# Physics 227 – Final Exam
Wednesday, May 9, 2018

CIZEWSKI

Physics 227,  Section
RUID:
**Code: 000**

Your name with **exam code**

**Your signature** ______________________

Turn off and put away ALL electronic devices NOW. NO cell phones, NO smart watches, NO calculators.

1. The exam will last from 4:00 to 7:00 PM.
   Use a # 2 pencil to make entries in the circles at the bottom of the cover sheet.
2. Make sure your name and RU ID are correct on the cover page. **CAREFULLY detach the cover sheet (with your name, ID and the answer circles).**
3. During the exam, you may use pencils, NO calculator. and **THREE** $8\frac{1}{2}'' \times 11''$ sheets of paper with handwritten (both sides) equations and notes.

No marks except filled in answer circles below the line, please.

| | A | B | C | D | E | | A | B | C | D | E | | A | B | C | D | E |
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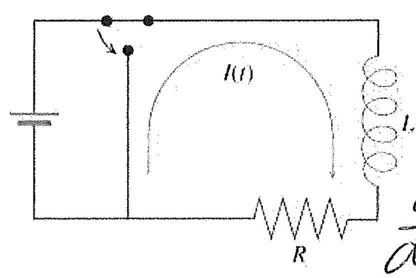
| 1: | A | B | C | D | E | 11: | A | B | C | D | E | 21: | A | B | C | D | E |
| 2: | A | B | C | D | E | 12: | A | B | C | D | E | 22: | A | B | C | D | E |
| 3: | A | B | C | D | E | 13: | A | B | C | D | E | 23: | A | B | C | D | E |
| 4: | A | B | C | D | E | 14: | A | B | C | D | E | 24: | A | B | C | D | E |
| 5: | A | B | C | D | E | 15: | A | B | C | D | E | 25: | A | B | C | D | E |
| 6: | A | B | C | D | E | 16: | A | B | C | D | E | 26: | A | B | C | D | E |
| 7: | A | B | C | D | E | 17: | A | B | C | D | E | 27: | A | B | C | D | E |
| 8: | A | B | C | D | E | 18: | A | B | C | D | E | 28: | A | B | C | D | E |
| 9: | A | B | C | D | E | 19: | A | B | C | D | E | 29: | A | B | C | D | E |
| 10: | A | B | C | D | E | 20: | A | B | C | D | E | 30: | A | B | C | D | E |

1. The energy density on a parallel plate capacitor stays the same when its dimensions (length x width x height) are all doubled. By what factor $X$ does the stored energy change? $u = U/\text{Volume}$

a) $X = 1$ $\quad U = u(\text{volume})$
b) $X = 1/2$ $\quad$ increase volume by 8
c) $X = 2$ $\quad \Rightarrow$ increase $U$ by $X = 8$
d) $X = 8$
e) $X = 4$

2. A DC voltage source is connected to a resistor of resistance $R$ and an inductor with inductance $L$, forming the circuit in the figure. For a long time before $t = 0$, the switch has been in the position shown, so that a current $I_0$ has been built up in the circuit by the voltage source. At $t = 0$, the switch is thrown to remove the voltage source from the circuit. After $t = 0$, what happens to the voltage $V(t)$ across the inductor and the current $I(t)$ through the inductor relative to their values prior to $t = 0$?




$V_L = L\dfrac{di}{dt}$

$\dfrac{di}{dt}$ changes abruptly

$\Rightarrow V_L$ changes abruptly

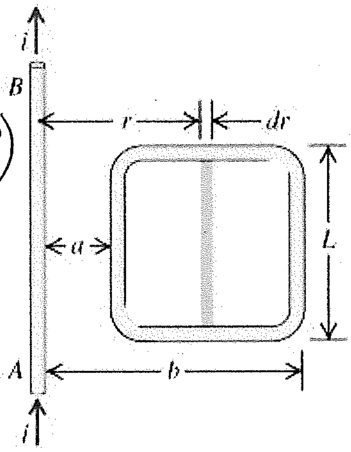
$I$ changes slowly

a) $V$ changes slowly and $I$ changes abruptly.
b) $I$ changes slowly and $V$ changes abruptly.
c) Both $V$ and $I$ change slowly.
d) Both $V$ and $I$ change abruptly but do not immediately go to zero.
e) Both $V$ and $I$ go immediately to zero.

3. The current in the long-straight wire $AB$ shown in the figure is upward and is increasing steadily at a rate $di/dt$. What is the magnitude of the induced emf $\mathcal{E}$ in the loop of height $L$ and width $b-a$?

$$d\Phi_B = \frac{\mu_0 i}{2\pi r} L\,dr$$

$$\Phi_B = \int_a^b \left(\frac{\mu_0 i L}{2\pi}\right)\frac{dr}{r} = \frac{\mu_0 i L}{2\pi}\ln\left(\frac{b}{a}\right)$$




a) $\mathcal{E} = \frac{\mu_0 L(b-a)}{2\pi}\frac{di}{dt}$
b) zero
c) $\mathcal{E} = \frac{\mu_0 L}{2\pi}\ln\left(\frac{b}{a}\right)\frac{di}{dt}$
d) $\mathcal{E} = \frac{\mu_0 L}{2\pi}\ln\left(\frac{a}{b}\right)\frac{di}{dt}$
e) $\mathcal{E} = \frac{\mu_0 L^2}{2\pi}\frac{di}{dt}$

$$|EMF| = \frac{d\Phi_B}{dt} = \frac{\mu_0 L}{2\pi}\ln\left(\frac{b}{a}\right)\frac{di}{dt}$$

4. A resistor with resistance $R$ is connected to the plates of a charged capacitor with capacitance $C$. Just before the connection is made, the charge on the capacitor is $Q$. What is the electrical power $P$ dissipated in the resistor just after the connection is made?

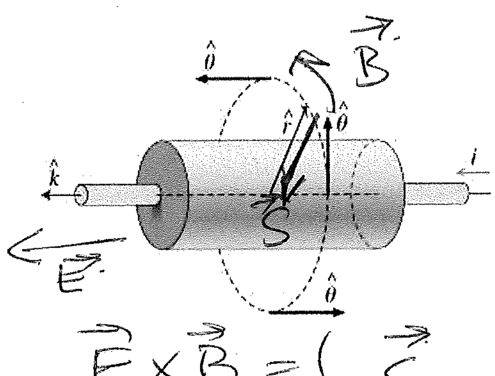
Current is max as soon as connection made and potential drop across capacitor $V = \frac{Q}{C}$

a) $P = Q^2/(RC^2)$
b) $P = Q^2/(RC)$
c) $P = Q^2R$
d) $P = Q/(RC)$
e) $P =$ zero

$$P = \left(\frac{V^2}{R^2}\right)(R) = \frac{Q^2}{C^2R} \qquad I = \frac{V}{R}$$

5. A cylindrical resistor is displayed in the Figure. It has a radius $r_0$, length L and resistance $R$. A steady current $i$ flows along the axis of the cylinder. In what direction does the Poynting vector $\vec{S}$ point?

a) $\vec{S}$ points in the $\hat{\imath}$, $x$ direction.
b) The Poynting vector is zero inside the resistor including its surface.
c) $\vec{S}$ points in the $-\hat{r}$, radial direction.
d) $\vec{S}$ points in the $\hat{\theta}$, angular direction.
e) $\vec{S}$ points in the $\hat{k}$, direction.




$$\vec{E}\times\vec{B} = \frac{1}{\mu_0}\vec{S}$$

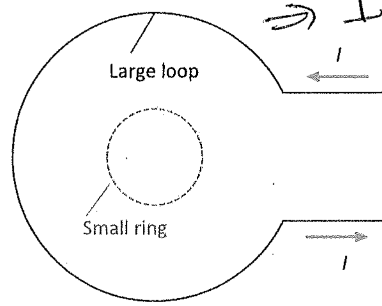
6. A small, circular ring of wire (dotted circle) is inside a larger loop of wire that carries a current $I$ as shown in the figure. The small ring and the larger loop both lie in the same plane. If $I$ increases, which of the following is a correct statement about the current in the small ring?

a) The current in the small ring is clockwise and caused by self inductance.
b) The current in the small ring is zero, because the two rings of wire are not connected.
c) The current in the small ring is clockwise and caused by mutual inductance.
d) The current in the small ring is counter-clockwise and caused by self inductance.
e) The current in the small ring is counter-clockwise and caused by mutual inductance.

$\vec{B} \odot$ from current in large loop.

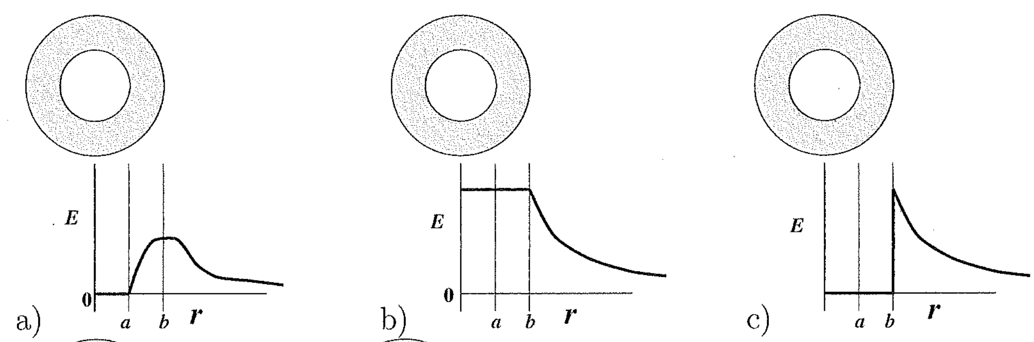
$\frac{dI}{dt} > 0 \Rightarrow \vec{B}_{induced} \otimes$

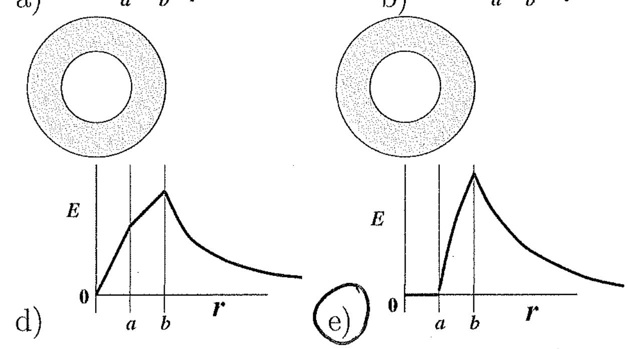
$\Rightarrow I_{induced}$ CW




Mutual inductance

7. An insulating spherical shell of inner radius $a$ and outer radius $b$ is uniformly charged with a positive charge density. Which figure best depicts the radial component of the electric field $\vec{E}_r$




$E(r) = 0$ when $0 < r < a$.

$E(r) \propto 1/r^2$ when $r > b$

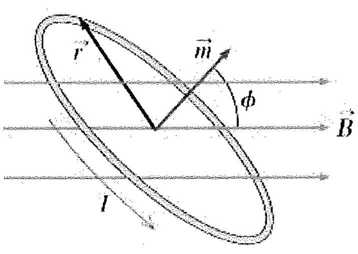
$E(r)$ increases when $a < r < b$

8. A current $I$ =1 A flows around a plane circular loop of radius $r$=1 cm, giving the loop a magnetic moment of magnitude $m$. The loop is placed in a uniform magnetic field $\vec{B}$=2 T with an angle $\phi$=30 degrees between the direction of the field lines and the magnetic dipole moment, as shown in the figure. What is the magnitude of the torque $\tau$ on the current loop?

$\vec{\tau} = \vec{m} \times \vec{B} = I \vec{A} B \sin\phi$

$= (1A)(\pi)(10^{-2} m)^2 (2T)(\frac{1}{2})$

$= \pi \times 10^{-4}$ N-m.




a) $\tau = 2\pi \times 10^{-2}$ N-m
b) $\tau = \pi \times 10^{-4}$ N-m
c) $\tau = 2\pi \times 10^{-4}$ N-m
d) $\tau = \pi \times 10^{-2}$ N-m
e) $\tau = \sqrt{3}\pi \times 10^{-4}$ N-m

9. Which of the following equations implies that you get a greater emf the faster you rotate the coils of a generator?

a) $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$
b) $\oint \vec{E} \cdot d\vec{A} = q/\epsilon_0$
c) $\oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$
d) $\oint \vec{B} \cdot d\vec{A} = 0$
e) $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I + \mu_0\epsilon_0 \frac{d\Phi_E}{dt}$

This is Faraday's Law

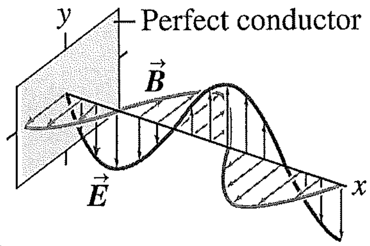
10. A point charge $q_1$=+2nC is located at the origin ($x = 0$) and a second point charge $q_2$=-6nC is at $x = 0.2$ m. What is the magnitude of the electric force $\vec{F}$ on each charge in terms of $k = 1/4\pi\epsilon_0$?

a) $F = 10^{-16}k$ N
b) $F = 12 \times 10^{-16}k$ N
c) $F = 10^{-18}k$ N
d) $F = 4 \times 10^{-18}k$ N
e) $F = 3 \times 10^{-16}k$ N

$F = \frac{k q_1 q_2}{r_{12}^2} = \frac{k(+2\times10^{-9}C)(-6\times10^{-9}C)}{(2\times10^{-1}m)^2}$

$= 3 \times 10^{-16}$ k N.

11. The figure displays a sinusoidal electromagnetic standing wave. Which of the following is a TRUE statement for the average Poynting vector $\vec{S}_{av}$?




a) $\vec{S}_{av}$ is zero.
b) $\vec{S}_{av}$ points along the $+x$ axis.
c) $\vec{S}_{av}$ points along the $+y$ axis.
d) $\vec{S}_{av}$ points along the $+z$ axis.
e) $\vec{S}_{av}$ points along the $-x$ axis.

For standing wave $S_{average} = 0$

12. An L-R-C series circuit with an inductance $L = 0.10$ H, resistance $R = 150\ \Omega$, and a capacitance $C = 1 \times 10^{-5}$ F carries an rms current $I_{rms} = 0.5$ A with an angular frequency $\omega = 2000$ rad/s. What is the power factor cos$\phi$ for this circuit, where $\phi$ is the phase difference between the current and the voltage in the circuit? [Note: refer to "Possibly useful constants" for cos of simple angles.]

$\tan\phi = \frac{X_L - X_C}{R} = \omega L - 1/\omega C / R$

a) $\cos\phi = 1$
b) $\cos\phi = 1/2$
c) $\cos\phi = \sqrt{2}/2$
d) $\cos\phi = \sqrt{3}/2$
e) $\cos\phi = 0$

$= (2000\,rad/s)(.1\,H) - 1/(2000\,rad/s)(10^{-5}\,F) / 150\,\Omega$

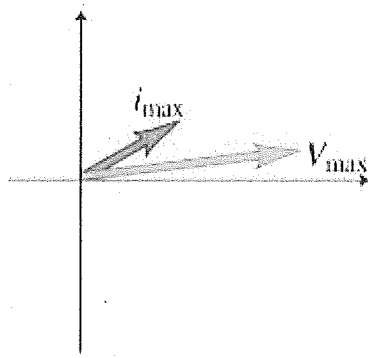
$= 200 - 50/150 = 1 \Rightarrow \phi = \pi/4 \Rightarrow \cos\phi = \sqrt{2}/2$

13. Which of the following is FALSE?

a) The direction of the force on a charged particle is in the direction of the electric field. FALSE
b) A magnetic field accelerates moving charges but never changes their speed. TRUE
c) Maxwell's theory of electromagnetism predicts that energy can be stored in a vacuum. TRUE
d) The electric field between the plates of a charged parallel-plate capacitor can be calculated with Gauss' law. TRUE
e) The EMF across an inductor is a consequence of Faraday's law.

TRUE

14. In the figure the phasors for current $i$ and voltage $V$ rotate counter-clockwise with angular frequency $\omega$. Which of the following is a correct statement about this phasor diagram?




current leads voltage, but phasors not perpendicular.
$\Rightarrow$ need a capacitor and a resistor

a) The phasor diagram represents an AC circuit consisting of only a resistor.
b) The phasor diagram represents an AC circuit consisting of only an inductor.
c) The phasor diagram represents an AC circuit consisting of resistor and a capacitor.
d) The phasor diagram represents an AC circuit consisting of only a resistor and inductor.
e) The phasor diagram represents an AC circuit consisting of only a capacitor.

15. You are given two charges $q_1 = +4$ nC and $q_2 = -4$ nC separated by a distance $d = 6$ mm. What are the magnitude and direction of the electric dipole moment $\vec{p}$?

a) $\vec{p} = 24 \times 10^{-12}$ C-m, from $q_1$ to $q_2$.
b) $\vec{p} = 16 \times 10^{-12}$ C-m, from $q_1$ to $q_2$.
c) $\vec{p} = 24 \times 10^{-12}$ C-m, from $q_2$ to $q_1$.
d) $\vec{p} = 16 \times 10^{-12}$ C-m, from $q_2$ to $q_1$.
e) $\vec{p} = 96 \times 10^{-12}$ C-m, from $q_2$ to $q_1$.

$$\vec{p} = q\vec{d} = (+4 \times 10^{-9}\,C)(6 \times 10^{-3}\,m) = 24 \times 10^{-12}\,C\text{-}m$$

from neg. $q_2$ to pos. $q_1$

16. A long solenoid of 800 turns is 0.5 m in length and it carries a current of 2.0 A. What is the magnetic field $B$ inside the solenoid at its center?

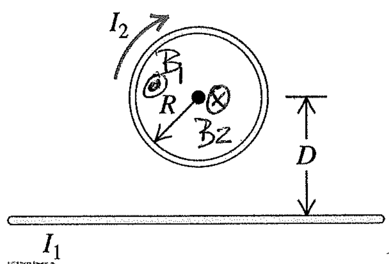
a) $B = \mu_0(1600)$ in units of T.
b) $B = \mu_0(800)$ in units of T.
c) $B = \mu_0(400)$ in units of T.
d) $B = \mu_0(3200)$ in units of T.
e) $B = 0$ T

$B = \mu_0 n I = \mu_0 \frac{N}{L} I$

$= (\mu_0) \frac{(800)}{1/2} 2A = 3200 \mu_0 T$

17. In the figure a circular loop has radius $R$ and carries current $I_2$ in a clockwise direction. The center of the loop is a distance $D$ above a long, straight current carrying wire. If the magnetic field at the center of the loop is zero, what are the magnitude and direction of the current $I_1$ in the wire?

a) $I_1 = I_2$ and goes from right to left.
b) $I_1 = \pi D I_2/R$ and goes from right to left.
c) $I_1 = \pi D I_2/R$ and goes from left to right.
d) $I_1 = D I_2/R$ and goes from right to left.
e) $I_1 = D I_2/R$ and goes from left to right.




$I_1$ = from L to R.

$B_2 = \frac{\mu_0 I_2}{2R}$ into page $\Rightarrow B_1 = \frac{\mu_0 I_1}{2\pi D} = \frac{\mu_0 I_2}{2R} \Rightarrow I_1 = \frac{\pi D I_2}{R}$
out of page

18. A capacitor $C_1$ is charged to potential $V$. It is then connected in parallel to an uncharged capacitor of capacitance $C_2$, and the potential drops to $V/3$. What is the value of $C_2$? Initially

a) $C_2 = 2C_1$
b) $C_2 = 3C_1$
c) $C_2 = C_1/3$
d) $C_2 = C_1$
e) $C_2 = C_1/2$

$Q_2 = 0 \quad Q_1 = C_1 V$

Connect in parallel $\Rightarrow C_{eq} = C_1 + C_2$

Finally $Q_1 = Q_2 = (C_1 + C_2)\frac{V}{3} = C_1 V \Rightarrow C_2 = 2C_1$

19. The resonant frequency of a certain $L - C$ circuit is $10^5$ rad/s. If the capacitance and inductance each increase by a factor of 5, what will be the new resonant frequency $\omega_0$?

a) $\omega_0 = (1/25) \times 10^5$ rad/s
b) $\omega_0 = (1/5) \times 10^5$ rad/s
c) $\omega_0 = 1 \times 10^5$ rad/s
d) $\omega_0 = 5 \times 10^5$ rad/s
e) $\omega_0 = 25 \times 10^5$ rad/s

initial $\omega_0 = 1/\sqrt{LC} = 10^5$ rad/s

final $\omega_0 = \frac{1}{\sqrt{5L5C}} = \frac{1}{5}(10^5 \text{ rad/s})$

20. An ideal transformer connected to an AC line with an rms voltage $V_{rms-1}$=120 V is to supply an rms volatage $V_{rms-2}$=12 V to a portable electronic device. The load resistance in the portable electronic device is $R = 4\ \Omega$. What rms current $I_{1-rms}$ is in the primary?

$I_1 V_1 = I_2 V_2 = \left(\frac{V_2}{R}\right) V_2$

$I_1 = \left(\frac{V_2}{R}\right) \frac{V_2}{V_1} = \frac{(12)(12)}{4(120)} = \frac{3}{10}$

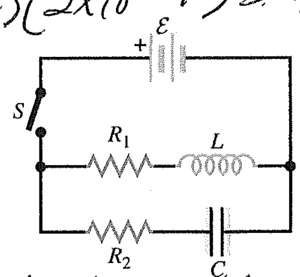
$I_1 = 0{,}3$ A

a) $I_{rms-1} = 3.0$ A
b) $I_{rms-1} = 0.3$ A
c) $I_{rms-1} = 30$ A
d) $I_{rms-1} = 3.0/\sqrt{2}$ A
e) $I_{rms-1} = 0.3\sqrt{2}$ A

21. The figure displays a circuit with EMF=10 V, $R_1 = R_2 = 2\ \Omega$, $L = 2\ \mu$H, and $C = 2\ \mu$F. At time $t = 0$ the switch is closed. What is the current $I$ at time $t = 1$ s?

$\tau(RC) = RC = (2\Omega)(2\times10^{-6}\,F) = 4\times10^{-6} \ll 1s$

$\Rightarrow$ no current in bottom path




a) $I$ = 0 A
b) $I$ = 5 A
c) $I$ = 15 A
d) $I$ = 20 A
e) $I$ = 2.5 A

$\tau(LR) = \frac{L}{R} = \frac{2\times10^{-6}\,H}{2\Omega}$

$= 10^{-6}s \ll 1s \Rightarrow$ full current in top loop

$I = V/R = 10V/2\Omega = 5A$

22. An electromagnetic standing wave in air has a frequency $f$ = 30 MHz. What is the distance $\Delta x$ between a nodal plane of the electric field $\vec{E}$ and the closest nodal plane of the magnetic field $\vec{B}$? Note $c = 3 \times 10^8$ m/s.

a) $\Delta x$ = 10 m
b) $\Delta x$ = 1.0 m
c) $\Delta x$ = 5 m
d) Need to be given the wavelength of the standing wave.
e) $\Delta x$ = 2.5 m

distance between node of E wave and node of B wave $= \lambda/4$

$\lambda = v/f = \frac{3\times10^{8}\,m/s}{30\times10^{-6}\,1/s} = 10m.$

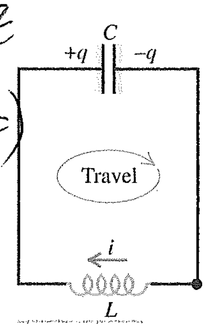
$\lambda/4 = 2{,}5\,m$

25. In the L-C circuit in the figure, the inductance $L = 0.5$ H and the capacitance $C = 4$ $\mu$F. At the instant when the current in the inductor is changing at a rate of $dI/dt$=3 A/s, what is the magnitude $Q$ of the charge on the capacitor?

$$V_C = \frac{Q}{C} = V_L = L\frac{dI}{dt}$$

$$Q = \left(\tfrac{1}{2}H\right)\left(\tfrac{3A}{s}\right)\left(4\times10^{-6}F\right)$$

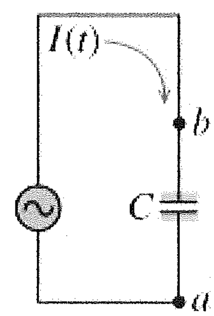
$$= 6\times10^{-6}\,C$$




a) $Q = 6 \times 10^{-6}$ C
b) $Q = 6 \times 10^{-9}$ C
c) $Q = 12 \times 10^{-6}$ C
d) $Q = 12 \times 10^{-9}$ C
e) $Q = 2 \times 10^{-6}$ C

26. In the figure a circuit is displayed with a voltage source that varies as a function of time $V(t) = V_0\cos(\omega t)$. Which of the following statements is FALSE?

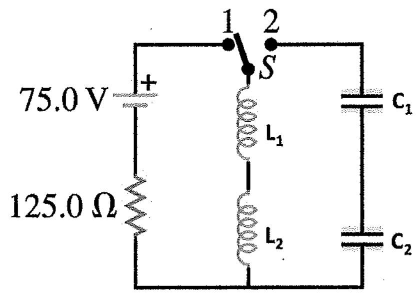
a) When the alternating voltage $V_C(t)$ across the capacitor is zero, the magnitude of the current $I(t)$ must be a maximum. TRUE
b) When the charge $Q$ on the capacitor is maximum, the current must be zero. TRUE
c) When $V_b > V_a$ the current $I$ may be directed either clockwise or counterclockwise. TRUE
d) The current through the capacitor is given by $I_C(t) = V_0\omega C\cos(\omega t + \pi/2)$ TRUE
e) When $V_b > V_a$ the derivative of the current $dI(t)/dt$ is positive. FALSE




Voltage drop across C does not depend on $\frac{dI(t)}{dt}$.

27. In the circuit in the figure, neither the battery nor the inductors have any appreciable resistance, the capacitors are initially uncharged and the switch $S$ has been in position 1 for a very long time. $L_1 = 2L_2 = 2L$; $C_1 = C_2 = C$. The switch is now suddenly switched to position 2. What is the angular frequency $\omega$ of this circuit? $L_{eq} = L_1 + L_2 = 3L$

$$\omega = \frac{1}{\sqrt{L_{eq}C_{eq}}} = \frac{1}{\sqrt{(3L)(C/2)}}$$




a) $\omega = \sqrt{LC}$
b) $\omega = 1/(\sqrt{LC})$
c) $\omega = 6LC$
d) $\omega = 1/(\sqrt{3LC/2})$
e) $\omega = 1/(\sqrt{6LC})$

$C_{eq} = \frac{C}{2}$

28. An intense light source radiates uniformly in all directions. At a distance $r$ from the source, the radiation pressure on a perfectly absorbing surface is $p_{rad}$ and the intensity is $I$. What is the total average power output $P_{av}$ of the source?

tot ally absorbing

$p_{rad} = \frac{S}{c} = \frac{P_{av}}{cA} = \frac{P_{av}}{c(4\pi r^2)}$

$P_{av} = c\,p_{rad}(4\pi r^2)$

a) $P_{av} = cp_{rad}$
b) $P_{av} = cp_{rad}(4\pi r^2)$
c) $P_{av} = 2cp_{rad}(4\pi r^2)$
d) $P_{av} = cp_{rad}(2\pi r)$
e) $P_{av} = 2cp_{rad}$

29. A positive point charge is moving directly towards point P with velocity $v$. Which of the following statements about the magnetic field that the point charge produces at point P is TRUE?

a) The magnetic field that the point charge produces at P points from the charge toward point P. FALSE
b) The magnetic field that the point charge produces at P points from point P toward the charge. FALSE
c) The magnetic field that the point charge produces at P is perpendicular to the line from the point charge to point P. FALSE
d) The magnetic field that the point charge produces at P is zero. TRUE
e) The answer depends on the speed of the point charge. FALSE

$\vec{B}(r) = \frac{\mu_0}{4\pi} q \frac{\vec{v} \times \hat{r}}{r^2}$ $\quad$ $\vec{v}$ & $\hat{r}$ are in same direction $\Rightarrow \vec{B} = 0$

30. You are given two metals. Metal A has $\rho_A = 20 \times 10^{-8}$ $\Omega$-m and Metal B has $\rho_B = 5 \times 10^{-8}$ $\Omega$-m. What diameter $d_B$ of a Metal B wire has the same resistance as a wire of the same length of Metal A with $d_A = 4$ mm?

a) $d_B = 2$ mm
b) $d_B = 4$ mm
c) $d_B = 1$ mm
d) $d_B = 0.5$ mm
e) $d_B = 0.25$ mm

$$R_A = \frac{\rho_A L}{A_A} = \frac{\rho_A L}{(\pi)\left(\frac{d_A}{2}\right)^2} = R_B = \frac{\rho_B L}{\pi\left(\frac{d_B}{2}\right)^2}$$

$$\left(\frac{d_B}{d_A}\right)^2 = \frac{\rho_B}{\rho_A} = \frac{5 \times 10^{-8}\ \Omega - m}{20 \times 10^{-8}\ \Omega - m} = \frac{1}{4}$$

$$d_B = \sqrt{\tfrac{1}{4}}\, d_A = \left(\tfrac{1}{2}\right)(4\,mm) = 2\,mm.$$