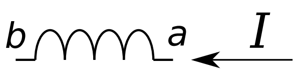
Physical Constants:

proton charge $= e = 1.60 \times 10^{-19}$ C	Coulomb constant $= k = 9 \times 10^9$ $\mathrm{N \cdot m^2/C^2}$
proton mass $= m_p = 1.67 \times 10^{-27}$ kg	permittivity $= \epsilon_0 = 8.85 \times 10^{-12}$ $\mathrm{C^2/(N \cdot m^2)}$
electron mass $= m_e = 9.11 \times 10^{-31}$ kg	permeability $= \mu_0 = 4\pi \times 10^{-7}$ $\mathrm{T \cdot m/A}$
Bohr magneton $= \mu_B = 9.27 \times 10^{-24}$ J/T	light velocity $= c = 3.00 \times 10^8$ m/s

Circle the letter of the single best answer. (1 pt.)

1. A current I flows through an inductor L in the direction from point a to point b. There is zero resistance in the wires of the inductor. If the current is decreasing:



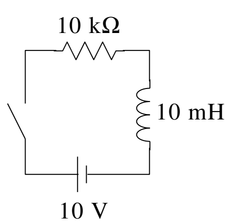
   A. the potential at point a is less than at point b.

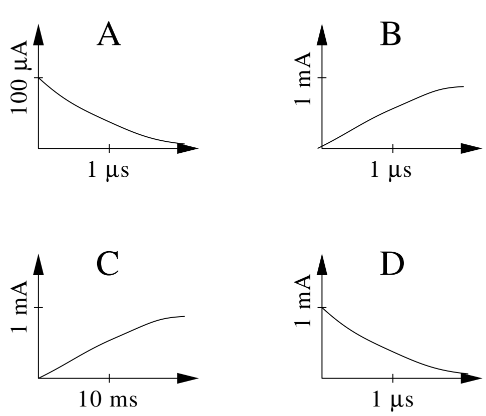
   B. the potential at point a is greater than at point b.

   C. if the current flow is in the positive direction, the potential at point a is greater than at point b.

   D. the answer depends on the whether the current is leading or lagging the voltage.

2. The below circuit shows a series LR circuit. The switch is closed at $t = 0$. Which graph best represents how the current changes in time?





3. The energy stored in an inductor is given by:

$$U = \frac{1}{2} LI^2$$

   In terms of units this equation is:

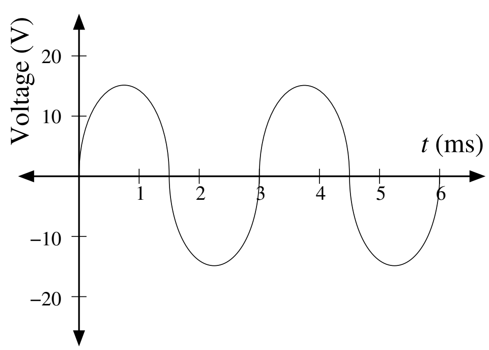
   A. $\mathrm{J = (V \cdot s/A) \times A^2}$

   B. $\mathrm{J = F \times A^2}$

   C. $\mathrm{W = H \times A^2}$

   D. $\mathrm{V = H \times C^2}$

4. The below plot—similar to that of an oscilloscope—displays voltage vs. time. Such signals may be characterized by the rms voltage ($V_{\rm rms}$), the period (T), the frequency (f), and the angular frequency (ω). Which of the below is a good estimate of one of these quantities?



   A. $f = 30$ Hz

   B. $V_{\rm rms} = 10$ V

   C. $T = .0015$ s

   D. $\omega = 3$ ms

5. In a series LRC circuit, the inductive reactance is 12 Ω, the capacitive reactance is 8 Ω, the resistance is 3 Ω, and the frequency in 10 kHz. The impedance is most nearly:

   A. 20 Ω

   B. 15 Ω

   C. 10 Ω

   D. 5 Ω

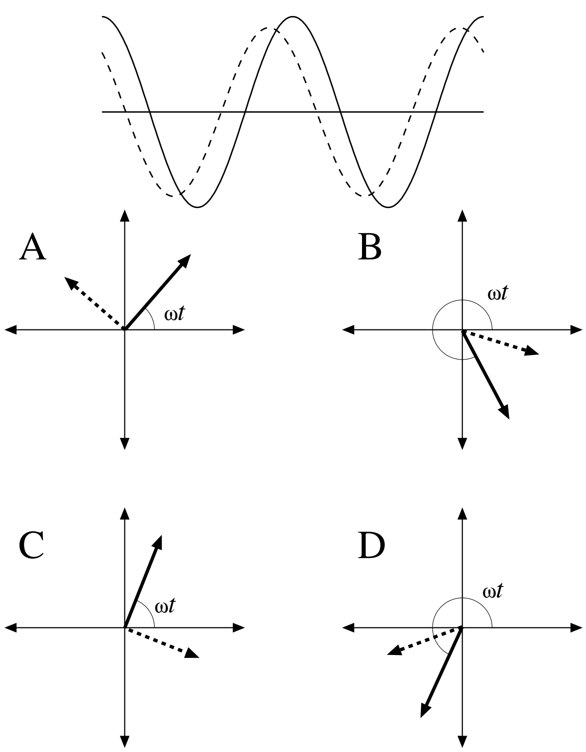
6. An oscillating voltage of fixed amplitude is applied across a circuit element. If the frequency of this voltage is increased, the amplitude of the current will

   A. increase if the circuit element is an inductor.
   B. decrease if the circuit element is an inductor.
   C. increase if the circuit element is a capacitor.
   D. both B and C

7. An LRC series circuit is operating at a frequency less than its resonant frequency. How are the values of the capacitive reactance X_C, the inductive reactance X_L, and the resistance R related to each other?

   A. $X_C = X_L$
   B. $X_C < X_L$
   C. $X_C > X_L$
   D. $R < X_L$

8. The below plot displays two voltages (solid and dotted) as functions of time. Which of the below phasor pairs is consistent with this plot?



9. The primary winding of a transformer has 400 turns and is connected to a normal household receptacle. The secondary has 200 turns. The output (secondary) voltage is most nearly

   A. 240 V at 30 Hz
   B. 60 V at 120 Hz
   C. 60 V at 60 Hz
   D. 240 V at 60 Hz

10. Plane wave light has a magnetic field given by:

$$\mathbf{B} = -B_0\,\widehat{\mathbf{i}}\,\sin(ky + \omega t)$$

where B_0, ω, and k are positive constants. Which of the below is the corresponding electric field?

   A. $\mathbf{E} = +cB_0\,\widehat{\mathbf{j}}\,\sin(ky + \omega t)$
   B. $\mathbf{E} = -cB_0\,\widehat{\mathbf{k}}\,\sin(ky + \omega t)$
   C. $\mathbf{E} = +cB_0\,\widehat{\mathbf{k}}\,\sin(ky + \omega t)$
   D. None of the above.

11. At a certain time and point in space, the electric and magnetic fields of an electromagnetic wave are given by

$$\begin{aligned}\mathbf{E} &= \widehat{\mathbf{i}}\,6 \times 10^3\ \mathrm{V/m}\\ \mathbf{B} &= \widehat{\mathbf{k}}\,2 \times 10^{-5}\ \mathrm{T}\end{aligned}$$

This wave is propagating in the

   A. negative x-direction.
   B. positive y-direction.
   C. positive z-direction.
   D. negative y-direction.

12. As an electromagnetic wave travels through free space, its speed can be increased by:

   A. increasing its frequency.
   B. increasing its energy and momentum.
   C. increasing it wavelength.
   D. none of the above.

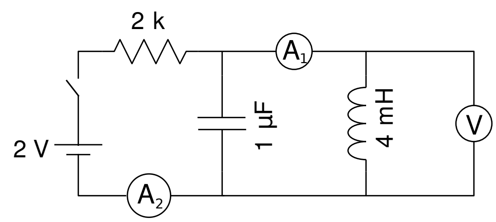
The following questions are worth 12 pts each

Record your steps! (Grade based on method displayed not just numerical result)

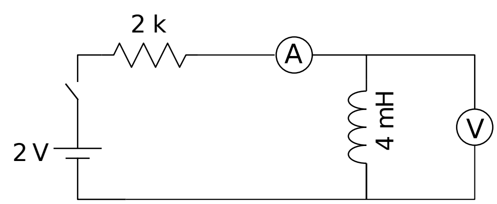
13. Consider capacitor's and inductor's immediate behavior in switched-on circuits and their long term behavior. Report the actual behavior of these components using the options: **A**='like a wire (short circuit)', **B**='like a disconnect (open circuit)' or **C**='neither'

    - the immediate behavior of a capacitor is like a ______
    - the long-term behavior of a capacitor is like a ______
    - the immediate behavior of an inductor is like a ______
    - the long-term behavior of an inductor is like a ______

    A. Report the immediate and long-term reading of each of the three meters in the following circuit when the switch is closed.



    B. If the capacitor is removed, approximately plot the current and voltage as functions of time. Be sure to include approximate scales for current, voltage, and time.



14. Consider the below right LRC circuit, driven by a generator at a frequency of $f = 20$ kHz

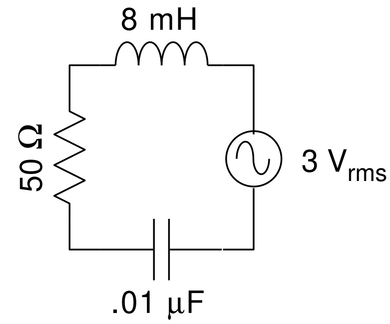
A. What rms current flows through the circuit?

B. What is the rms voltage across the inductor (V_L)? Across the capacitor (V_C)? Across the resistor (V_R)?

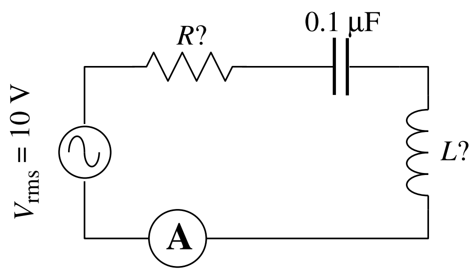
C. Accurately draw a phasor diagram showing/labeling how the voltages: V_L, V_R, V_C add to produce the total voltage of the source.

D. On your phasor diagram label the angle ϕ that is used to find the power factor $\cos\phi$. (No need to calculate this angle, just label it.)

E. Circle one: the total voltage leads the current
the total voltage lags the current

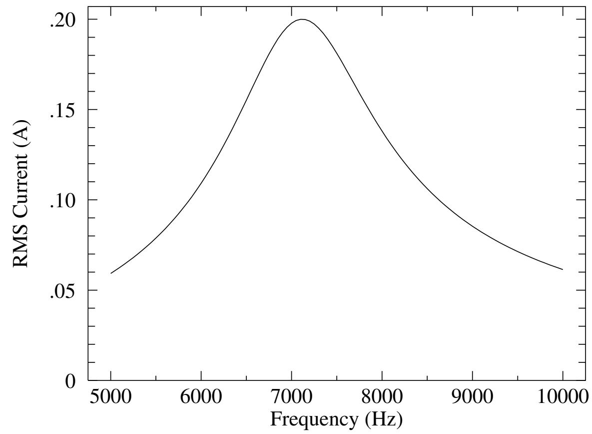


15. A series LRC circuit has known capacitance ($C = .1\ \mu$F) but unknown inductance L and resistance R. The circuit is powered by an adjustable frequency generator which maintains a fixed output voltage: 10 V_{rms} as the frequency is varied. The rms current measured by the ammeter in this circuit is plotted as a function of the frequency of the generator.



A. Using the data at resonance, calculate L and R.

B. Using the data at a frequency of 8000 Hz, calculate the total impedance of the circuit. Sketch the phasor diagram showing (and labeling) the three voltages V_C, V_L, V_R and the voltage produced by the generator.



16. A relatively high power laser (Class 4—not available to the general public) produces 1.5 W (average power) of 488 nm light with a beam diameter of 1.0 mm. Find the parameters describing this wave: $E_{max}, B_{max}, f, \omega, k$ (maximum electric and magnetic fields, frequency, angular frequency, and wave number)

Please sign the following statement:

In answering these questions I have used no aids other then the textbook.