

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.

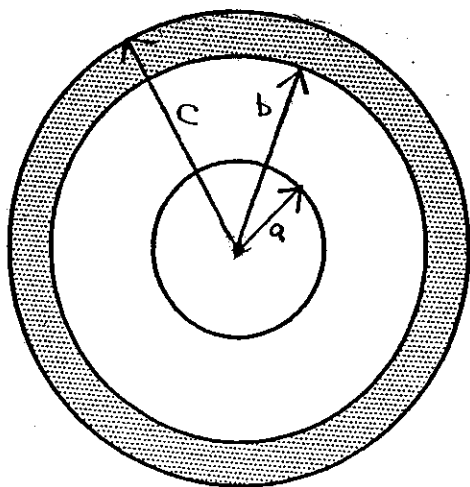
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*Show your work* for the free-response problems, including neat and clearly labeled figures, in your blue book. Answers without explanation (even correct answers) will not be given credit.

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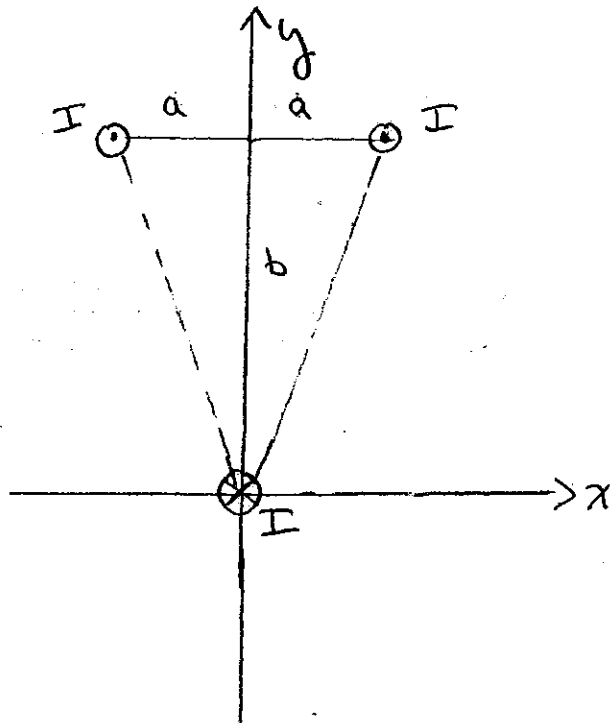
I. A nonconducting spherical shell of radius  $a$  and negligible thickness is centered at the origin. It carries a net positive charge of  $+3Q$ , uniformly distributed over its surface. A second, larger spherical shell is also centered at the origin and has inner radius  $b$  and outer radius  $c$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

- Determine the electric field  $\vec{E}(r)$  for all values of  $r$ . Sketch  $|\vec{E}(r)|$  vs.  $r$ .
- 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.  $r$ .
- Determine the total electrostatic energy  $U_E$  contained in the electric field for all  $r$ .



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  $\vec{B}(\vec{r})$  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.



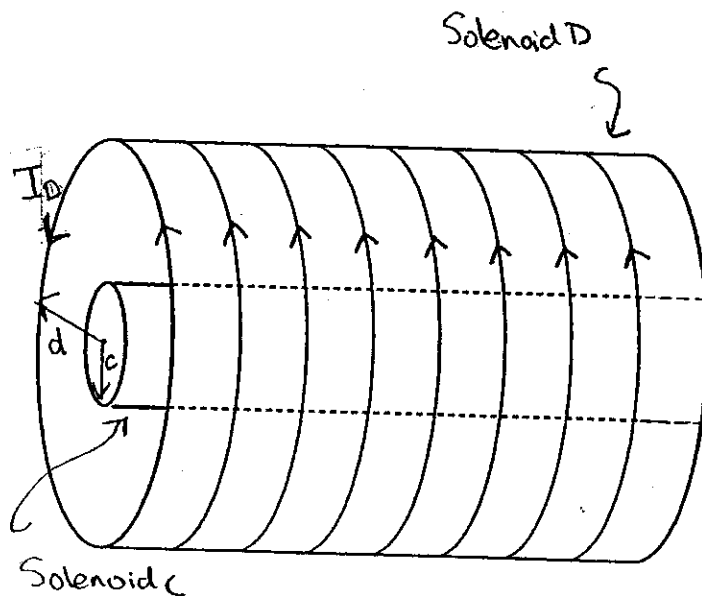
III. Consider two solenoids, both of the same length  $L$  and same number of turns per unit length  $n$ . The smaller solenoid  $C$  has radius  $c$ , and the larger one  $D$  has radius  $d$ . The smaller solenoid is placed inside the larger one so that their axes coincide. The coordinate  $r$  represents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

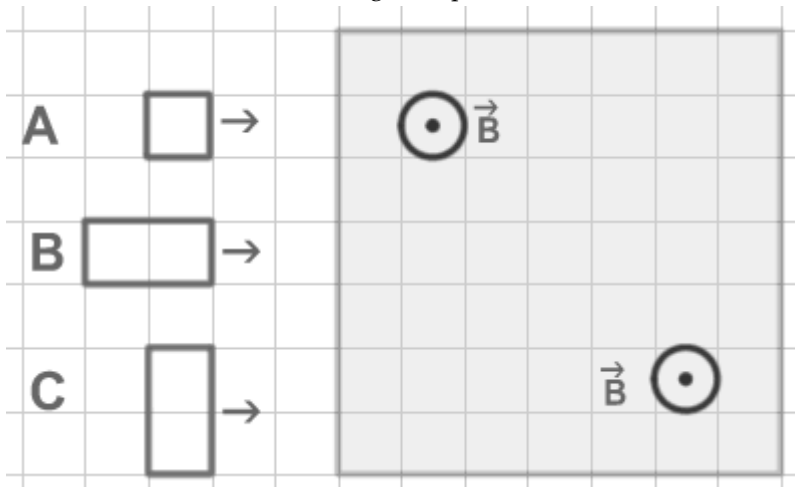


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### Physics 102 Spring 2005: Final Exam -- Multiple-Choice Questions

- 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?

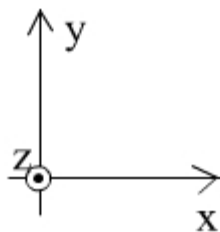


- A) A  
B) B  
C) C  
D) The current is the same in all 3 cases  
E) There is no induced current when the frames move at constant speed.

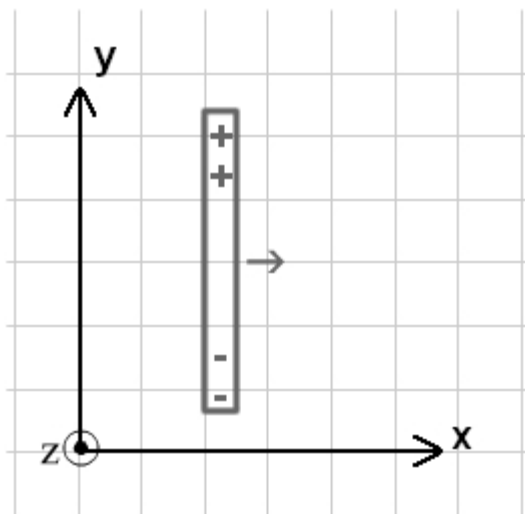
- 4) The electric current in a solenoid is uniformly decreased from its initial value to zero. During that time an electric field is generated inside the solenoid. Which of the following statement applies to the electric field?
- A) The magnitude of the electric field is constant in time but increases 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

Definition of coordinate system

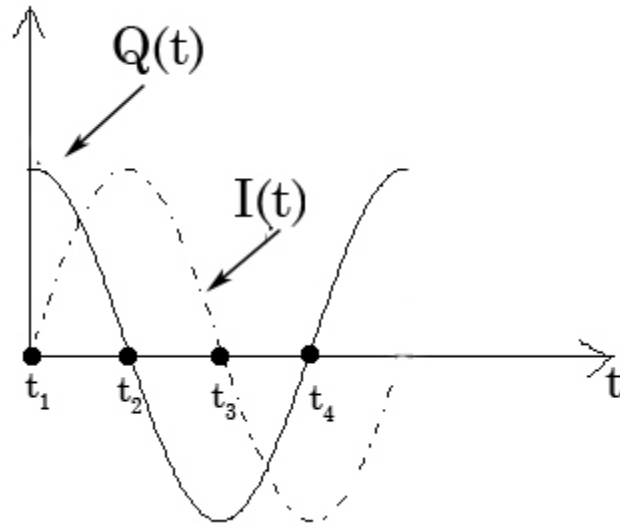


- A) x-y plane.
  - B) x-direction.
  - C) negative z-direction.
  - D) positive z-direction.
  - E) direction halfway between the x- and y-directions.
- 8) A metallic rod moves at constant speed in the positive x direction inside a uniform magnetic field as shown in the figure below. Positive and negative charges build up on the rod as indicated. What is the direction of the magnetic field?



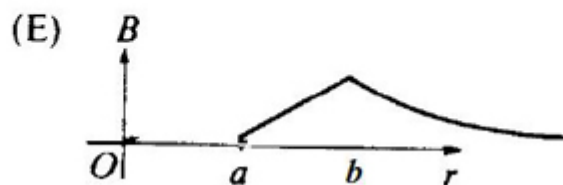
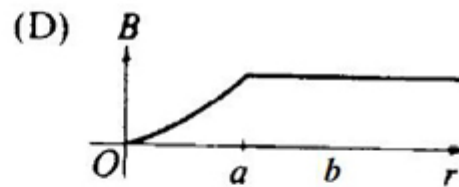
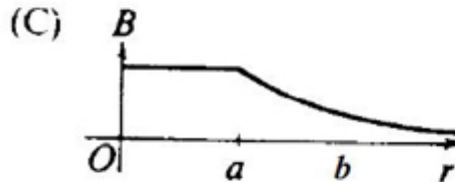
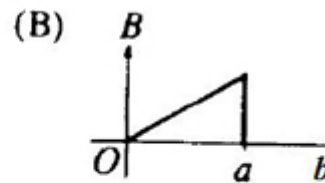
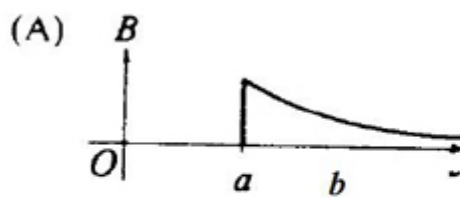
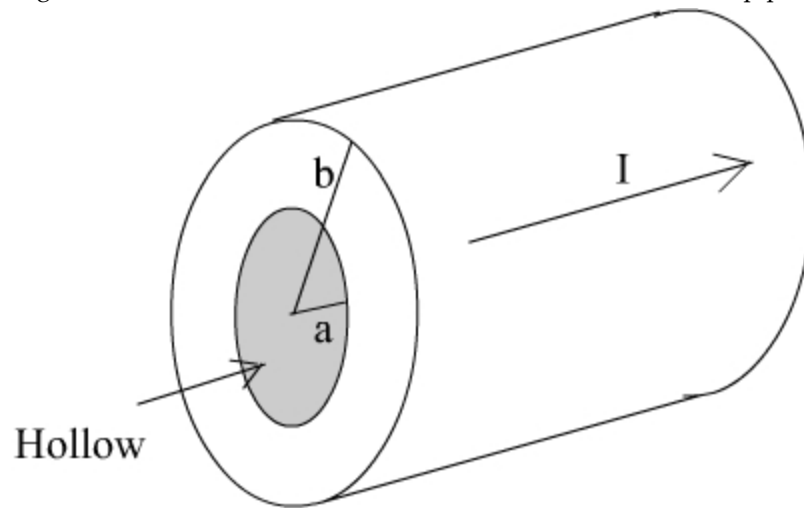
- A) Positive y
- B) Negative y
- C) Positive z
- D) Negative z
- E) Negative x

- 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?

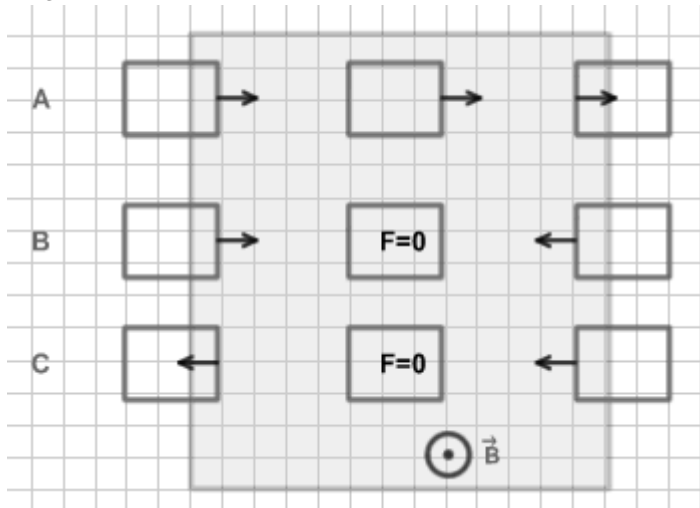


- 12) Consider two points at a distance  $r_1$  and  $r_2 = 2 r_1$  away from a long, straight wire conducting a current  $I$ . How does the energy density  $u_1$  in the magnetic field at  $r_1$  compare to the magnetic energy density  $u_2$  at  $r_2$ ?

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

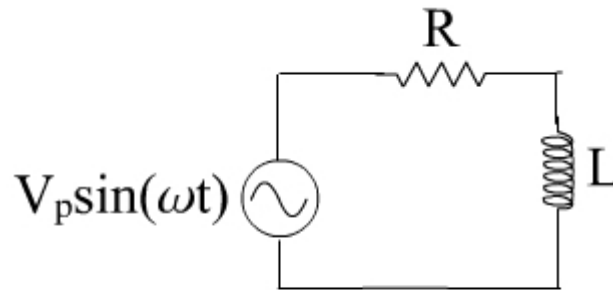


13) In the figure below a metallic frame enters a region with a uniform magnetic field pointing in the direction shown. The frame is viewed at three different times as it moves from left to right. For each instant an arrow representing the magnetic force on the frame is indicated. Which sequence (A,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



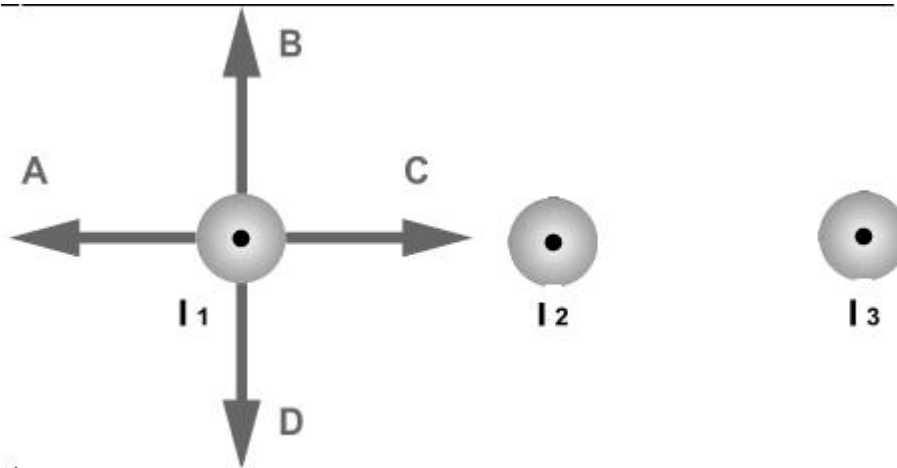
- A) A                      B) B                      C) C                      D) B or C                      E) A or B

14) As the frequency  $\omega$  in this simple ac circuit increases, keeping  $V_p$  constant, the rms current through the resistor



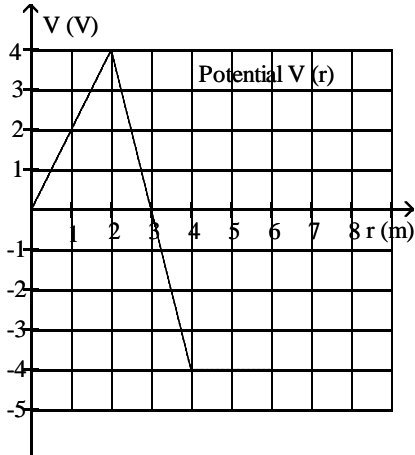
- A) increases.
- B) does not change.
- C) may increase or decrease depending on the magnitude of the original frequency.
- D) decreases.

- 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?



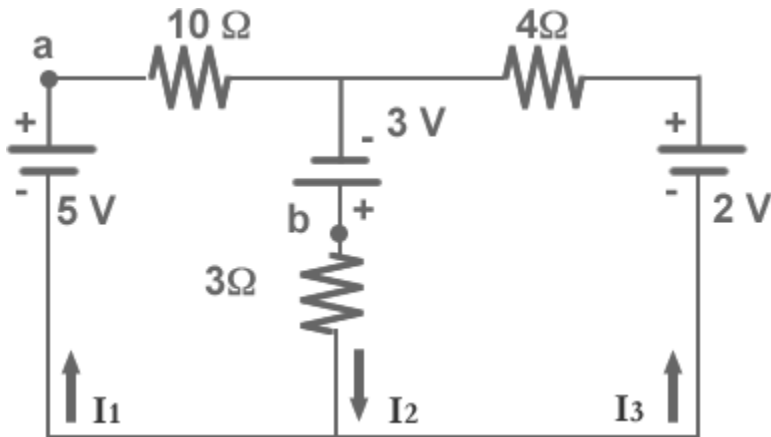
- A) A  
 B) B  
 C) C  
 D) D  
 E) The magnetic force is equal to zero
- 16) Two equal charges  $Q$  are separated by a distance  $d$ . One of the charges is released and moves away from the other due to the force between them. When the moving charge is a distance  $3d$  from the other charge, what is its kinetic energy?  
 A)  $Q/\pi\epsilon_0 d$       B)  $Q^2/4\pi\epsilon_0 d$       C)  $Q^2/2d$       D)  $Q^2/12\pi\epsilon_0 d$       E)  $Q^2/6\pi\epsilon_0 d$
- 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?

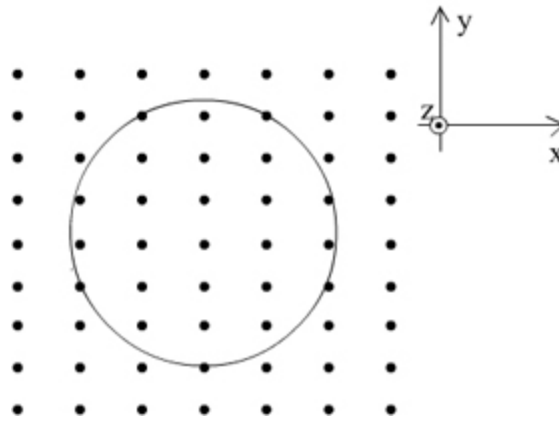


- A) From  $r = 0$  to  $r = 2$  m
- B) From  $r = 2$  m to  $r = 4$  m
- C) More information is needed to answer the question
- D) The magnitude of the field is the same everywhere
- E) From  $r = 4$  m to  $r = 6$  m

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  $V_a - V_b$ ?

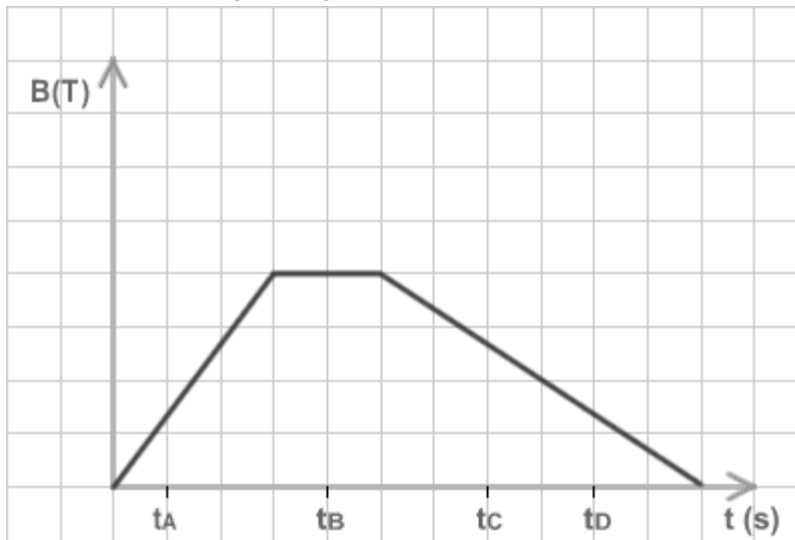


- A) -3 V
- B) 5.0 V
- C) -1.7 V
- D) 0
- E) 2.4 V



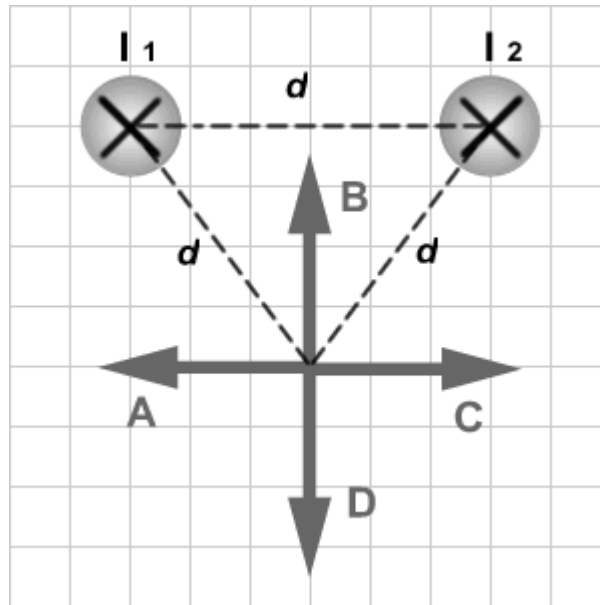
20)

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?



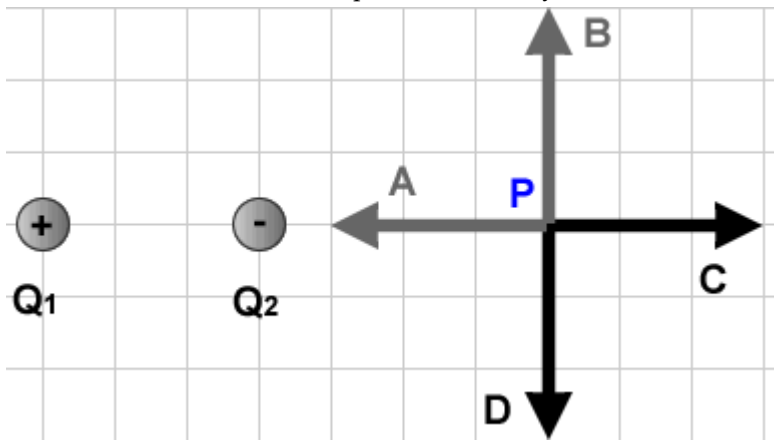
- A)  $t_A$
- B) The current is the same at all these times
- C)  $t_C$
- D)  $t_B$
- E)  $t_D$

- 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?



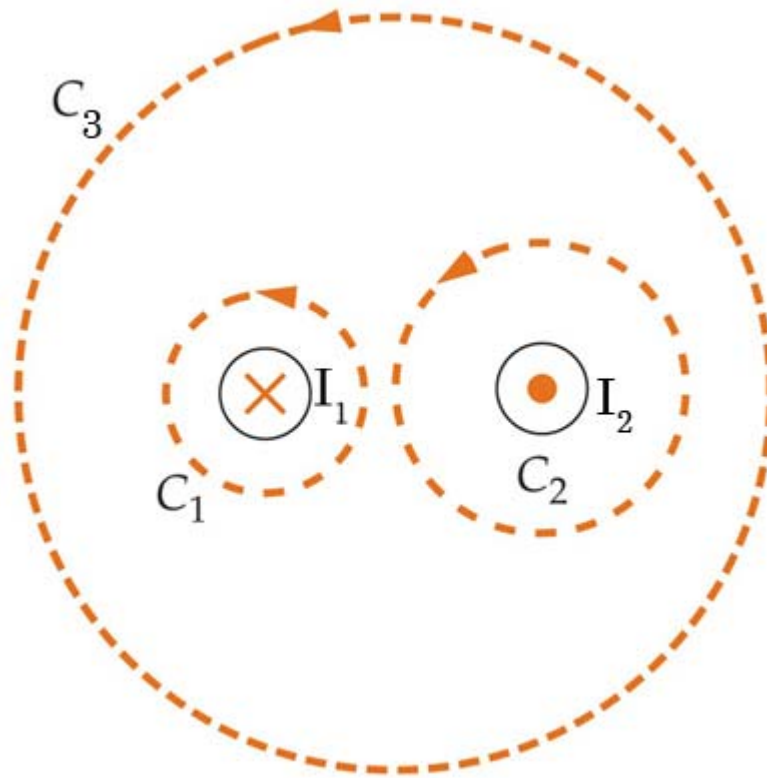
- A) A  
 B) B  
 C) C  
 D) D  
 E) The magnetic field is equal to zero at that point
- 22) If the voltage on a capacitor is doubled, then the energy stored by the capacitor
- A) stays the same.  
 B) quadruples.  
 C) halves.  
 D) triples.  
 E) doubles.
- 23) A parallel-plate capacitor of capacitance  $C$  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)  $4u$ .                      C)  $u/4$ .                      D)  $u/2$ .                      E)  $2u$ .

- 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 one of the following line integrals is correct? Note: The direction of the loops orientation is shown in the diagram.



- A)  $\oint_{C_1} \vec{B} \cdot d\vec{l} = \mu_0 I_1$   
 B)  $\oint_{C_2} \vec{B} \cdot d\vec{l} = -\mu_0 I_2$   
 C)  $\oint_{C_1} \vec{B} \cdot d\vec{l} = -\mu_0 I_2$   
 D)  $\oint_{C_3} \vec{B} \cdot d\vec{l} = \mu_0 (I_2 - I_1)$   
 E)  $\oint_{C_3} \vec{B} \cdot d\vec{l} = \mu_0 (I_1 - I_2)$