Physics 2220 HW # 22

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1. PSE6 32.P.052. [317949] The switch in Figure P32.52 is connected to point *a* for a long time (C = 1.00 μF). Suppose that the switch is thrown to point *b*.

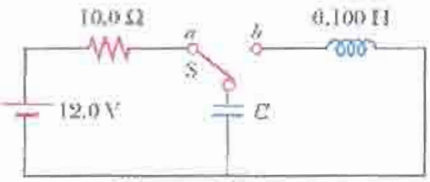

Figure P32.52

(a) What is the frequency of oscillation of the *LC* circuit?

[503] Hz

(b) Determine the maximum charge that appears on the capacitor.

[12] μC

(c) Determine the maximum current in the inductor.

[37.9] mA

(d) Determine the total energy the circuit possesses at t = 3.00 s.

[72] μJ

(a) $$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(0.100)\,H \times 1.00 \times 10^{-6}\,F}}$$

$$= \boxed{503\ Hz}$$

(b) $$Q_{max} = C\mathcal{E} = (1.00 \times 10^{-6}\,F)(12.0\,V) = \boxed{12.0\,\mu C}$$

(c) maximum energy stored in capacitor

= maximum energy stored in inductor.

so $$\frac{1}{2}C\mathcal{E}^2 = \frac{1}{2}L I_{max}^2$$

so $$I_{max} = \mathcal{E}\sqrt{C/L} = (12.0\,V)\sqrt{\frac{1.00 \times 10^{-6}\,F}{0.100\,H}} = \boxed{37.9\ mA}$$

(d) Energy is conserved, so at all times

$$U = \frac{1}{2}C\mathcal{E}^2 = \frac{1}{2}(1.00 \times 10^{-6}\,F)(12.0\,V)^2 = \boxed{72.0\ \mu J}$$

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2. PSE6 33.P.026. [317952] An AC source with ΔV_{max} = 150 V and f = 50.0 Hz is connected between points *a* and *d* in Figure P33.26.

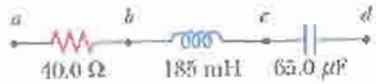

Figure P33.26

Calculate the maximum voltages between the following points.

(a) *a* and *b*

[146] V

(b) *b* and *c*

[212] V

(c) *c* and *d*

[179] V

(d) *b* and *d*

[33.4] V

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi(50.0\,Hz)(65\times10^{-6}F)} = 49.0\,\Omega$$

$$X_L = \omega L = 2\pi(50.0\,Hz)(185\times10^{-3}H) = 58.1\,\Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(40.0)^2 + (58.1 - 49.0)^2}\,\Omega$$

$$= 41.0\,\Omega$$

$$I_{max} = \Delta V_{max}/Z = 150V/41.0\,\Omega = 3.66\,A$$

(a) $\Delta V_R = I_{max} R = (3.66\,A)(40\,\Omega) = \boxed{146\,V}$

(b) $\Delta V_L = I_{max} X_L = (3.66\,A)(58.1\,\Omega) = \boxed{212\,V}$

(c) $\Delta V_C = I_{max} X_C = (3.66\,A)(49.0\,\Omega) = \boxed{179\,V}$

(d) ΔV_L and ΔV_C are out of phase by an angle π, so the potential difference between b & d is

$$\Delta V_L - \Delta V_C = (212.5 - 179.1)V = \boxed{33.4\,V}$$

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3. PSE6 34.P.061. [317861] A microwave source produces pulses of 15.0 GHz radiation, with each pulse lasting 1.00 ns. A parabolic reflector with a face area of radius R = 5.50 cm is used to focus the microwaves into a parallel beam of radiation, as shown in Figure P34.61. The average power during each pulse is 20.0 kW.

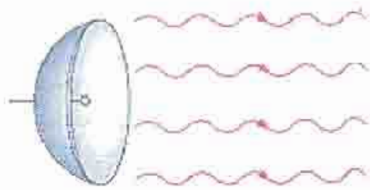

Figure P34.61

(a) What is the wavelength of these microwaves?

[2] cm

(b) What is the total energy contained in each pulse?

[20] μJ

(c) Compute the average energy density inside each pulse.

[7.02] mJ/m^3

(d) Determine the amplitude of the electric field and magnetic field in these microwaves.

E_{max} = [39.8] kV/m

B_{max} = [133] μT

(e) Compute the force exerted on the surface during the 1.00 ns duration of each pulse. Assume this pulsed beam strikes an absorbing surface.

[66.7] μN

(a) $\lambda = c/f = \dfrac{3.00\times10^{8}\ m/s}{15.0\times10^{9}\ Hz} = \boxed{2.00\ cm}$

(b) $U = \text{power} \times \Delta t = (20.0\times10^{3}\ W)(1.00\times10^{-9}\ s)$

$= \boxed{20\,\mu J}$

(c) $u_{av} = U/\text{volume} = \dfrac{U}{(\pi r^2)\ell} = \dfrac{U}{(\pi r^2)c\Delta t}$

$= \dfrac{20\times10^{-6}\ J}{\pi(0.055\ m)^2(3.00\times10^{8}\ m/s)(1.00\times10^{-9}\ s)}$

$= 7.02\times10^{-3}\ J/m^3 = \boxed{7.02\ mJ/m^3}$

(d) $u_{av} = \frac{1}{2} \epsilon_0 E_{max}^2$

so $E_{max} = \sqrt{\frac{2 u_{av}}{\epsilon_0}} = \sqrt{\frac{2(7.02 \times 10^{-3}\ J/m^3}{8.85 \times 10^{-12}\ C^2/N.m^2}}$

$= \boxed{39.8\ kV/m}$

$B_{max} = \frac{E_{max}}{c} = \frac{4.08 \times 10^4\ V/m}{3.00 \times 10^8\ m/s}$

$= \boxed{133\ \mu T}$

(e) $F = PA = \frac{S}{c} A = u_{av} A$

$= (7.02 \times 10^{-3}\ J/m^3)\pi(0.055\ m)^2$

$= \boxed{66.7\ \mu N}$

	pts
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4. PSE6 31.P.010. [317990] A coil of 16 turns and radius 10.0 cm surrounds a long solenoid of radius 1.80 cm and 1.0×10^3 turns/meter (Fig. P31.10). The current in the solenoid changes as I = (4.00 A) sin(105 t). Find the induced emf in the 16-turn coil as a function of time t.

$\Phi_B = (\mu_0 n I) A_{solenoid}$

$\mathcal{E} = -N\, d\Phi_B/dt = -N\mu_0 n (\pi r_{solenoid}^2) \frac{dI}{dt}$

$\mathcal{E} = -16 (4\pi \times 10^{-7}\ T.m/A)(1.0 \times 10^3\ m^{-1})$
$\times (\pi \times (0.018\ m)^2)(4.00 \times 105\ A/s) \cos(105 t)$

so $\boxed{\mathcal{E} = 8.596 \cos(105t)\ mV}$

$|\mathcal{E}| =$ [8.596 cos(105 t)] mV

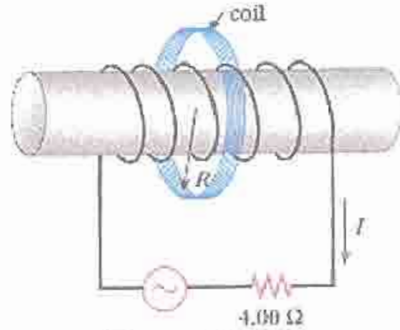

Figure P31.10

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5. PSE6 31.P.011. [317946] Find the current through section *PQ* of length *a* = 60.0 cm shown in Figure P31.11. The circuit is located in a magnetic field whose magnitude varies with time according to the expression $B = (1.00 \times 10^{-3}\ \text{T/s})t$. Assume the resistance per length of the wire is 0.096 Ω/m.

Magnitude

[272] μA

Direction

(_) from *P* to *Q*

(o) from *Q* to *P*

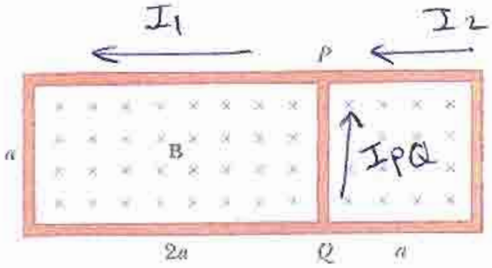

Figure P31.11

- Let $B = At$
- Applying Kirchoffs voltage rule to the right-hand loop in the counterclockwise direction, we get:

$$\frac{d}{dt}\left[At(2a^2)\right] - I_1(5R) - I_{PQ}R = 0$$

where $R = a \times 0.096\ \Omega/m = 0.0576\ \Omega$

- For the right-hand loop:

$$\frac{d}{dt}\left[At\,a^2\right] + I_{PQ}R - I_2(3R) = 0$$

where I_{PQ} is the upward current in PQ so $\quad 2Aa^2 - 5R[I_{PQ} + I_2] - I_{PQ}R = 0$

and $\quad Aa^2 + I_{PQ}R = I_2(3R)$

so, $\quad 2Aa^2 - 6RI_{PQ} - \frac{5}{3}(Aa^2 + I_{PQ}R) = 0$

$$I_{PQ} = \frac{Aa^2}{23R} \quad \text{upward}$$

$$\Rightarrow \quad I_{PQ} = \frac{(1.00 \times 10^{-3}\ \mathrm{T/s})(0.60)^2}{23(0.0576\ \Omega)} = \boxed{272\ \mu\mathrm{A}}$$

$\boxed{\text{in the direction from } Q \text{ to } P}$

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3	-
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6. PSE6 31.P.028. [317851] Use Lenz's law to answer the following questions concerning the direction of induced currents.

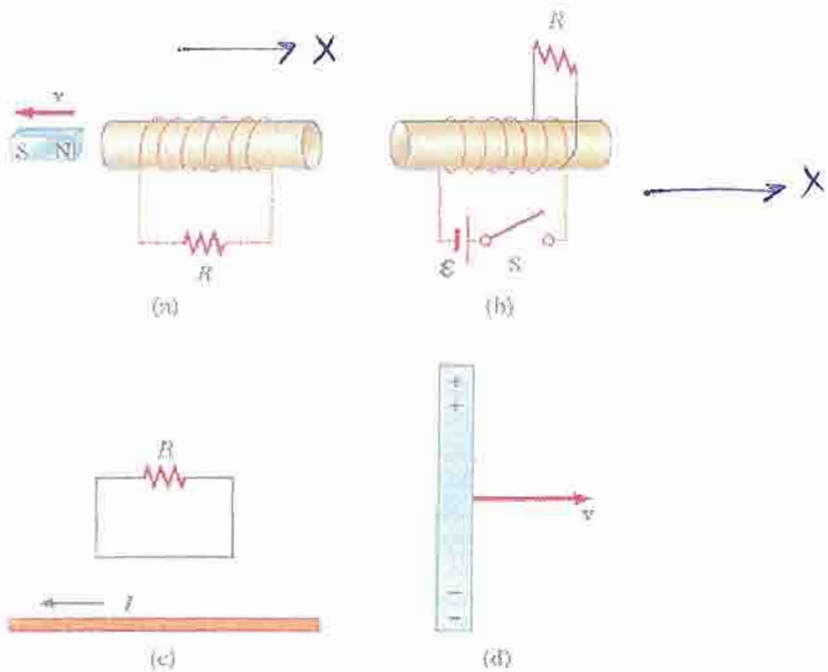

Figure P31.28

(a) What is the direction of the induced current in resistor R in Figure P31.28a when the bar magnet is moved to the left?

---Select--- [to the right]

(b) What is the direction of the current induced in the resistor R after the switch S in Figure P31.28b is closed?

---Select--- [out of the page]

(c) What is the direction of the induced current in R when the current I in Figure P31.28c decreases rapidly to zero?

---Select--- [to the right]

(d) A copper bar is moved to the right while its axis is maintained in a direction perpendicular to a magnetic field as shown in Figure P31.28d. If the top of the bar becomes positive relative to the bottom, what is the direction of the magnetic field?

---Select--- [into the page]

(a) The external magnetic field is in the x-direction and is decreasing so the induced field must also be in the x-direction and the current in the resistor R is <u>to the right</u>

(b) the external B is in the − x direction and increases, so the induced field must be in the x direction so the current in R is

<u>out of the page</u>

(c) external B is into the paper and is decreasing so induced B is also into the paper and therefore the current in R is <u>to the right</u>

(d) $\vec{F}_B = q\vec{v} \times \vec{B}$. $\vec{F}$ is upward and since q is +ve then $\vec{v} \times \vec{B}$ is toward the top of the bar. If $\vec{v}$ is along $\hat{i}$ and $\vec{F}$ is along $\hat{j}$ then $\vec{B}$ would have to be along $-\hat{k}$ <u>into the page</u>

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7. PSE6 31.P.034. [317875] A long solenoid with 1000 turns per meter and radius 2.00 cm carries an oscillating current given by $I = (4.00 \text{ A}) \sin(90\pi t)$.

(a) What is the electric field induced at a radius $r = 1.00$ cm from the axis of the solenoid?

$E =$ [7.106 cos(90 pi t)] mV/m

(b) What is the direction of this electric field when the current is increasing counterclockwise in the coil?

( ) counterclockwise
(o) clockwise

(a) $\oint \vec{E} \cdot dl = \left| \dfrac{d\Phi_B}{dt} \right|$

so $2\pi r E = \pi r^2 \, dB/dt \longrightarrow E = \frac{\pi}{2} r (\mu_0 n) \, dI/dt$

so $E = \frac{\pi}{2}(0.01\text{m})(4\pi \times 10^{-7} \text{ Tm/A})(1000)(4.00 \times 90\pi \text{ A/m}) \cos(90\pi t)$

$= \boxed{7.106 \cos(90\pi t) \text{ mV/m}}$

(b) E is always opposite to increasing B $\Rightarrow$ $\boxed{\text{clockwise}}$

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8. PSE6 32.QQ.002. [328143] The circuit in Figure 32.8 consists of a resistor, and inductor, and an ideal battery with no internal resistance.

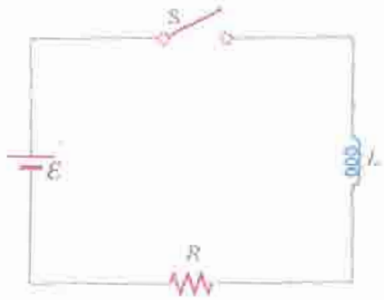

Figure 32.8

At the instant just after the switch is closed, across which circuit element is the voltage equal to the emf of the battery?

(_) both the inductor and resistor
(_) the resistor
(o) the inductor

After a very long time, across which circuit element is the voltage equal to the emf of the battery?

(o) the resistor
(_) the inductor
(_) both the inductor and resistor

* $I = (\varepsilon/R)(1 - e^{-t/\tau})$

$\varepsilon_L = -L\, dI/dt = -\frac{L\varepsilon}{R}\frac{1}{\tau}\, e^{-t/\tau}$

at $t = 0$ $\quad \varepsilon_L = -\frac{L\varepsilon}{R}\frac{1}{\tau} = -\frac{\cancel{L}\varepsilon}{\cancel{R}} \times \frac{\cancel{R}}{\cancel{L}} = -\varepsilon$

$\Rightarrow$ at $t = 0$ the voltage accros L is equal to $-\varepsilon$

* using the above eqn for ε_L we get at $t = \infty$

$\varepsilon_L = 0$ so $V_R = \varepsilon - V_L = \varepsilon$

so $\boxed{\begin{array}{ll} \text{at } t = 0 & |\varepsilon_L| = \varepsilon \\ \text{at } t \to \infty & |V_R| \to \varepsilon \end{array}}$

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9. PSE6 32.QQ.008. [328163] At an instant of time during the oscillations of an LC circuit, the current is momentarily zero. At this instant, the voltage across the capacitor is described by which of the following?

(_) different from that across the inductor
(_) zero
(o) has its maximum value
(_) is impossible to determine

$U = \frac{1}{2} C \Delta V_c^2 + \frac{1}{2} L I^2$ is conserved

when $I = 0$ then all energy is stored in the capacitor, so $\frac{1}{2} C \Delta V_c^2$ is maximum and Therefore ΔV_c is maximum and equal to $\mathcal{E}$ such that $U = \frac{1}{2} C \mathcal{E}^2$