Last Name: First Name:

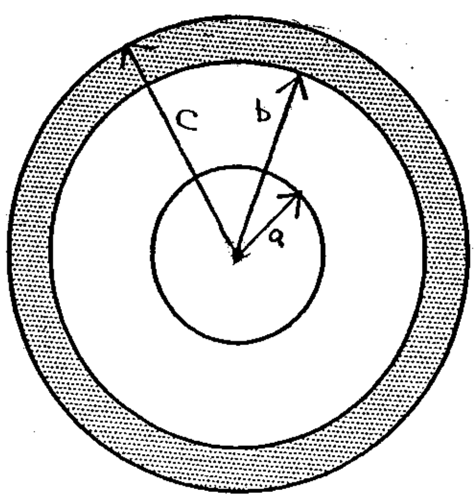
Physics 102 Spring 2005: Final Exam, May 6, 2005
Free Response and Instructions

- Print your LAST and FIRST name on the front of your blue book, on this question sheet, the multiple-choice question sheet and the multiple-choice answer sheet.
- TIME ALLOWED 3 HOURS
- The test consists of three free-response questions and 25 multiple-choice questions.
- The test is graded on a scale of 180 points; the free-response questions account for 105 points (35 points each), and the multiple-choice questions account for 75 points (3 points each).
- Answer the three free-response questions in your blue book. Answer the multiple-choice questions by marking a dark X in the appropriate column and row in the table on the multiple-choice answer sheet.
- Consult no books or notes of any kind. You may use a hand-held calculator in non-graphing, non-programmed mode.
- Do NOT take test materials outside of the class at any time. Return this question sheet along with your blue book and multiple-choice question sheet.
- Write and sign the Pledge on the front of your blue book.

Show your work for the free-response problems, including neat and clearly labeled figures, in your blue book. Answers without explanation (even correct answers) will not be given credit.

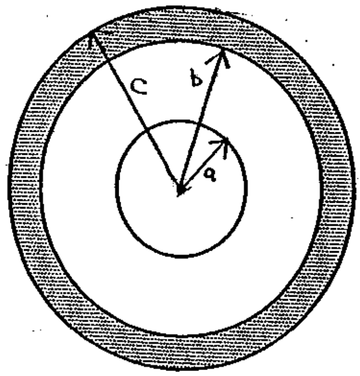
I. A nonconductiong spherical shell of radius a and negligible thickness is centered at the origin. It carries a net positive charge of $+3Q$, uniformly distributed over its surface. A second, larger spherical shell is also centered at the origin and has inner radius b and outer radius c. The outer shell is made of a conducting material and has zero net charge. The coordinate r measures the distance from the origin.

(a) Determine the electric field $\vec{E}(r)$ for all values of r. Sketch $|\vec{E}(r)|$ vs. r.
(b) Take the zero of the electrostatic potential $V(r)$ to be at infinity. Determine $V(r)$ for all values of r. Sketch $V(r)$ vs. r.
(c) Determine the total electrostatic energy U_E contained in the electric field for all r.



Phys 102
Final Exam - Spring 2005

I.



(a) $\vec{E}(r)$ for all r.

for $r < a$, $\vec{E} = 0$ by Gauss' Law. The charge distribution is spherically symmetric, and $Q_{encl} = 0$.

$$\oint \vec{E}\cdot d\vec{A} = 4\pi r^2 E = 0 \Rightarrow E = 0$$

for $a < r < b$,

$$\oint \vec{E}\cdot d\vec{A} = 4\pi r^2 E_r = \frac{Q_{encl}}{\varepsilon_0} = \frac{3Q}{\varepsilon_0}$$

for $a < r < b$

$$\vec{E}(r) = \frac{3Q}{4\pi\varepsilon_0 r^2}\hat{r}$$

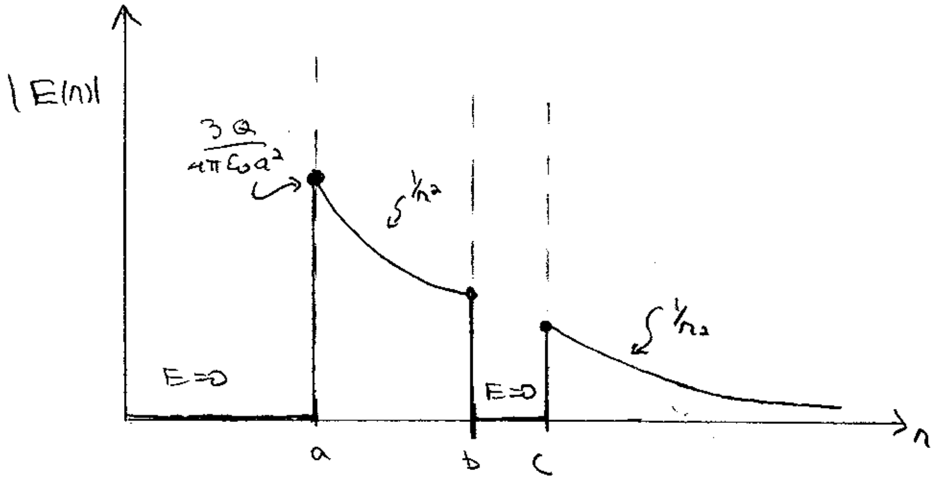
Field is everywhere radially outward

for $b < r < c$, $\vec{E} = 0$ since this region is inside a conductor.

for $r > c$, the net charge enclosed $= 3Q$ since the net charge on the conductor $= 0$.

$$\vec{E} = \frac{3Q}{4\pi\varepsilon_0 r^2}\hat{r} \qquad r > c$$

· Note: Although the problem doesn't ask this, the conductor must have $-3Q$ on the inner surface & $+3Q$ on the outer surface.



(b) Determine $V(r)$ for all r. $V(\infty)=0$.

It's easiest to start at large r & work inward.

Outside a spherically symmetric charge distribution, $\vec{E}$ & V are the same as for a point charge at the center:

$$V(r) = \frac{3Q}{4\pi\epsilon_0 r} \quad r > c$$

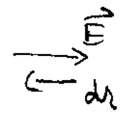
Inside the conductor, $\vec{E}=0$ and $\Delta V = 0$, that is, the change in potential $=0$.

$V(r=c) = \dfrac{3Q}{4\pi\epsilon_0 c}$ and this must be the potential at every point inside the conductor, since $V=$ constant inside a conductor

$$V(r) = \frac{3Q}{4\pi\epsilon_0 c} \quad b < r < c$$

for $a<r<b$, we can determine $V(r)$ by finding ΔV & adding it to $V(r=b) = \frac{3Q}{4\pi\varepsilon_0 c}$.

$$\Delta V = -\int_r^b \vec{E}\cdot d\vec{l}$$



(ΔV from b to r)

$\vec{E}\cdot d\vec{r} = -E\,dr$ since $\vec{E}$ & $d\vec{r}$ are antiparallel.

$$\Delta V \quad \int_r^b \frac{3Q}{4\pi\varepsilon_0 r^2}\,dr$$

$$\Delta V = \frac{3Q}{4\pi\varepsilon_0}\left(-\frac{1}{r}\right)_r^b = -\frac{3Q}{4\pi\varepsilon_0}\left(\frac{1}{b}-\frac{1}{r}\right) = \frac{3Q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{b}\right)$$

Check sign: V must be increasing as we move from $b \to r$, since we are moving against $\vec{E}$; potential energy of a positive charge & therefore potential are increasing. ΔV above has the right sign since $r<b$.

Now add ΔV to $V(r=c)$

$a<r<b \qquad V(r) = \frac{3Q}{4\pi\varepsilon_0 c} + \frac{3Q}{4\pi\varepsilon_0 r} - \frac{3Q}{4\pi\varepsilon_0 b}$

$a<r<b \qquad \boxed{V(r) = \frac{3Q}{4\pi\varepsilon_0}\left[\frac{1}{r}+\frac{1}{c}-\frac{1}{b}\right]}$

Alternative solution: match $V(r)$ at $r=b$.

$V(a<r<b) = \frac{3Q}{4\pi\varepsilon_0 r} + K \qquad$ where $K =$ constant

We also know $V(r)$ is continuous, so

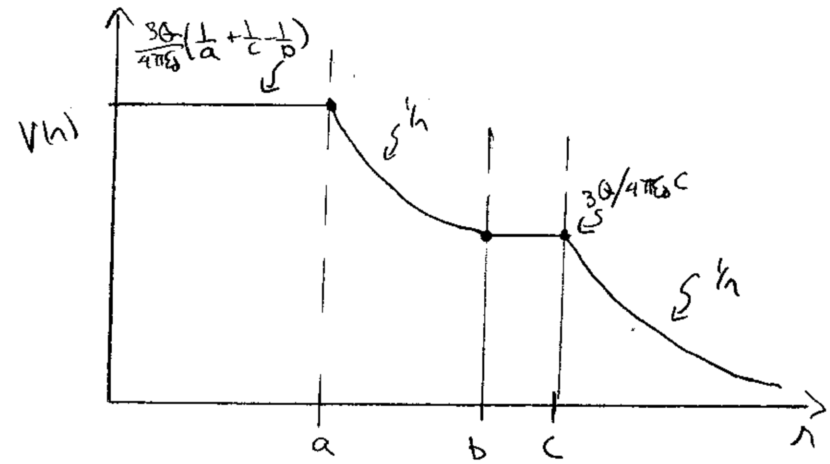
$$V(r=b) = \frac{3Q}{3\pi\varepsilon_0 b} + K = \frac{3Q}{4\pi\varepsilon_0 C} \qquad \text{(from above)}$$

Then $K = \frac{3Q}{4\pi\varepsilon_0}\left(\frac{1}{c}-\frac{1}{b}\right)$ &

$a<r<c \qquad V(r) = \frac{3Q}{4\pi\varepsilon_0 r} + \frac{3Q}{4\pi\varepsilon_0}\left(\frac{1}{c}-\frac{1}{b}\right)$ — as above

for $r<a$, $\vec{E}=0$ & $\Delta V=0$.

$$V(r<a) = V(r=a) = \frac{3Q}{4\pi\varepsilon_0}\left[\frac{1}{a}+\frac{1}{c}-\frac{1}{b}\right]$$



(C) Electrostatic energy in field — integrate $u_E(r)$ over regions $a\to b$ & $c\to\infty$. $\vec{E}=0$ elsewhere

$$u_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0\left(\frac{3Q}{4\pi\varepsilon_0 r^2}\right)^2 = \frac{9Q^2}{16\pi^2\varepsilon_0\cdot 2\cdot r^4} = \frac{9Q^2}{32\pi^2\varepsilon_0 r^4}$$

Region of r from $a\to b$

$$U_1 = \int_a^b u_E \underbrace{dV}_{4\pi r^2 dr} = \frac{9Q^2}{32\pi^2\varepsilon_0}\int_a^b \frac{4\pi r^2 dr}{r^4}$$

$$U_1 = \frac{9Q^2}{8\pi\varepsilon_0}\int_a^b \frac{dr}{r^2} = \frac{9Q^2}{8\pi\varepsilon_0}\left(-\frac{1}{r}\right)_a^b$$

$$U_1 = \frac{9Q^2}{8\pi\varepsilon_0}\left(\frac{1}{a}-\frac{1}{b}\right)$$

for the region r from $c\to\infty$, the integral is the same except for the limits:

$$U_2 = \frac{9Q^2}{8\pi\varepsilon_0}\left(-\frac{1}{r}\right)_c^\infty = \frac{9Q^2}{4\pi\varepsilon_0 c}$$

$$U_{TOT} = U_1 + U_2 = \frac{9Q^2}{8\pi\varepsilon_0}\left(\frac{1}{a}-\frac{1}{b}+\frac{1}{c}\right)$$

Grading Criteria

I. 35 pts

(a) 10 pts

- 2 pts E for $r<a$
- 2 pts E for $a<r<b$
- 2 pts E for $b<r<c$
- 2 pts E for $r>c$
- 2 pts sketch

(b) 10 pts

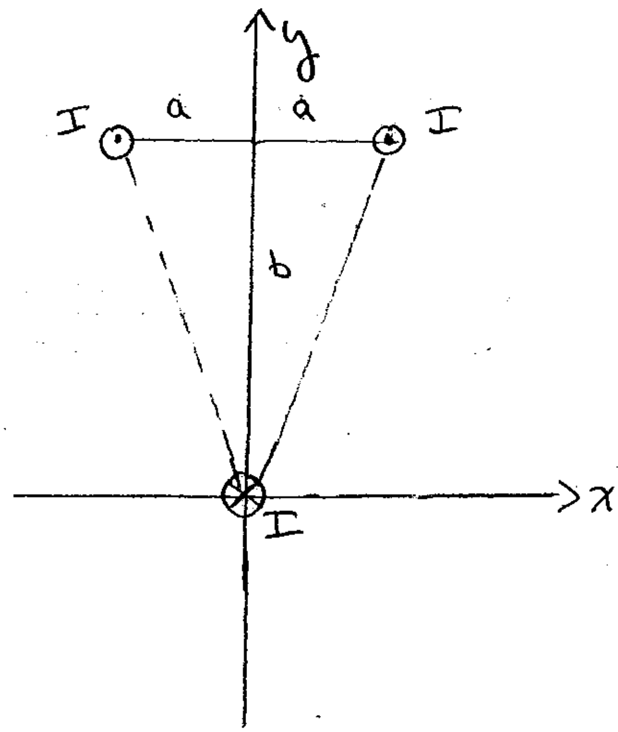
- 2 pts V for $r>c$
- 2 pts V for $b<r<c$
- 2 pts V for $a<r<c$
- 2 pts V for $r<a$
- 2 pts sketch

(c) 15 pts

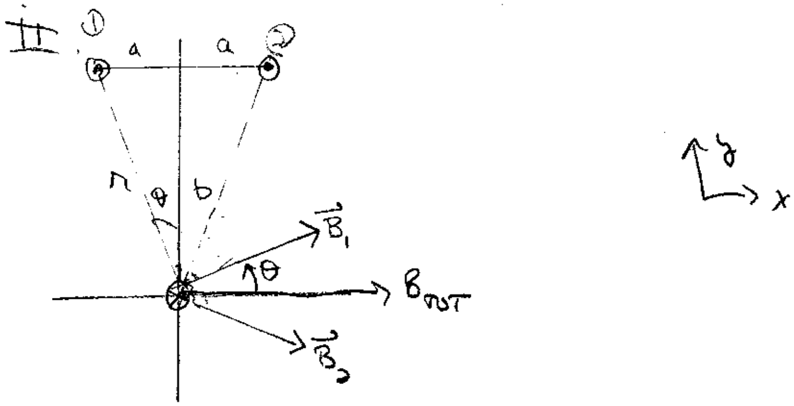
- 2 pts correct expression for u_E
- 3 pts setting up integral
- 5 pts U_E in region $a<r<b$
- 5 pts U_E in region $r>c$ & sum

II. Three very long wires, all parallel to the z-axis, carry current I. One wire passes through the origin, and the others pass through the points $y = b$ and $x = \pm a$, as shown in the sketch below. The wire located at the origin carries current into the page, and the other two carry current out of the page.

(a) Determine the magnetic field $\vec{B}(r)$ at the origin due to the two wires located at $y = b$, $x = \pm a$
(b) Determine the force per unit length on the wire located at the origin due to the magnetic field determined in (a).
(c) Determine the magnetic field $\vec{B}(y)$ for all points on the y-axis due to all three wires.



II.



(a) $\vec{B}$ at origin due to two wires at $y = b$:

from the sketch, it's clear that the y-components cancel & the x-components add.

from Ampere's law,

$$\oint \vec{B}_i \cdot d\vec{l} = \mu_0 I$$

$$2\pi r |\vec{B}| = \mu_0 I$$

$$|\vec{B}_2| = |\vec{B}_1| = \frac{\mu_0 I}{2\pi r} \quad \text{with } r = \sqrt{a^2+b^2}$$

Take the x-component

$$\vec{B}_{TOT} = \frac{2\mu_0 I}{2\pi r} \cdot \cos\theta = \frac{\mu_0 I}{\pi(a^2+b^2)^{1/2}} \cdot \underbrace{\frac{b}{(a^2+b^2)^{1/2}}}_{\cos\theta} \hat{\imath}$$

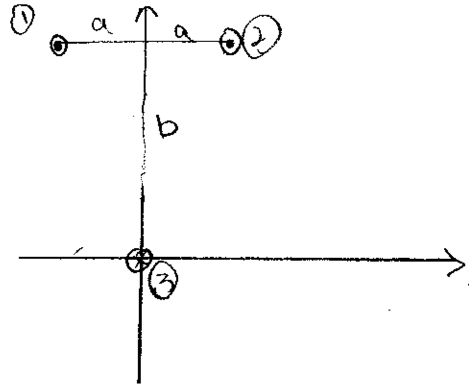
$$\boxed{\vec{B}_{TOT} = \frac{\mu_0 I b}{\pi(a^2+b^2)} \hat{\imath}} \quad \vec{B} \text{ at origin}$$

(b) $\vec{F} = I\vec{L} \times \vec{B} = ILB(-\hat{\jmath})$

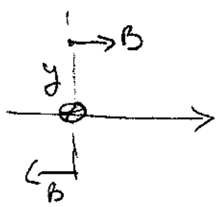
Direction of $\vec{F}$ is $-y$

$$\frac{\vec{F}}{L} = IB(-\hat{\jmath}) = \boxed{\frac{\mu_0 I^2 b}{\pi(a^2+b^2)}(-\hat{\jmath}) = \frac{\vec{F}}{L}}$$

(c) Now pick an arbitrary point on the y-axis & determine $\vec{B}$ from all three wires.



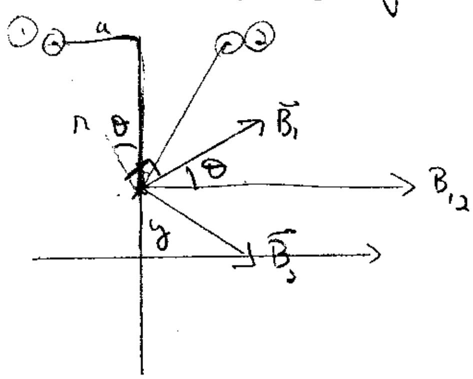
First consider $\vec{B}_3$, due to wire at the origin



$$\vec{B}_3 = \frac{\mu_0 I}{2\pi y}\,\hat{\imath}$$

$\vec{B}$ changes sign at the origin, but so does y, so this expression is correct for $y>0$ and $y<0$

Now consider $\vec{B}_1$ & $\vec{B}_2$ together.

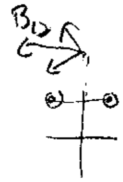


$$|\vec{B}_1| = |\vec{B}_2| = \frac{\mu_0 I}{2\pi r} \qquad r = \sqrt{a^2+(b-y)^2}$$

$$\vec{B}_{12} = 2B_1\cos\theta\,\hat{\imath}$$

$$= \frac{2\mu_0 I}{2\pi r}\cdot\frac{b-y}{r}$$

$$\vec{B}_{12} = \frac{\mu_0 I(b-y)}{\pi[a^2+(b-y)^2]}\,\hat{\imath}$$



The sketch is for $0<y<b$. For $y<0$, this expression is still correct, since y changes sign. For $y>b$, the direction of $\vec{B}$ changes, but so does the sign of $(b-y)$, so this expression works for all y!

$$\vec{B}_{tot} = \left[\frac{\mu_0 I}{2\pi y} + \frac{\mu_0 I(b-y)}{\pi[a^2+(b-y)^2]}\right]\hat{\imath}$$

Grading Criteria

II. 35 pts

(a) 15 pts

3 pts - correct direction of vectors & cancellation of y components

2 pts Ampere's law

5 pts Correct $|B_1|$ & $|B_2|$

5 pts Correct components, final sum & direction

(b) 5 pts

2 pts $\vec{F} = I\vec{L} \times B$

3 pts correct answer including direction

(c) 15 pts

5 pts - Contribution due to wire at origin

9 pts - Contribution due to two wires at y = b

3 pts - Correct direction & cancellation of y components

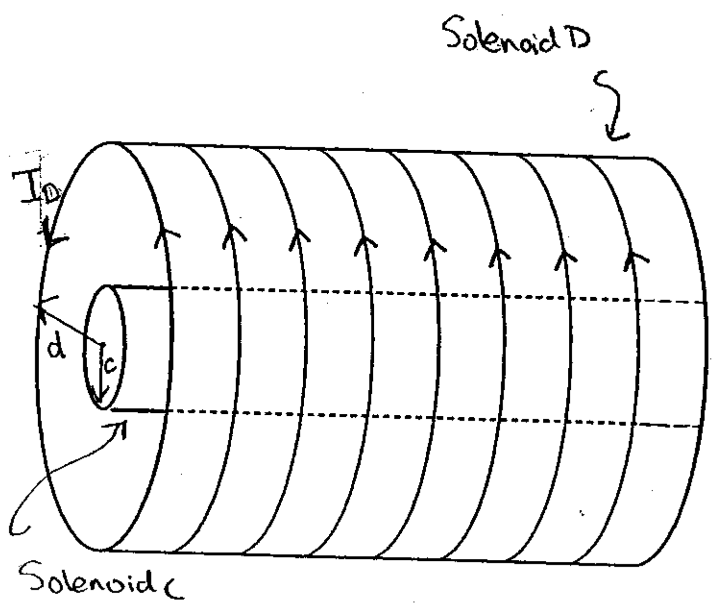
3 pts - Correct $|B_1|$ & $|B_2|$

3 pts Correct components, sum & direction

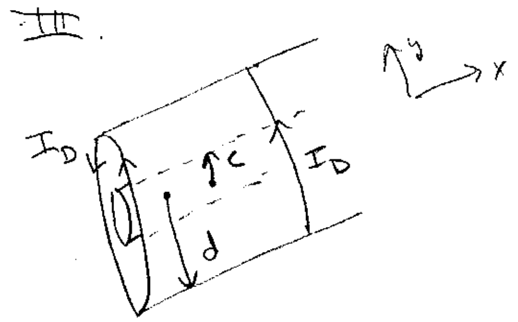
1 pt - Add together all three contributions

III. Consider two solenoids, both of the same length L and same number of turns per unit length n. The smaller solenoid C has radius c, and the larger one D has radius d. The smaller solenoid is placed inside the larger one so that their axes coincide. The coordinate r represents the distance from the axes of the solenoids.

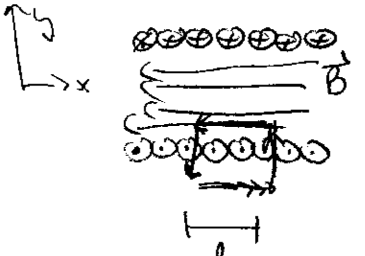
(a) Solenoid D is connected to an EMF source so that it carries a counterclockwise current I_D as seen from the left, as shown below. Assuming that the field is constant inside the solenoid and zero outside, and neglecting edge effects, use Ampere's law to determine the magnetic field $\vec{B}$ inside solenoid D.
(b) Now suppose the current in solenoid D is increasing at the constant rate $\frac{dI_D}{dt}$. Determine the induced electric field $\vec{E}$ as a function of r for $0 < r < d$ and for $r > d$. Be sure to indicate both magnitude and direction of the electric field.
(c) Sketch $|\vec{E}|$ as a function of r.
(d) Determine the total EMF induced in solenoid C due to the changing current in solenoid D. In what direction will current flow in solenoid C?



III.



(a) first consider only Solenoid D, carrying current I_D. A slice through it looks like:



By symmetry $\vec{B}$ inside is constant & outside $\vec{B} \sim 0$. Use a small rectangle as an Amperian loop, as shown.

$$\oint \vec{B} \cdot d\vec{l} = Bl \underbrace{+0+0}_{\vec{B} \perp d\vec{l} \text{ along the vertical segments}} \overset{B=0 \text{ outside}}{+0} = \mu_0 I \underbrace{nl}_{\text{number of turns of wire enclosed}}$$

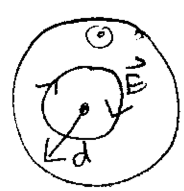
$$Bl = \mu_0 I n l$$

$$\boxed{\vec{B} = \mu_0 I n \,(-\hat{\imath})}$$ or to the left in the sketch.

(b) The current in solenoid D is increasing at the rate $\frac{dI_D}{dt}$.

To determine $\vec{E}$ due to the changing $\vec{B}$, use Faraday's law.

$$\oint \vec{E} \cdot d\vec{l} = \frac{-d\Phi_B}{dt}$$



$\vec{B}$ out of page, and increasing upward.

$\vec{E}$ forms concentric loops around $\vec{B}$. for $r < d$,

$$2\pi r|\vec{E}| = \frac{d\Phi_B}{dt} \qquad \Phi_B = \pi r^2 B = \pi r^2 \mu_0 n I$$

$$2\pi r|\vec{E}| = \frac{d\Phi_B}{dt} = \pi r^2 \mu_0 n \, dI_D/dt$$

$$|\vec{E}| = \frac{r\mu_0 n}{2}\frac{dI_D}{dt} \qquad (r<d)$$

The direction is given by Lenz's Law ⇒ the direction of $\vec{E}$ is such as to produce a current opposing the change in ϕ_B. Since ϕ_B is increasing upward, $\vec{E}$ will form clockwise loops to oppose the change in ϕ_B

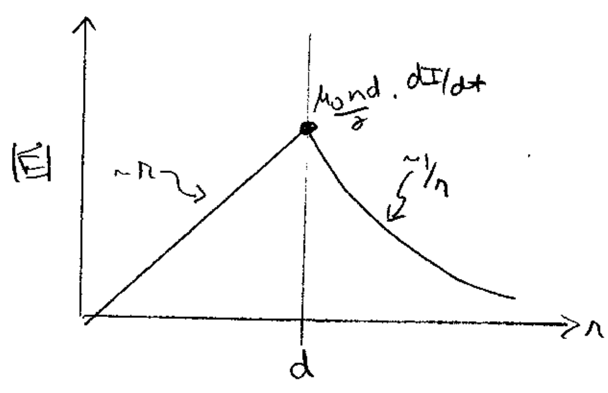
$$\vec{E} = \frac{\mu_0 n r}{2}\cdot\frac{dI_D}{dt}$$ clockwise loops as viewed from left ↻ $r<d$

for $r>d$, $\phi_B = \pi d^2 B$, since $B=0$ for $r>d$. Then

$$\oint \vec{E}\cdot d\vec{l} = 2\pi r|\vec{E}| = \pi d^2 \frac{dB}{dt} = \pi d^2(\mu_0 n)\frac{dI_D}{dt}$$

$r>d$ $$|\vec{E}| = \frac{\mu_0 n d^2}{2r}\frac{dI_D}{dt}$$, direction CW loops ↻ as viewed from left

(c)



(d) $\mathcal{E} = -\frac{d\phi_B}{dt}$ $\phi_B = \pi c^2 B$ for a single turn of wire in Solenoid C. Since $c<d$, Solenoid C is completely within the region of uniform field.

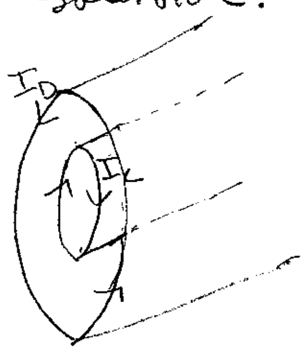
$$\frac{d\phi_B}{dt} = \pi c^2 \frac{dB}{dt} = \pi c^2 \mu_0 n \frac{dI_D}{dt}$$

But Solenoid C has a total of $N = nL$ turns, each of which sees this $\frac{d\phi_B}{dt}$. Then

$$|\mathcal{E}| = N \frac{d\phi_B}{dt} = nL(\pi c^2 \mu_0 n) \frac{dI_D}{dt}$$

$$|\mathcal{E}| = \mu_0 n^2 \pi c^2 L \frac{dI_D}{dt}$$

The direction will be so as to oppose the change in ϕ_B, so current will flow in the clockwise direction in solenoid C.



Grading Criteria

III. 35 pts

(a) 5 pts

2 pts Ampere's Law
3 pts Set up Amperian loop, correct answer

(b) 15 pts

2 pts Faraday's Law
2 pts $\vec{E}$ forms concentric loops
1 pts correct direction of $\vec{E}$
5 pts Correct $\vec{E}$ for $r<d$
5 pts Correct E for $r>d$

(c) 5 pts for sketch

(d) 10 pts

2 pts Faraday's Law
5 correct $\mathcal{E}$ for a single loop
2 multiply by # of loops in C
1 Correct direction of current

Last Name: ______________________ First Name: ______________________

Physics 102 Spring 2005: Final Exam -- Multiple-Choice Questions

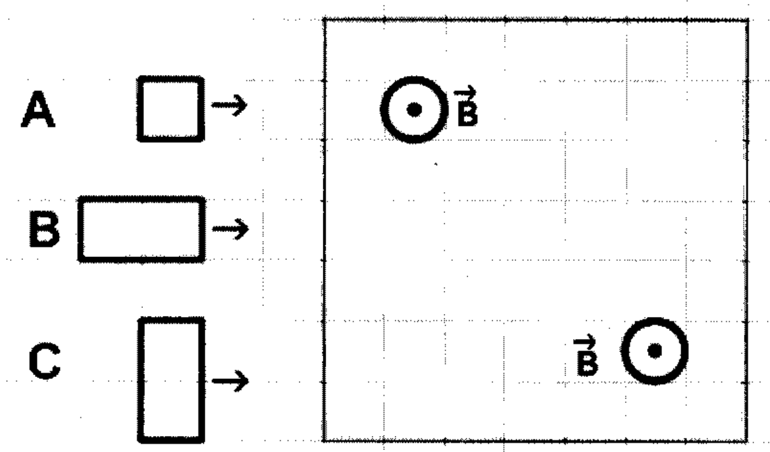
1) An electron beam moving horizontally at a speed v_0 enters a region between two horizontally oriented plates of length L_1. When the electrons reach a fluorescent screen located at a distance L_2 past these plates, they have been deflected a vertical distance y from their original direction. If the speed of the electrons is doubled what is the new value of the deflection?

A) 4y B) 2y C) y/2 → (D) y/4 E) y

2) A charged particle is moving with speed v perpendicular to a uniform magnetic field. A second identical charged particle is moving with speed 2v perpendicular to the same magnetic field. The frequency of revolution of the first particle is f. The frequency of revolution of the second particle is

A) 2f. → (B) f. C) f/4. D) f/2. E) 4f.

3) The figure below shows 3 metallic frames labeled A, B, and C heading towards a region where a uniform magnetic field exists. The frames all have the same resistance R, and move with the same constant velocity. Their relative sizes are indicated by the background grid. As they enter the magnetic field the frames will have an induced electric current along their perimeter. For which frame will the current be the greatest?



A) A

B) B

→ (C) C

D) The current is the same in all 3 cases

E) There is no induced current when the frames move at constant speed.

4) The electric current in a solenoid is uniformly decreased from its initital value to zero. During that time an electric field is generated inside the solenoid. Which of the following statement applies to the electric field?

→ (A) The magnitude of the electric field is constant in time but increases along the radial direction away from the axis of the solenoid

B) There is no relationship between the electric field inside the solenoid and the variation of its electric current

C) The magnitude of the electric field is the same at every point within the solenoid but it decreases uniformly in time at the same rate as the electric current

D) The magnitude of the electric field is the same everywhere within the solenoid and is constant in time.

E) The magnitude of the electric field is constant in time but decreases along the radial direction away from the axis of the solenoid

5) Starting from zero, an electric current is established in a circuit made of a battery of emf E, a resistor of resistance R and an inductor of inductance L. The electric current eventually reaches its steady-state value. What would be the effect of using a resistor with a higher resistance in this circuit?

A) The steady-state value of the current would be smaller, and it would take the same amount of time to reach it

B) The steady-state value of the current would be larger, and it would take more time to reach it

→ (C) The steady-state value of the current would be smaller, and it would take less time to reach it

D) The steady-state value of the current would be smaller, and it would take more time to reach it

E) The steady-state value of the current would be larger, and it would take less time to reach it

6) Starting from zero, an electric current is established in a circuit made of a battery of emf E, a resistor of resistance R and an inductor of inductance L. The electric current eventually reaches its steady-state value. What would be the effect of using an inductor with a larger inductance in this circuit?

A) The steady-state value of the current would be larger, and it would take more time to reach it

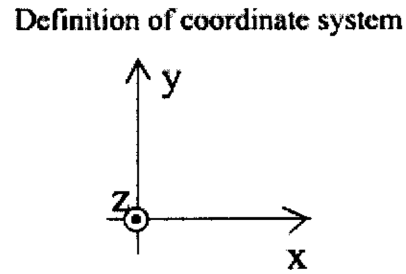
B) The steady-state value of the current would be the same, and it would take less time to reach it

C) The steady-state value of the current would be the same, and it would take the same amount of time to reach it

D) The steady-state value of the current would be larger, and it would take the same amount of time to reach it

→ (E) The steady-state value of the current would be the same, and it would take more time to reach it

7) If the magnetic field in an EM wave is in the positive x-direction and the electric field in the wave is in the positive y-direction, the wave is traveling in the



A) x-y plane.

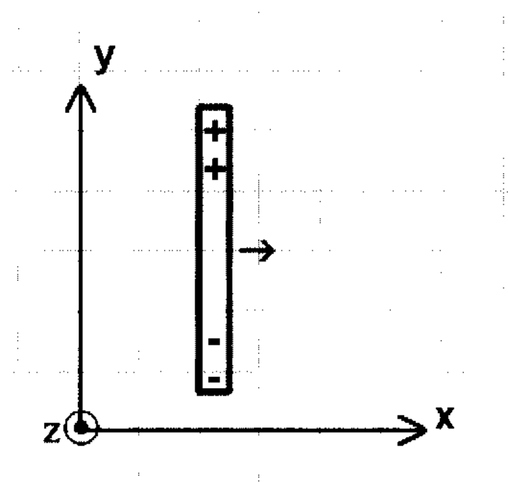
B) x-direction.

→ (C) negative z-direction.

D) positive z-direction.

E) direction halfway between the x- and y-directions.

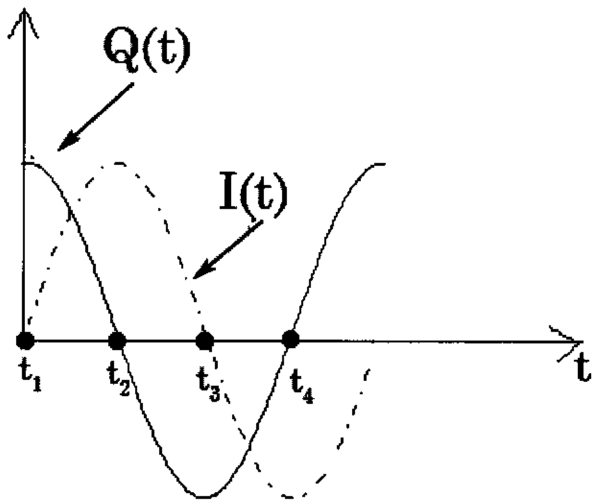
8) A metallic rod moves at constant speed in the positive x direction inside a uniform magnetic field as shown in the figure below. Positive and negative charges build up on the rod as indicated. What is the direction of the magnetic field?



A) Positive y B) Negative y C) Positive z → (D) Negative z E) Negative x

4

9) A capacitor, initially charged, and an inductor form an LC circuit. The graphs of current (I(t)) through the inductor and charge (Q(t)) on the capacitor are shown below at various times. At what time(s) labelled on the graph is the energy stored in the inductor a maximum?

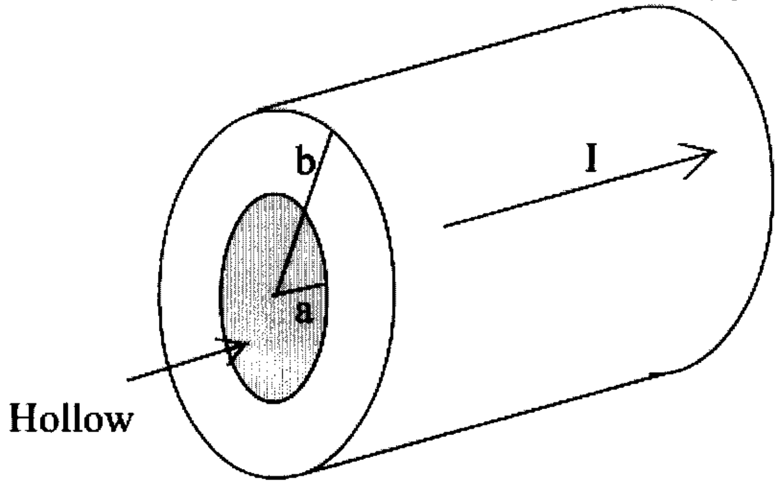


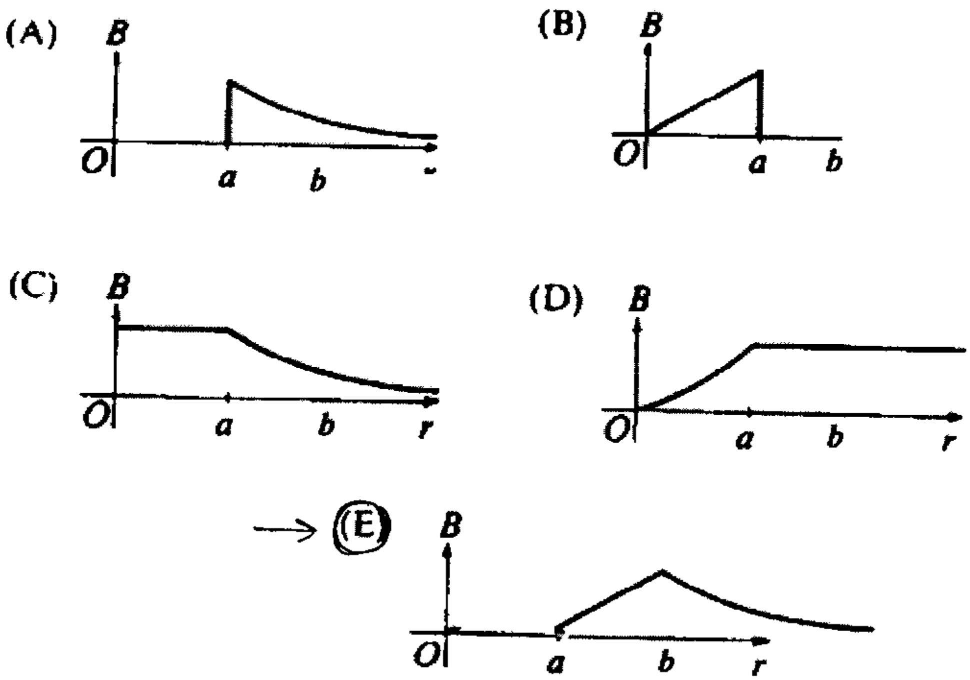
A) t_1 and t_3 . B) t_2 and t_3 . → (C) t_2 and t_4 . D) t_2. E) t_4.

10) Two charged particles A and B enter a magnetic field oriented along the positive z-axis. Particle A has a velocity $\vec{v} = v_0\,\hat{i} + v_0\,\hat{j}$, a charge q and a mass m. Particle B has a velocity $\vec{v} = v_0\,\hat{i}$, a charge q and a mass 2m. What is the ratio $\frac{R_A}{R_B}$ of the circles on which the two particles are moving?

A) 1 B) $\sqrt{2}$ → (C) $\frac{1}{\sqrt{2}}$ D) $\frac{1}{2}$ E) 2

11) A current I, uniformly distributed over the cross section of a long hollow cylindrical conducting pipe of inner radius a and outer radius b, is directed as shown below. Which of the following graphs best represents the magnitude B, of the magnetic field as a function of the distance r from the axis of the pipe?

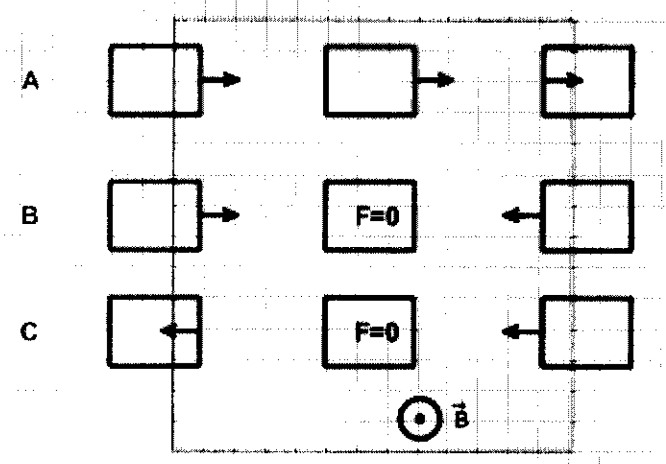




12) Consider two points at a distance r_1 and $r_2 = 2\,r_1$ away from a long, straight wire conducting a current I. How does the energy density u_1 in the magnetic field at r_1 compare to the magnetic energy density u_2 at r_2?

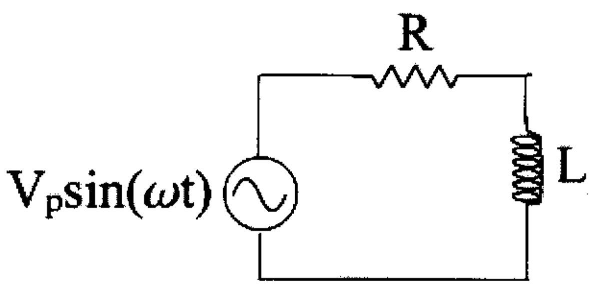
A) $u_1 = u_2/4$ B) $u_1 = u_2/2$ C) $u_1 = 4\,u_2$ D) $u_1 = u_2$ E) $u_1 = 2\,u_2$

13) In the figure below a metallic frame enters a region with a uniform magnetic field pointing in the direction shown. The frame is viewed at three different times as it moves from left to right. For each instant an arrow representing the magnetic force on the frame is indicated. Which sequence (A, B, C) correctly describes the magnetic force at each of those instants?



A) A B) B → (C) C D) B or C E) A or B

14) As the frequency ω in this simple ac circuit increases, keeping Vp constant, the rms current through the resistor



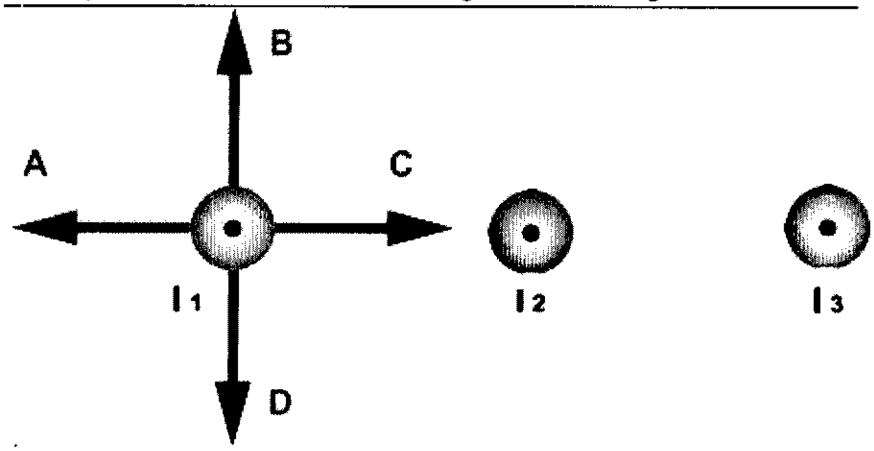
A) increases.

B) does not change.

C) may increase of decrease depending on the magnitude of the original frequency.

→ (D) decreases.

15) The figure below shows 3 long, parallel current–carrying wires. The magnitudes of the currents are equal and their directions are indicated in the figure. Which of the arrows drawn near the wire carrying current 1 correctly indicates the direction of the magnetic force acting on that wire?



A) A

B) B

→ (C) C

D) D

E) The magnetic force is equal to zero

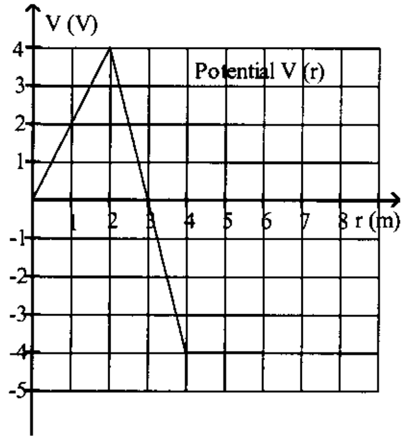
16) Two equal charges Q are separated by a distance d. One of the charges is released and moves away from the other due to the force between them. When the moving charge is a distance 3d from the other charge, what is its kinetic energy?

A) $Q/\pi\varepsilon_0 d$ B) $Q^2/4\pi\varepsilon_0 d$ C) $Q^2/2d$ D) $Q^2/12\pi\varepsilon_0 d$ → (E) $Q^2/6\pi\varepsilon_0 d$

17) Two metal spheres of radii R_1 and R_2 carry an equal electric charge Q. The spheres are at potentials V_1 and V_2 respectively with $V_1 = 3V_2$. The spheres are then connected by a conducting wire. When equilibrium is reached, what is the charge on the sphere of radius R_2?

→ (A) 3Q/2 B) Q/3 C) 2Q D) Q/2 E) Q

18) The graph below shows the variation of the electric potential V (measured in Volts) as a function of the radial direction r (measured in meters). For which range of r is the magnitude of the electric field the largest?



A) From r = 0 to r = 2 m

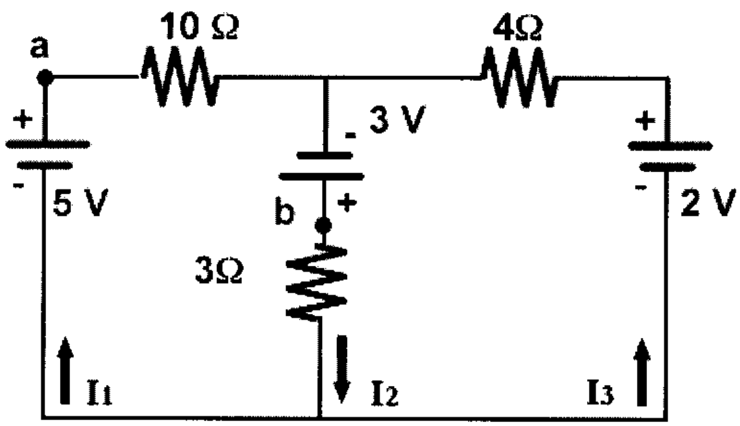
→ (B) From r = 2 m to r = 4 m

C) More information is needed to answer the question

D) The magnitude of the field is the same everywhere

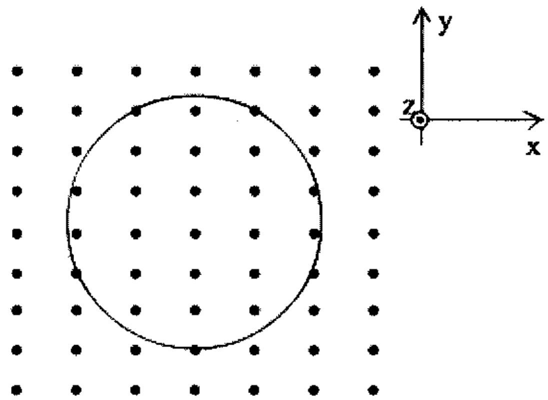
E) From r = 4 m to r = 6 m

19) In the figure below the currents I_1 and I_2 are equal to 0.13 A and 2.22 A respectively. What is the potential difference $V_a - V_b$?

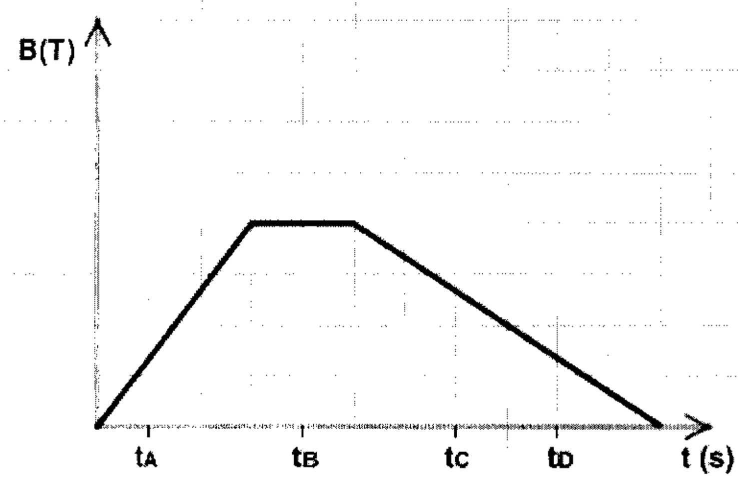


A) - 3 V B) 5.0 V → (C) -1.7 V D) 0 E) 2.4 V

20)



A magnetic field ($\mathbf{B} = B(t)\hat{\mathbf{k}}$) passes through a circular coil whose normal is parallel to the direction of the field as shown in the figure above. The figure below shows the time evolution of a uniform magnetic field. Four particular instants labeled t_A to t_D are also identified on the graph. At what time does the current induced in the coil have the largest magnitude?



→ (A) t_A

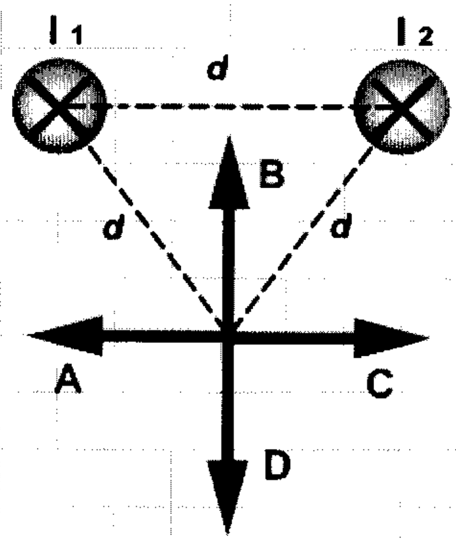
B) The current is the same at all these times

C) t_C

D) t_B

E) t_D

21) The figure below shows two long wires carrying equal currents I_1 and I_2 flowing in opposite directions. Which of the arrows labeled A to D correctly represents the direction of the magnetic field due to the wires at a point located at an equal distance d from each wire?



→ (A) A
→ (B) B
C) C
→ (D) D
E) The magnetic field is equal to zero at that point

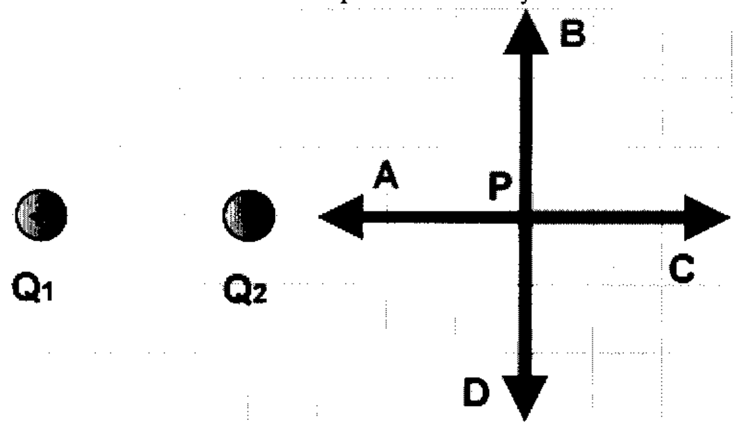
22) If the voltage on a capacitor is doubled, then the energy stored by the capacitor

A) stays the same.
→ (B) quadruples.
C) halves.
D) triples.
E) doubles.

23) A parallel-plate capacitor of capacitance C is connected to a battery of voltage V until it is fully charged. The energy density in the capacitor is then equal to u. If the same capacitor is then connected to a battery of voltage 2V its energy density becomes equal to

A) u. → (B) 4 u. C) u/ 4. D) u /2. E) 2 u.

24) Two charges Q_1 and Q_2 of equal magnitudes and opposite signs are positioned as shown in the figure below. Which of the shown arrows represents correctly the electric field at point P?



→ (A) A

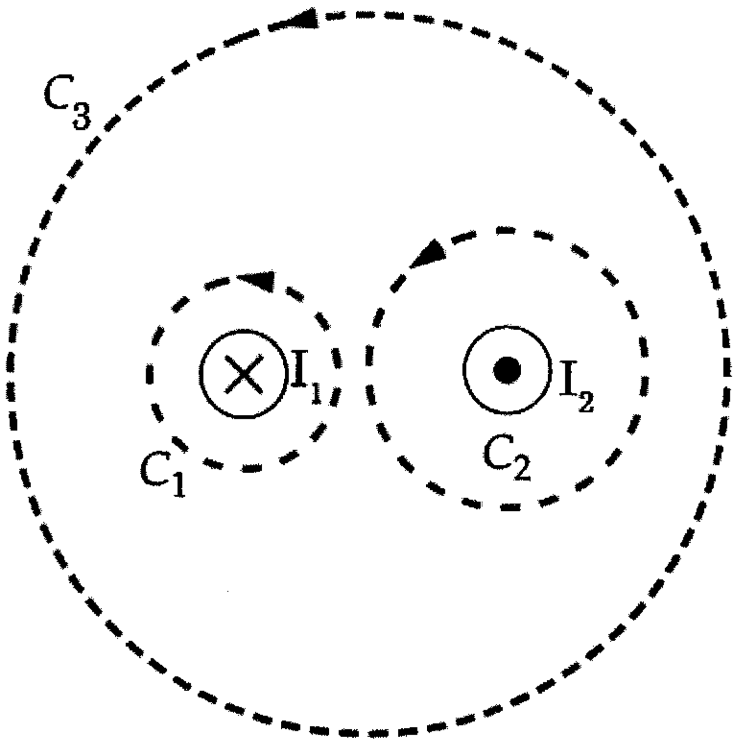
B) B

C) C

D) D

E) The field is equal to zero at point P.

25) Which oneof the following line integrals is correct? Note: The direction of the loops orientation is shown in the diagram.



A) $\oint_{C1} \vec{B}\cdot d\vec{l} = \mu_0 I_1$

B) $\oint_{C2} \vec{B}\cdot d\vec{l} = -\mu_0 I_2$

C) $\oint_{C1} \vec{B}\cdot d\vec{l} = -\mu_0 I_2$

→ (D) $\oint_{C3} \vec{B}\cdot d\vec{l} = \mu_0 (I_2 - I_1)$

E) $\oint_{C3} \vec{B}\cdot d\vec{l} = \mu_0 (I_1 - I_2)$