Physics 227 - Final Exam

December 20, 2005

Prof. Coleman and Dr. Francis

$\Longrightarrow$ Your name sticker with **exam code** $\Longrightarrow$

Your signature ____________________

Turn off and put away cell phones now!

1. The exam will last from 4:00 PM to 7:00 PM. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.

2. In the section labeled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.

3. Under STUDENT # enter your 9-digit student ID.

4. Enter 227 under COURSE, and your section number (see label above) under SEC.

5. Under CODE enter the exam code given above.

6. During the exam, you may use pencils, a calculator, and one **handwritten** 8.5 x 11 inch sheet with formulas and notes, without attachments.

7. There are 30 multiple-choice questions on the exam. Mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. **At the end of the exam, hand in the answer sheet and the cover page.** Retain this question paper for future reference and study.

8. When you are asked to open the exam, make sure that your copy contains all 30 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.

9. Please SIGN the cover sheet under your name sticker and have your student ID ready to show to the proctor during the exam.

Some possibly useful information:

c = speed of light = 3.00×10^8 m/s

$q_e = -e$ = charge on an electron = -1.602×10^{-19} Coulombs

$q_p = +e$ = charge on a proton = $+1.602 \times 10^{-19}$ Coulombs

m_e = electron mass = 9.11×10^{-31} kg

m_p = proton mass = 1.67×10^{-27} kg

$k_e = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$

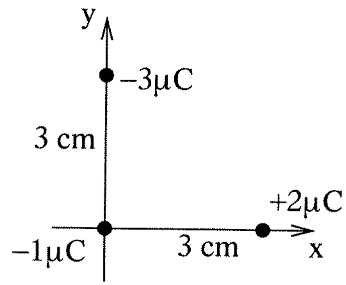
$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$

$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$

$g = 9.80\ \mathrm{m/s^2}$

1 mHz = 10^{-3} Hz	1 kHz = 10^{+3} Hz
1 MHz = 10^{+6} Hz	1 GHz = 10^{+9} Hz
1 mC = 10^{-3} C	1 μC = 10^{-6} C
1 nC = 10^{-9} C	1 pC = 10^{-12} C

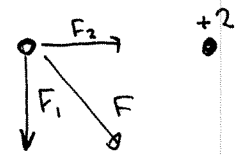
119. A charge of $+2.0\mu C$ is fixed on the x-axis at x = 3 cm, while a charge of $-3.0\mu C$ is fixed on the y-axis at y = 3 cm. The force on a third charge of $-1.0\mu C$ placed at the origin is of magnitude



a. 10 N
b. 20 N
c. 30 N
d. 50 N
e. 36.1 N

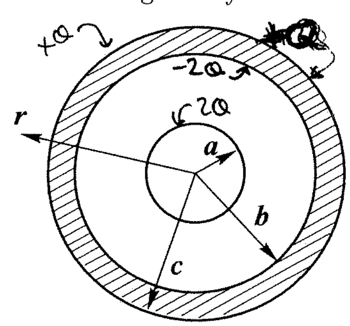
$$F_1 = \frac{k \times 3 \times 1 \times 10^{-12}}{(3\times10^{-2})^2} = \frac{9\times10^9 \times 3\times10^{-12}}{9\times10^{-4}} = 30N$$

$$F_2 = \frac{k \times 2\times10^{-12}}{(3\times10^{-2})^2} = 20N$$

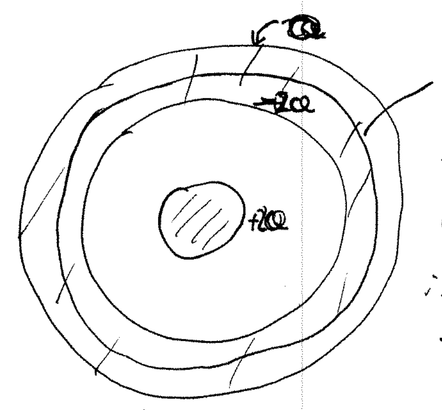


$$F = \sqrt{F_1^2 + F_2^2} = \sqrt{20^2 + 30^2} = \underline{36.1N}$$

161. A solid conducting sphere of radius a carries a charge $+2Q$. A conducting spherical shell of inner radius b and outer radius c is concentric with the solid sphere and carries a net charge $-Q$. The charge on the inside surface of the shell and the magnitude of the electric field for $r > c$ are given by



a) $-2Q,\quad +2kQ/r^2$
b) $+Q,\quad +2kQ/r^2$
c) $-2Q,\quad +kQ/r^2$
d) $+2Q,\quad +kQ/r^2$
e) $-Q,\quad +kQ/r^2$



$\oint E.dA = 0$

$\Rightarrow Q_{encl} = 0$

$Q_{encl} = 2Q + Q'$

$\therefore \underline{\underline{Q' = -2Q}}$

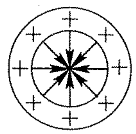
$-2Q$ inside shell,

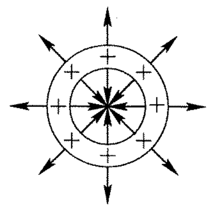
$$E = \frac{kQ}{r^2}$$

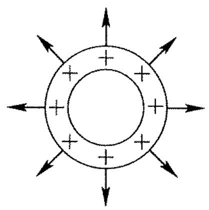
$$\oint E.dA = \frac{2Q - Q}{\epsilon_0}$$

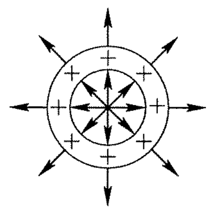
$$4\pi r^2 E = \frac{Q}{\epsilon_0}$$

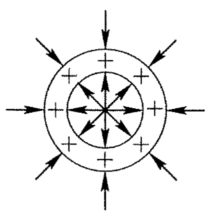
447. A very long hollow lucite tube is rubbed with cat's fur so that it acquires a net positive charge that is uniformly distributed on its surface. Looking down the end of the tube, which diagram best represents the electric field lines near the tube?

a) 

b) 

c) 

d) 

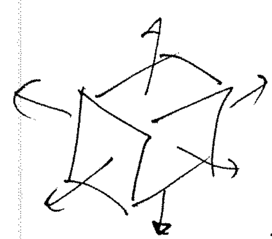
e) 

$E = 0$ inside tube since

$\int E \cdot dS = 0$ on any Gaussian surface.

209. A point charge of $+10.0\mu C$ is located at the center of a cube with edge 0.0200 m. What is the flux of electric field through one face of the cube?

a) 1.88×10^5 Nm^2/C
b) 1.68×10^4 Nm^2/C
c) -7.12×10^4 Nm^2/C
d) -1.68×10^4 Nm^2/C
e) none of the above

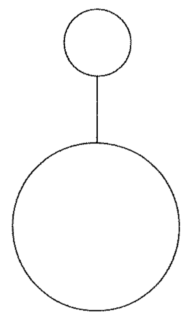


$\Phi_{TOT} = 6\Phi = \frac{Q}{\epsilon_0}$

$\Phi = \frac{1}{6}\left(\frac{10 \times 10^{-6}}{\epsilon_0}\right) = \frac{10 \times 10^{-6}}{6 \times (8.854 \times 10^{-12})} = 1.88 \times 10^5 \frac{Nm^2}{C}$.

113. Two conducting, hollow spheres have different radii. A thin, conducting wire connects the spheres. A charge Q is placed on the smaller sphere. Then,

a) charge will flow until the spheres have equal potentials.
b) charge will flow until the spheres have equal charges.
c) all of the charge will flow to the larger sphere.
d) charge will flow until the spheres have equal electric fields at their surfaces.
e) There will be no flow of charge, so the charge Q will remain on the smaller sphere.



In equilibrium, potential @ surface of a conductor is constant – equipotential.

227. What is the total potential energy (energy of assembly) of the charge configuration shown?

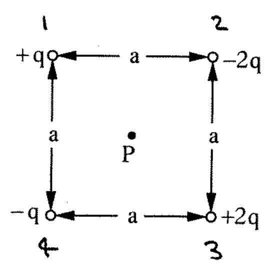
a) $\frac{6kq^2}{a}$

b) $\frac{-5kq^2}{a} + \frac{4kq^2}{\sqrt{2}a}$

c) $\frac{-4kq^2}{a} + \frac{4kq^2}{\sqrt{2}a}$

d) $\frac{-9kq^2}{a} + \frac{4kq^2}{\sqrt{2}a}$

e) 0



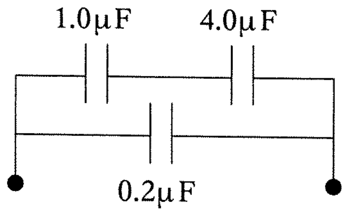
$$U = \sum_{i,j} U_{ij} \qquad U_{ij} = \frac{k q_i q_j}{r_{ij}}$$

$$U_{sides} = U_{12} + U_{23} + U_{34} + U_{41}$$
$$= \frac{kq^2}{a}\left(-2 - 4 - 2 - 1\right) = -\frac{9kq^2}{a}$$

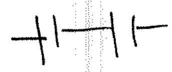
$$U_{DIAG} = U_{13} + U_{24} = \frac{kq^2}{\sqrt{2}a}\left(2+2\right) = +\frac{4kq^2}{\sqrt{2}a}$$

$$U = \left(-9 + \frac{4}{\sqrt{2}}\right)\frac{kq^2}{a}.$$

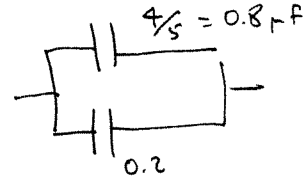
118. The equivalent capacitance of the three capacitors is



a) $0.16\mu F$
b) $0.19\mu F$
c) $1.00\mu F$
d) $5.20\mu F$
e) $6.25\mu F$



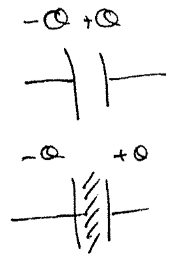
$: \frac{1}{1} + \frac{1}{4} = \frac{5}{4} \Rightarrow C = \frac{4}{5}\,\mu F$



$0.2 + 0.8 = \underline{1\,\mu F}$

111. A parallel-plate capacitor is charged and then disconnected from the charging battery. A dielectric slab is inserted in the gap between the capacitor plates. As a result,

a) the capacitance stays the same, while the electric field decreases
b) the capacitance stays the same, while the electric field increases
c) the capacitance and electric field both increase
d) the capacitance increases, while the electric field decreases
e) the capacitance and electric field both decrease



charge is conserved

C increases $C \to C\epsilon$

$V = \frac{Q}{C} \to \frac{Q}{C\epsilon} = \frac{V}{\epsilon}$

$\underline{V \downarrow}$ $\underline{E \downarrow}$ (d)

238. A cylindrical copper wire (resistivity $= 1.70 \times 10^{-8}\,\Omega \cdot \mathrm{m}$) with a diameter of 1×10^{-3} m and 0.01 m long is used to connect two points on a printed circuit board at room temperature. If the current in the wire is 10 mA, what is the potential drop across the wire?

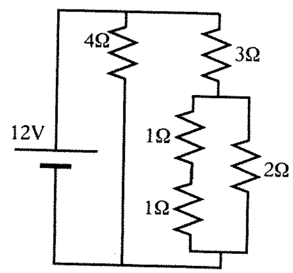
a) $0.54\ \mu V$
b) $2.16\ \mu V$
c) $5.4\ \mu V$
d) 2.16 mV
e) 5.4 mV

$R = \frac{\rho L}{A} = \frac{1.7 \times 10^{-8} \times 0.01}{\pi \times (0.5 \times 10^{-3})^2} = 2.16 \times 10^{-4}\,\Omega$

$V = IR = 10^{-2}A \times 2.16 \times 10^{-4}$

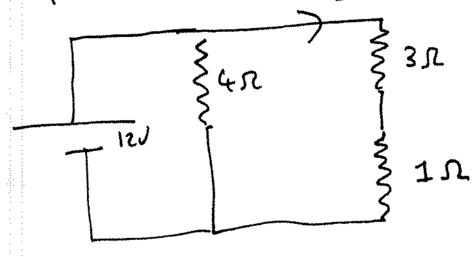
$= 2.16 \times 10^{-6}\,V \equiv \underline{2.16\,\mu V}$

73. In the circuit shown, what is the current through the 2Ω resistor?



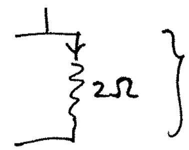
a) 1.5 A
b) 1.0 A
c) 2.0 A
d) 3.0 A
e) 2.5 A

Equivalent circuit



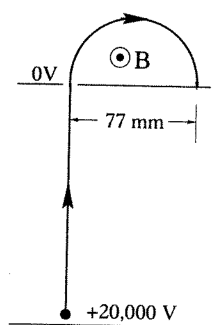
$I = \frac{12}{4} = 3A$

$V = 3 \times 1 = 3V$



$I = \frac{3}{2} = 1.5A$

639. A positive ion is produced at rest from the filament of a vacuum tube which is at an electric potential of +20,000 V, relative to ground. It accelerates in the y direction towards a cathode, which is grounded, and then passes through the cathode into a region with a uniform magnetic field of 0.75 T in the z direction. In this region it makes a semicircular path of diameter 0.077 m. The ion has a charge-to-mass ratio q/m of



a. 9.6×10^{7} C/m
b. 4.8×10^{7} C/m
c 2.4×10^{7} C/m
d. 1.2×10^{7} C/m
e. 2.1×10^{-8} C/m

$$\frac{mv^2}{2} = qV \Rightarrow \left(\frac{q}{m}\right)V = \frac{v^2}{2} \quad (1)$$

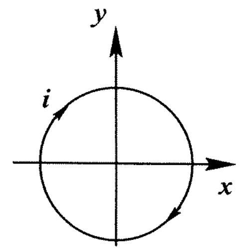
$$\frac{mv^2}{r} = qvB \Rightarrow v = \left(\frac{q}{m}\right) rB \quad (2)$$

$$\frac{q}{m} V = \left(\frac{q}{m}\right)^2 \frac{r^2 B^2}{2}$$

$$\Rightarrow \left(\frac{q}{m}\right) = \frac{2V}{(rB)^2} = \frac{2\times 20{,}000}{(3.85\times10^{-2}\times 0.75)^2}$$

$$= 4.8\times10^{7} \text{ C/kg.}$$

174. A 20 loop circular coil of radius 5.0 cm lies in the x-y plane in a uniform magnetic field of magnitude 0.80 T in the $+x$ direction. The current in the loop is 6.0 A (as shown in the figure). The magnitude of the torque acting on the coil is

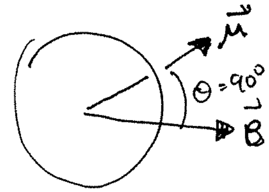


The z-axis is coming out of the page.

a) 0.25 Nm
b) 0.50 Nm
c) 0.75 Nm
d) 1.5 Nm
e) none of the others

$\tau = \mu B \sin\theta = IABN$

(NAI)

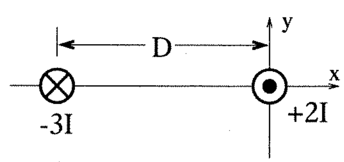


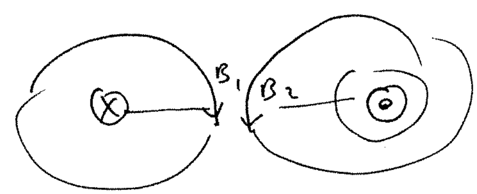
$\tau = 6 \times \pi \times (5 \times 10^{-2})^2 \times (0.8\,T) \times 20$

$= \underline{\underline{0.75\ Nm}}$

134. At $x = 0$, a long straight wire carries current $2I$ **out** of the plane of the paper. At $x = -D$, another long straight wire carries current $3I$ **into** the plane of the paper. Midway between them, *i.e.*at $x = -D/2$, what is the magnetic field?

a) $\mu_0 I/\pi D$ in the positive y-direction
b) $\mu_0 I/\pi D$ in the negative y-direction
c) Zero
d) $5\mu_0 I/\pi D$ in the positive y-direction
e) $5\mu_0 I/\pi D$ in the negative y-direction

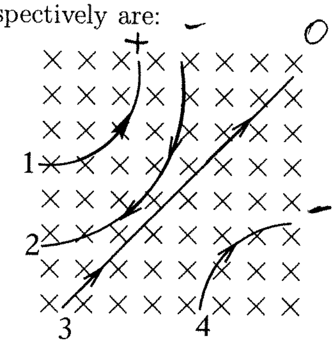




$B = B_1 + B_2 = \frac{\mu_0 3I}{2\pi(D/2)} + \frac{\mu_0 (2I)}{2\pi(D/2)}$

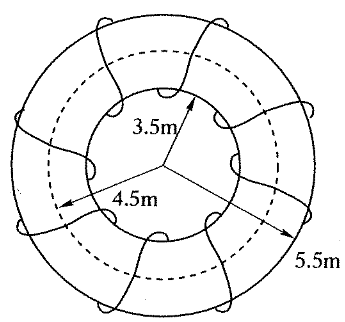
$= \frac{5\mu_0 I}{\pi D}$ in $-ve$ y direction.

239. Four particles follow the paths as shown as they pass through a magnetic field. All the paths are in the plane of the paper and the magnetic field is perpendicular to this plane, directed into the paper as indicated by the $\times$'s. The signs of the charges carried by particles 1, 2, 3 and 4 respectively are:



a. +, 0, −, +
b. −, +, 0, −
c. −, +, 0, +
d. +, +, 0, −
e. +, −, 0, −

396. A Tokamak Fusion Test Reactor has a magnetic field generated by a 1600-turn toroidal coil as shown. The inner and outer radii of the toroidal coil are $a = 3.5$ m and $b = 5.5$ m, respectively. In operating, a current of 73,000 amperes is passed through the coil. What is the magnitude of the magnetic field at the midpoint of the toroid, i.e. at a radius of 4.5 m?



a) 5.2 T
b) 23.4 T
c) 0.19 T
d) 9.0×10^{-8} T
e) 10.6 T

$2\pi r B = \mu_0 N I$

$B = \frac{\mu_0 N I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 1600 \times 73000}{2 \times \pi \times 4.5\,m.}$

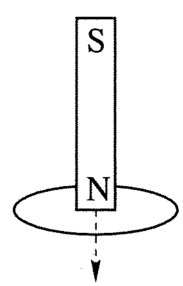
$= 5.2T$

93. Which of the following is **not** true?

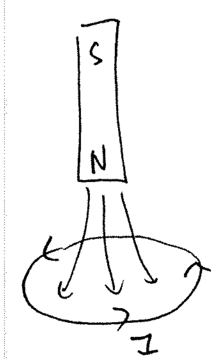
a) The magnetic flux through a closed surface is always zero.
b) Maxwell's displacement current must be added to the ordinary current in Ampere's law to make the law complete.
c) Changing electric fields give rise to magnetic fields, and changing magnetic fields give rise to electric fields.
d) Maxwell's displacement current is necessary for the existence of electromagnetic waves.
e) Maxwell's displacement current exists only where a magnetic field changes with time.

$I = \epsilon_0 \frac{\partial \Phi_E}{\partial t}$ – changing E-field.

87. A bar magnet with its north end down is dropped through a circular loop of wire from far above. Magnetic field lines leave the magnet through its north end and enter the magnet through its south end. Seen from above, the direction of the current induced in the loop will

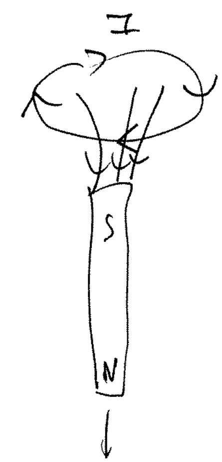


a) first be counterclockwise and later clockwise.
b) be nonexistent.
c) always be counterclockwise.
d) always be clockwise.
e) first be clockwise and later counterclockwise.



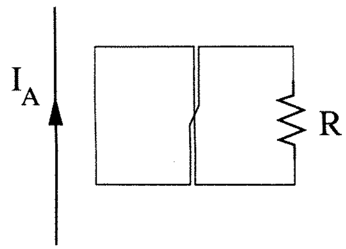
Flux down is increasing
∴ I counterclockwise

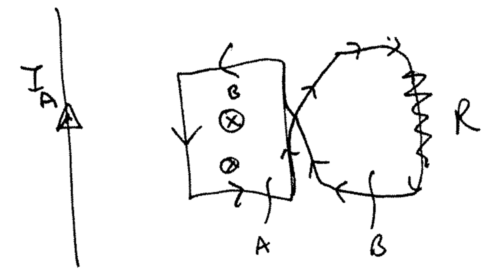
Flux down is decreasing ∴
I clockwise



265. A long straight wire and a circuit are in the same plane as shown. The circuit contains two loops of equal area separated by a twist. An increasing current I_A flows in the wire in the direction indicated by the arrow. In what direction does the current in the circuit, I_c, flow through resistor R?

a) Up
b) Down
c) Neither, $I_c = 0$
d) Depends on the magnitude of I_A.
e) Not enough information.

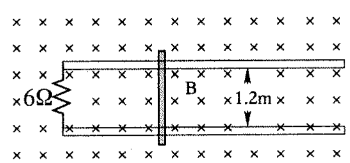




B-field through A dominates flux. Flux increasing ⇒ current must flow down through R to oppose change producing it

462. A conducting bar can slide without friction across two parallel metal rails that are separated by 1.2m and connected by a 6Ω resistor as shown. A uniform magnetic field of 2.5 T is oriented perpendicular to the page. At what speed should the bar be moved to produce a current of 0.5A in the resistor?

a) (1.6×10^{-6}) m/s
b) (1×10^{-7}) m/s
c) (3.33×10^{-3}) m/s
d) 1.0 m/s
e) 31.4 m/s



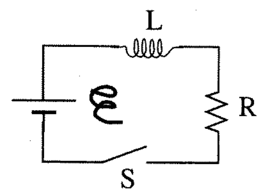
$$\mathcal{E} = \left| \frac{d\Phi_B}{dt} \right| = vBL$$

$$I = \frac{\mathcal{E}}{R} = \frac{vBL}{R}$$

$$\Rightarrow v = \frac{IR}{BL} = \frac{0.5 \times 6}{2.5 \times 1.2m} = \underline{\underline{1 m/s}}$$

55. When the switch in this LR circuit is closed, the current does not immediately jump to its ultimate value of $\mathcal{E}/R$. Which of these reasons is correct?
(i) The energy in the magnetic field of the inductor cannot change discontinuously.
(ii) The increasing current in the inductor produces an EMF which opposes the EMF of the battery.
(iii) The resistor opposes too rapid a change in the current through it.

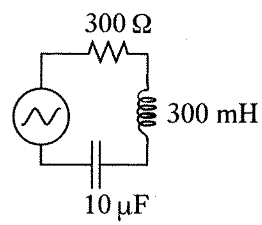
a) only (i) is correct.
b) only (ii) is correct.
~~c)~~ only (iii) is correct.
d) (i) and (ii) are correct, (iii) is not.
e) all three reasons are correct.



i) ✓
ii) ✓
iii) FALSE.

62. A series RLC circuit with $R = 300\Omega$, $L = 300$ mH, $C = 10\mu$F, is driven by an applied voltage of (170V) sin(377t), where t is in seconds. The maximum current through the circuit is

a) 0.505 A
~~b)~~ 0.566 A
c) 0.407 A
d) 0.352 A
e) 0.944 A



$I X = V$

$X = \sqrt{R^2 + (X_L - X_C)^2}$

$X_L = \omega L = 113\Omega$

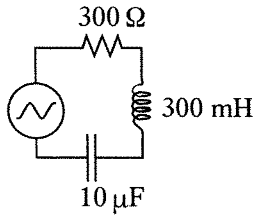
$X_C = 1/\omega C = 265\Omega$

$X = \sqrt{(300)^2 + (-152)^2} = 336\Omega$

$I = 170/336 = 0.505$ A.

63. A series RLC circuit with $R = 300\Omega$, $L = 300$ mH, $C = 10\mu F$, is driven by an applied voltage of (170V) sin(377t), where t is in seconds. In this circuit

a) the current lags behind the applied voltage by 27°.
b) the current leads the applied voltage by 27°.
c) the current and the applied voltage are in phase.
d) the current leads the applied voltage by 44°.
e) the current lags behind the applied voltage by 44°.



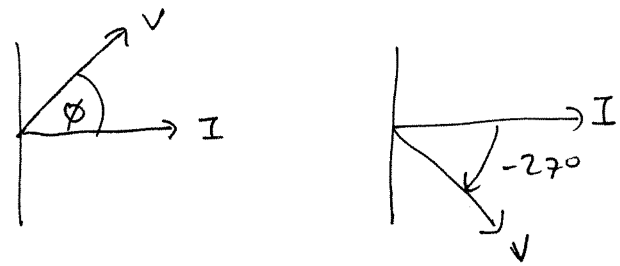
$X_L = \omega L = 377 \times 300\times10$

$= 113\,\Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{377 \times 10 \times 10^{-6}} = 265\,\Omega$

$\phi = \tan^{-1} \frac{X_L - X_C}{R} = \tan^{-1}(0.503) = -26.86^\circ$

$= -27^\circ$



Current leads voltage by 27°

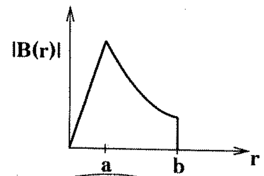
126. The maximum energy that can be stored in an 0.4 mH inductor is 0.01 J. What maximum current can the inductor carry?

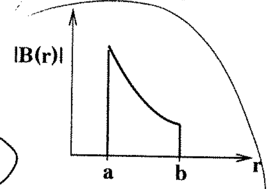
a) 7.1 A b) 50.0 A c) 25.0 A d) 5.0 A
e) 3.5 A

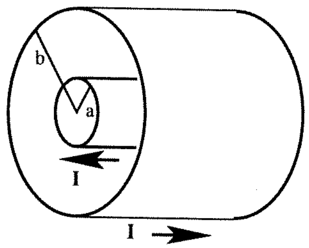
$U = \frac{1}{2} L I^2 \Rightarrow I = \sqrt{\frac{2U}{L}}$

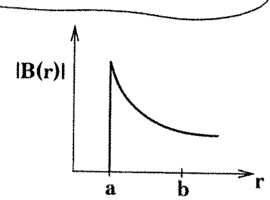
$I = \sqrt{\frac{2 \times (1 \times 10^{-2})}{(4 \times 10^{-4})}} = \underline{7.1\,A}$

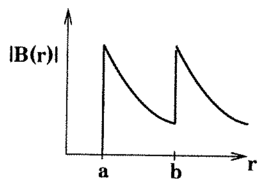
32. Two *hollow* coaxial cylindrical conductors (one inside the other) are carrying an equal current I in opposite directions. The inner cylinder has a radius of a, the outer cylinder has a radius of b, and the current is distributed evenly over the surface of both. Which plot best describes the magnitude of the magnetic field, as a function of distance from the axis?

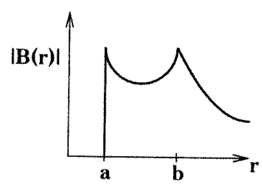
a. 

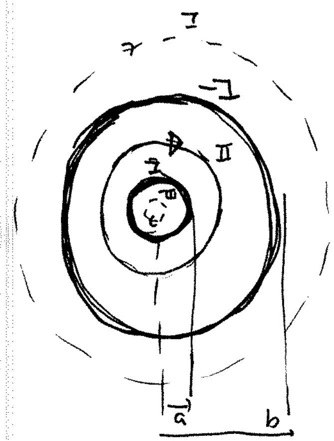
b. 



c. 

d. 

e. 



$$\oint_{I} \vec{B}\cdot d\vec{\ell} = \mu_0 \times (I - I) = 0 \qquad r > a$$

$$\Rightarrow B = 0 \quad r > 0$$

$$\oint_{II} B\cdot d\ell = \mu_0 I = B \times 2\pi r$$

$$\Rightarrow B = \frac{\mu_0 I}{2\pi r}$$

$$\oint_{III} B\cdot d\ell = 0 \qquad \Rightarrow B = 0 \quad r \not> b$$

633. A laser beam consists of a polarized beam of electromagnetic radiation with spot diameter 4mm, and magnetic field of amplitude 1mT. When it shines on a mirror surface, what ~~pressure~~ Force. does it exert?

a) 10μN b) 40μN c) 5μN d) 3×10^3N
e) 3.3×10^{-12}N

$$\overline{\quad c \quad}$$

$$S_{av} = \frac{1}{\mu_0}\frac{EB}{2} = \frac{cB^2}{2\mu_0}$$

$$P = \frac{2B^2}{2\mu_0} = \frac{B^2}{\mu_0} = \frac{(10^{-3})^2}{4\pi\times10^{-7}}$$

$$= \frac{(10^{-3})^2\times\pi(2\times10^{-3})^2}{4\pi\times10^{-7}} = 10^{-5}\text{N} = \underline{\underline{10\mu\text{N}}}.$$

634. An LC (series) circuit contains a $1pF$ capacitor in series with an inductor. It resonates at $101.5MHz$. What is the value of the inductance in the circuit?

a) 2.46μH
b) 97.1μ H
c) 2.46mH
d) 2.46×10^6H
e) 1.56kH

$$\omega = \frac{1}{\sqrt{LC}}$$

$$\Rightarrow L = \frac{1}{C(2\pi f)^2} = \frac{1}{10^{-12}\times(2\pi\times101.5\times10^6)^2}$$

$$= 2.46\times10^{-6}\text{H}$$
$$\equiv \underline{\underline{2.46\mu\text{H}}}$$

637. An electromagnetic wave has a magnetic field of form $\mathbf{B} = B_0\sin(\omega t + kz)\hat{\mathbf{x}}$. What direction is the Poynting vector?

a) $+y$-direction
b) $-y$-direction
c) $+z$-direction
d) $-z$-direction
e) $+x$-direction

$\phi = \omega t + kz$ is constant at $z = -\frac{\omega}{k}t + \text{cons}$

$\Rightarrow$ moving in $-$ve z direction.

$\therefore \vec{P} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$ in $\underline{\underline{-\text{ve } z \text{ direction.}}}$

139. The current in a solenoid increases steadily from 0 to 10 mA in 40 ms. If the self-induced emf is 8×10^{-4} V, what is the solenoid's inductance?

a) 0.2 mH
b) 3.2 mH
c) 8.0 mH
d) 0.8 mH
e) Cannot be determined from the information given

$$\mathcal{E} = -L\frac{dI}{dt} \Rightarrow L = \frac{|\mathcal{E}|}{dI/dt} =$$

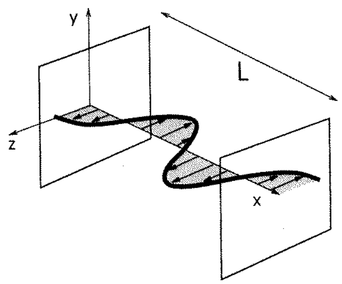
$$= \frac{8\times10^{-4}}{(10\times10^{-3}/40\times10^{-3})}$$

$$= 3.2\times10^{-3}\text{H}$$

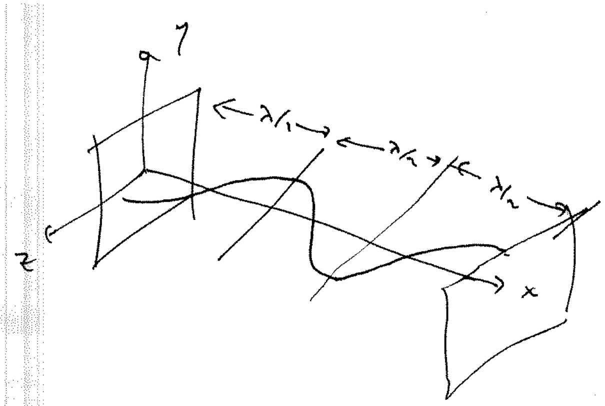
$$\equiv \underline{\underline{3.2\text{mH}.}}$$

35. A standing electromagnetic wave of wavelength λ is set up in a cavity of length L aligned along the $x-$ axis as shown in the figure below. One of the electromagnetic fields in the cavity is aligned along the $z-$ axis, as shown below, but you are not informed whether it is the electric, or the magnetic field. Which of the following is true?

a. This is the third harmonic of the cavity, with $\lambda = \frac{2}{3}L$, the magnetic field is polarized along the z axis.
b. This is the third harmonic of the cavity, with $\lambda = \frac{2}{3}L$ and the electric field is polarized along the z axis.



c. This is the third harmonic of the cavity, with $\lambda = \frac{1}{3}L$ and the electric field is polarized along the z axis.
d. This is the third harmonic of the cavity, with $\lambda = \frac{1}{3}L$, the magnetic field is polarized along the z axis.
e. This is the second harmonic of the cavity, with $\lambda = L$ and the electric field polarized along the z axis.

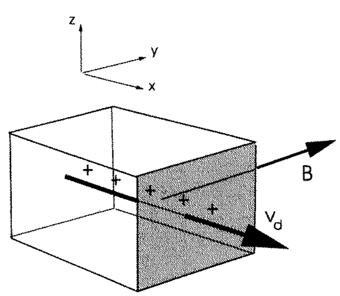


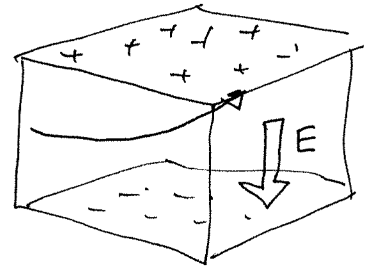
$L = 3 \times \lambda/_2 \Rightarrow n = 3. \Rightarrow \lambda = 2/_3 L.$

B - field (non zero at mirrors) along z axis

636. A current of positively charged carriers flows along the x-direction with a drift velocity of $0.01mm/s$ in a semiconductor that is immersed in a field of 10T oriented in the y direction, as shown below. What is the electric field that is induced as a consequence of the Hall effect?

a. $\mathbf{E} = -10^{-4}\hat{\mathbf{k}}\ V/m$
b. $\mathbf{E} = 10^{-4}\hat{\mathbf{k}}\ V/m$
c. $\mathbf{E} = 10^{6}\hat{\mathbf{k}}\ V/m$
d. $\mathbf{E} = -0.1\hat{\mathbf{k}}\ V/m$
e. $\mathbf{E} = 0.1\hat{\mathbf{k}}\ V/m$





$E = vB$

$= (0.01 \times 10^{-3} m/s) \times 10T = 10^{-4} V/m$

$\vec{E} = -10^{-4}\hat{k}\ V/m.$