Show all Work!! Circle your answer(s).

A capacitor and two resistors are connected to a battery as shown. The switch has been closed for a long time and then opened at \( t = 0 \). Given: \( V = 12.0 \text{ V}, C = 5.00 \mu\text{F} \) and \( R = 8.00 \times 10^3 \Omega \).

(a) [5 pts.] Calculate the current through the battery just before the switch is opened.

(b) [5 pts.] Calculate the charge on the capacitor just before the switch is opened.

(c) [5 pts.] Calculate the time constant \( \tau \) for discharging the capacitor after the switch is opened.

(d) [5 pts.] Calculate the charge on the capacitor as a function of time after the switch is opened.

\[ Q(t) = Q_{\text{max}} e^{-t/\tau} \]

\[ Q_{\text{max}} = 6 \times 10^{-5} \text{ C} \]

\[ (t \leq 0.08 \text{ s}) \]
Show all Work!! Circle your answer(s).

An infinite straight wire has a uniform positive linear charge density \( \lambda \). Express all your answers in terms of \( r, \lambda, q \) and \( k_e \) or \( \varepsilon_0 \), as appropriate. You must show all work.

(a) \( [10 \text{ pts.}] \) Draw the appropriate Gaussian surface for this situation and use Gauss's law to find the magnitude of the electric field at an arbitrary distance \( r \) from the wire. Sketch the direction of the electric field.

(b) \( [7 \text{ pts.}] \) Calculate the potential difference \( \Delta V \) between two points located at distances \( r \) and \( 2r \) from the wire.

(c) \( [3 \text{ pts.}] \) How much energy is required to move a particle of positive charge \( q \) from the distance \( 2r \) to \( r \)?

\[
(a) \quad \int \mathbf{E} \cdot d\mathbf{A} = \frac{Q_{enc}}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0} \\
\Rightarrow \mathbf{E} \cdot 2\pi rl = \frac{\lambda l}{\varepsilon_0} \\
\Rightarrow \mathbf{E} = \frac{\lambda}{2\pi \varepsilon_0 r} \quad \text{Direction = Radially Outward}
\]

\[
(b) \quad \Delta V_{A \to B} = -\int_{r_A}^{r_B} \mathbf{E}(r) \cdot d\mathbf{r} = -\frac{\lambda}{2\pi \varepsilon_0} \ln \left[ \frac{r_B}{r_A} \right] = -\frac{\lambda}{2\pi \varepsilon_0} \ln \left[ \frac{2r}{r} \right] = -\frac{\lambda}{2\pi \varepsilon_0} \ln (2) \quad \text{with} \quad r_B = 2r, \quad r_A = r
\]

\[
(c) \quad \Delta W = q \Delta V = -q \frac{\lambda}{2\pi \varepsilon_0} \ln (2)
\]
Show all Work!! Circle your answer(s).

The switch S is initially in position a and stays in that position for a long time.

(a) [4 pts.] What is the current and voltage across the 2.0 Ω resistor?

Now the switch is thrown quickly from a to b.

(b) [4 pts.] What is the initial current in the inductor?

(c) [4 pts.] What is the voltage across each resistor?

(d) [4 pts.] What is the voltage across the inductor?

(e) [4 pts.] What is the time constant for discharging the inductor?

\[ I = \frac{V}{R} = 6.0 \text{ A} \quad \text{as } t \to \infty \]

\[ V_{ac} = 12 \text{ V} \]

\[ I_L = \text{no discontinuity in current} \]

\[ I_L = 6.0 \text{ A} \]

\[ V_{2R} = R_{2R} I_L = 2 \cdot 6.0 = 12 \text{ V} \]

\[ V_{1200} = R_{1200} I_L = (1200 \Omega)(6.0 \text{ A}) = 7200 \text{ V} \]

\[ -V_{ac} + V_L - V_{1200} = 0 \quad \text{or} \quad V_L = I_L (R_{ac} + R_{1200}) \]

\[ V_L = 7212 \text{ V} \]

\[ T = \frac{1}{R_{eq}} \quad \text{resistors are in series so} \quad R_{eq} = R_{2R} + R_{1200} = 1202 \Omega \]

\[ T = \frac{2 \text{ H}}{1202 \text{ Ω}} = 1.66 \times 10^{-3} \text{ s} \]
Show all Work!! Circle your answer(s).

The electric field in a laser beam of light has amplitude 5.00 V/m and wavelength 650 nm. The cross section area of the beam is 5.00 mm². Given: \( \mu_0/4\pi = 10^{-7} \text{Tm/A} \), \( \varepsilon_0 = 8.854 \times 10^{-12} \text{C}^2/\text{Nm}^2 \) and \( c = 2.998 \times 10^8 \text{m/s} \).

(a) [4 pts.] Calculate the frequency of the laser beam in Hz.

\( \nu = \frac{c}{\lambda} = \frac{4.615 \times 10^{14}}{650 \times 10^{-9}} \text{ Hz} \)

(b) [4 pts.] Calculate the amplitude of the magnetic field.

\( B_{\text{max}} = \frac{E_{\text{max}}}{c} = \frac{5 \text{ V/m}}{3 \times 10^8} = 1.67 \times 10^{-8} \text{T} \)

(c) [4 pts.] Calculate the intensity of the laser beam.

\( I = \frac{E_{\text{max}} B_{\text{max}}}{2 \mu_0} = \frac{5 \times 1.67 \times 10^{-8}}{2 \times 10^{-7}} = 0.033 \text{ W/m}^2 \)

(d) [4 pts.] What radiation pressure would this wave exert, if it were directed at normal incidence onto a surface that absorbs 100% of the laser beam?

\( \text{Pressure} = \frac{I}{c} = 1.1 \times 10^{-10} \text{ Pa} \)

(e) [4 pts.] How much energy will the laser beam transfer to that surface in two minutes?

\[
\begin{align*}
\text{Energy} &= \text{Power} \times \text{time} \\
&= I \cdot \text{Area} \cdot t \\
&= 0.033 \times 5 \times 10^{-6} \times 120 = 1.99 \times 10^{-5} \text{ J}
\end{align*}
\]
Show all Work!! Circle your answer(s).

A loop of wire in the shape of a rectangle of width w and length L and a long straight wire, located at a distance h from the loop and carrying a current I, lie on a tabletop as shown in the figure. The current is changing with time according to $I = at^2$, where $a$ is a constant. Express all your answers in terms of $w$, $L$, $h$, $a$, $t$, $r$, and $\mu_0$ as appropriate.

(a) [5 pts.] Find the magnitude and direction of the magnetic field due to the current $I$ at an arbitrary distance $r$ from the long wire as a function of time.

(b) [10 pts.] Find the magnetic flux through the loop due to the current $I$ as a function of time.

(c) [5 pts.] Find the induced emf in the loop as a function of time.

\[ \oint \mathbf{B} \cdot d\mathbf{A} = \oint \mathbf{B} \cdot d\mathbf{a} = \oint \frac{\mu_0 a t^2}{2\pi r} \, dA; \quad dA = L \, dr \]

\[ = \frac{\mu_0 a t^2}{2\pi} \int \frac{L \, dr}{r} = \frac{\mu_0 a t^2}{2\pi} \ln \left( \frac{h+w}{w} \right) \]

\[ \mathcal{E} = -\frac{d\Phi_B}{dt} = -\frac{d}{dt} \left( \frac{\mu_0 a t^2}{2\pi} \ln \left( \frac{h+w}{w} \right) \right) \]

\[ = -\frac{2\pi \mu_0 a t L}{2\pi} \ln \left( \frac{h+w}{w} \right) \]