor tolerances, so there's usually no need to specify more than 3 sig figs).

Problems:

1) A designer wishes to replace the circuit below with an RC circuit that has the same voltage vs time characteristics (transient response in particular). Design an acceptable circuit. Include sketch of new circuit and component values.



2) (review of AC concepts) For this problem, refer to the circuit below. Assume the amplitude (V_p) of the input (function generator) voltage is 2.0 V.

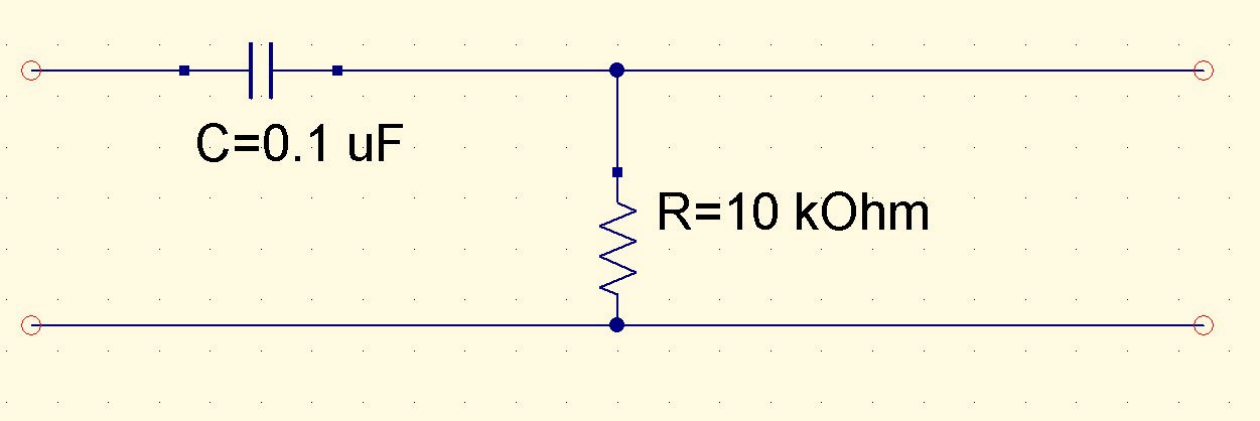


a) What is the magnitude of the total impedance of the circuit at this frequency?
b) What is the amplitude of the current in the circuit at this frequency?
c) Find the amplitude of the voltage across the resistor. Also find the amplitude of the voltage across the capacitor.
d) Draw a careful phasor diagram that shows the relationships between the voltages V_{in}, V_R, and V_C, labeling your diagram appropriately.
e) Does the voltage across the capacitor lead or lag the function generator voltage? Explain briefly.
f) Determine the phase angle of the voltage across the capacitor with respect to V_{in}.
g) What inductance would have to be added to the circuit (in series) in order for the circuit to be in resonance at the given frequency? How would the current in this case compare to what you found in b)?

4) a) You want to design a low-pass RC filter that has its breakpoint frequency at 700 Hz. You have a 560 pF capacitor and a large selection of resistors. Draw the appropriate circuit and label the values of its components. Be sure to show where V_{out} should be taken.
b) Use the formula for V_{out}/V_{in} to make a graph (preferably using software such as GnuPlot, Extrema, Octave, Mathematica, or Excel) of V_{out}/V_{in} vs. the frequency (in Hz) for your circuit. Label (by hand on a printout is fine) the breakpoint frequency and the corresponding value of V_{out}/V_{in} on your graph.
c) If V_{in} is a 5.0 V (amplitude) sine wave of frequency 200 Hz, what is V_{out}? If V_{in} is a 5.0 V sine wave of frequency 1200 Hz, what is V_{out}?
d) Make a table like the one below and fill it with the appropriate answers for this type of filter. The possible options are shown in parentheses at the top of the column where appropriate)::

	V_{out}/V_{in} (0, $1/\sqrt{2}$, 1)	V_{out} phase shift relative to V_{in} (0, 45, 90°)	V_{out} leads or lags V_{in}?
$f << f_B$			
$f = f_B$			
$f >> f_B$			

5) a) For what frequencies will the circuit below act as a differentiator?



b) If R and C are interchanged, at what frequencies will the circuit act as an integrator?

6) Reading questions:
a) If an RC circuit is to act as a good differentiator, what has to be true about the period of the signal compared to the RC time constant of the circuit?
b) For an ideal (no losses) step-down transformer, say whether each of the following is less than 1, greater than 1, or equal to 1: i) ratio of the output to input voltage; ii) ratio of the output to input current; iii) ratio of the output to input power; iv) ratio of the output to input impedance.
c) A particular square wave has a frequency of 1 kHz. Are the sharp corners of this square wave due to sinusoidal components with frequencies much higher than, much lower than, or roughly the same as 1 kHz?