EXAM 3

A metal bar is being pulled over two metal tracks with a constant velocity of 3.00 m/s in the x-direction as shown in the picture. The metal tracks are parallel and w = 10.0 cm apart. A constant magnetic field of 0.300 Tesla is pointing “into the page” as shown. Assume the metal tracks and the metal bar themselves have negligible resistance, so the only resistance is R = 100 Ω as shown. Initially the switch SW is closed.

(a) [3 pts.] While SW is closed, what is the charge on the capacitor?
(b) [5 pts.] Calculate the magnitude of the voltage that is induced between the two ends of the metal bar.
(c) [3 pts.] Calculate the electric current through R while SW is closed and determine the current direction (clockwise or counterclockwise).
(d) [5 pts.] A little later the switch is suddenly opened (let’s say at time t=0), allowing the capacitor to get charged. Determine the time constant of this charging process and the maximum charge on the capacitor.
(e) [2 pts.] Make a sketch of the current through R as a function of time starting at t=0 (the time SW is opened). Indicate approximately the time constant on this sketch.
(f) [2 pts.] Make a sketch of the charge on the capacitor as a function of time starting at t=0. Indicate approximately the time constant on this sketch.
(g) [5 pts.] In order to pull the metal bar at a constant velocity, a force must be applied. Does the magnitude of this force change, and if so how, after the switch is opened? Explain your answer.

(Neglect any effects due to the self-inductance of this circuit.)

b) $|\text{ind}| = Bwv = (0.300 \text{T})(0.100 \text{m})(3.00 \text{m/s}) = 0.0900 \text{V}$

c) $I = \frac{|\text{ind}|}{R} = \frac{0.090 \text{V}}{100 \Omega} = 0.0009 \text{A} = 0.9 \text{mA}$

d) $\tau = RC = (100 \Omega)(10.0 \times 10^{-6} \text{F}) = 0.001 \text{s}$; $Q_{\text{max}} = |\text{ind}|C = 0.900 \mu \text{C}$

e) $I_0 = 0.9 \text{mA}$

f) $Q_{\text{max}}$ is the current drop to $t$

g) For constant velocity: $F_{\text{app}} = F_B \Rightarrow F_{\text{app}} = IB \sin 90^\circ$. So, the applied force changes with current. Thus, the magnitude decreases as bar moves to the right.
EXAM 3

Name: _________________________ unid: u __ __ __ __ __ __

Discussion TA (circle): [ ] Eric [ ] Pei-I [ ] Rhett

SHOW ALL WORK!!!!!
REPORT ALL NUMBERS TO THREE SIGNIFICANT FIGURES!
Use the conversion constants and data given on the front page.

Assume you have an alternating voltage applied to a circuit containing a light bulb (consider it to be a pure resistance) and a capacitor in series. You have the ability to change the frequency of the alternating voltage, but you cannot change the amplitude.

(a) [5 pts.] Describe qualitatively what happens to the light output of the light bulb if you start out at very low frequencies and then gradually increase the frequency.

(b) [5 pts.] For a fixed frequency make a sketch of the current through the light bulb and the voltage across the capacitor as a function of time (draw one or two cycles).

Now, the capacitor is replaced with an inductor.

(c) [5 pts.] Describe qualitatively what happens to the light output of the light bulb if you start out at very low frequencies and then gradually increase the frequency.

(d) [5 pts.] For a fixed frequency make a sketch of the current through the light bulb and the voltage across the inductor as a function of time (draw one or two cycles).

Finally, both the capacitor and the inductor are placed in series into the circuit.

(e) [5 pts.] Describe qualitatively what happens to the light output of the light bulb if you start out at very low frequencies and then gradually increase the frequency.

\[
Z = (R^2 + (X_L - X_C)^2)^{1/2}
\]

\[
j = \frac{\Delta V}{Z} \quad j \Delta V_{\text{total}} = iR = \frac{\Delta V_{\text{max}} \sin(\omega t)}{(\omega^2 + (X_L - X_C)^2)^{1/2}} R \quad j X_C = \frac{X_C}{\omega C}
\]

See pages 932-935 in book for more details/help.

\[X_L = \omega L\]

\[X_C = \frac{1}{\omega C}\]

\[\begin{align*}
\text{a)} \quad & X_L = 0 \quad \text{for} \quad f > 0 \quad \Rightarrow \quad X_C \approx \infty \quad \Rightarrow \quad Z \approx \infty \quad \Rightarrow \quad \Delta V_{\text{bulb}} \approx 0 \\
& \text{as} \quad f \uparrow \quad X_L \downarrow \quad Z \downarrow \quad I \uparrow \quad \Delta V_{\text{bulb}} \uparrow \quad \text{dim} \rightarrow \text{bright}
\end{align*}\]

\[\begin{align*}
\text{b)} \quad & \Delta V_L = I_{\text{tot}} R \sin(\omega t) \\
& \Delta V_C = -I_{\text{tot}} X_C \cos(\omega t) \\
& I = I_{\text{max}} \sin(\omega t) \\
& \Delta V_{\text{max}} \rightarrow \text{bright} \quad \text{dim} \rightarrow \text{bright}
\end{align*}\]

\[\begin{align*}
\text{c)} \quad & X_C = 0 \quad \text{for} \quad f > 0 \quad \Rightarrow \quad X_L \approx 0 \quad \Rightarrow \quad Z \approx R \quad \Delta V_{\text{bulb}} \approx \Delta V_{\text{max}} \rightarrow \text{bright} \\
& \text{for} \quad f \leq \omega \quad \Rightarrow \quad X_L > 0 \quad \Rightarrow \quad Z > R \quad \Delta V_{\text{bulb}} < \Delta V_{\text{max}} \rightarrow \text{dim}
\end{align*}\]
SHOW ALL WORK!!!!
REPORT ALL NUMBERS TO THREE SIGNIFICANT FIGURES!
Use the conversion constants and data given on the front page.

extra space (if needed):

d) \[ I = I_{\text{max}} \sin(\omega t) \]
\[ \Delta V_L = I_{\text{tot}} x_L \cos(\omega t) \]

\[
\begin{array}{c}
  \text{at } f = \omega_0 \\
  x_L = 0, x_C = \infty \rightarrow Z = \infty, \Delta V_{\text{bulb}} \approx 0
\end{array}
\]
\[
\begin{array}{c}
  \text{at resonance } \quad x_L = x_C \rightarrow Z = R \quad (\text{a minimum}) \rightarrow \text{highest } \Delta V_{\text{bulb}}
\end{array}
\]
\[
\begin{array}{c}
  \text{above resonance } \quad Z > R \rightarrow \Delta V_{\text{bulb}} < \text{highest value } \quad \text{but } \Delta V_{\text{bulb}} \approx 0
\end{array}
\]

\[ \Rightarrow \text{low } f \text{ dim} \]

before resonance brighter

at resonance brightest

after resonance dimmer
A linearly polarized high power red laser beam emits light at 732nm wavelength (in vacuum). All the light emitted from the laser is concentrated into a thin laser beam of diameter 1.5 mm. The laser emits 20W of power.

(a) [5 pts.] What is the intensity of the laser light?

(b) [5 pts.] Calculate the amplitudes of the electric and the magnetic field of the laser light.

(c) [5 pts.] The laser is positioned in a vacuum tube, shining onto a perfectly absorbing sphere of mass 1.0 g and radius 3.0 mm. What is the radiation pressure exerted on the sphere?

(d) [5 pts.] Neglecting friction, calculate the acceleration of the sphere due to the laser light.

(e) [5 pts.] What is the average energy density of the laser light.

**Note:** Power = 20W has only 1 sig fig!
SHOW ALL WORK!!!!
REPORT ALL NUMBERS TO THREE SIGNIFICANT FIGURES!
Use the conversion constants and data given on the front page.

(a) [20 pts.] A beam of laser light falls onto a glass plate at an angle of $\alpha = 35^\circ$ as shown in the sketch. The glass plate is 8.5 cm thick. Calculate the separation $d$ of the two beams coming off the glass plate.

(b) [5 pts.] What is the critical angle for total internal reflection inside the glass?

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
\[ \Rightarrow 1.5 \sin 55^\circ = 1.5 \sin \theta_2 \]
\[ \Rightarrow \theta_2 = \sin^{-1} \left( \frac{\sin 55^\circ}{1.5} \right) \approx 33^\circ \]

Step 2

\[ n_2 \sin \theta_2 = n_3 \sin \theta_3 \]
\[ \Rightarrow 1.5 \sin 33^\circ = 1 \sin \theta_3 \]
\[ \Rightarrow \theta_3 \approx 55^\circ \]

Step 3

\[ \tan \theta_2 = \frac{DO}{8.5} \]
\[ \Rightarrow DO \approx 5.54 \text{ cm} \]

Step 4

\[ \cos \theta_3 = \frac{CB}{AC} \]
\[ \Rightarrow CB \approx 6.4 \text{ cm} \]