AP Physics C: Electricity and Magnetism

From the 2018 Administration

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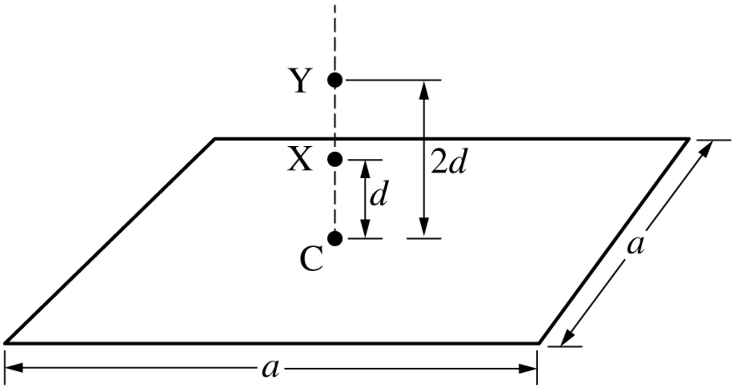
I Multiple Choice Questions

Time: 45 minutes
35 Questions

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

See the instruction for questions 1 to 2.



Note: Figure not drawn to scale.

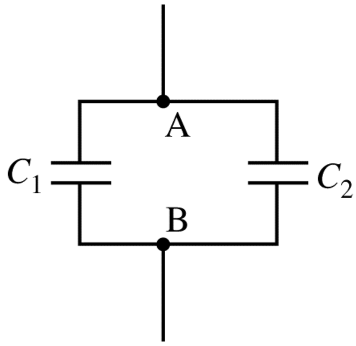
The figure above shows a thin, square, nonconducting sheet of positive charge uniformly distributed over its area. The length of each side of the sheet is a. Point C is at the center of the sheet. Point X is a distance d above the center of the sheet, and point Y is a distance $2d$ above the center of the sheet. Assume $a \gg d$. The effect of gravity is negligible.

1. If the magnitude of the electric field at point X is E, what is the magnitude of the electric field at point Y?

   (A) $E/4$ (B) $E/2$ (C) E (D) $2E$ (E) $4E$

2. A positive point charge $+q$ is released from rest at point X. If the magnitude of the electric field at point X is E, what is the kinetic energy of the charge at point Y?

   (A) qEd (B) $\sqrt{2}qEd$ (C) $2qEd$ (D) $2\sqrt{2}qEd$ (E) $4qEd$



3. Capacitors C_1 and C_2 are connected as shown in the circuit above. The capacitance of C_1 is C, and the capacitance of C_2 is $C/3$. The equivalent capacitance between points A and B is C_{EQ}. A dielectric is inserted into capacitor C_2, and the equivalent capacitance between points A and B is now $2C_{\text{EQ}}$. What is the value of the dielectric constant for this dielectric?

   (A) 2

   (B) 3

   (C) 4

   (D) 5

   (E) The value cannot be determined without knowing the value of C.

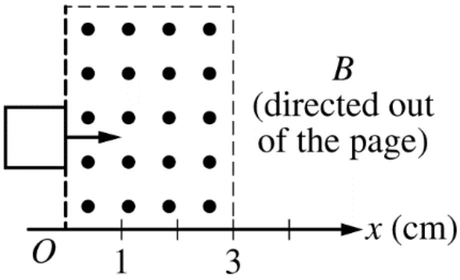
4. Which of the following could be true for a Gaussian surface through which the net flux is zero?

   I. There are no charges inside the surface.

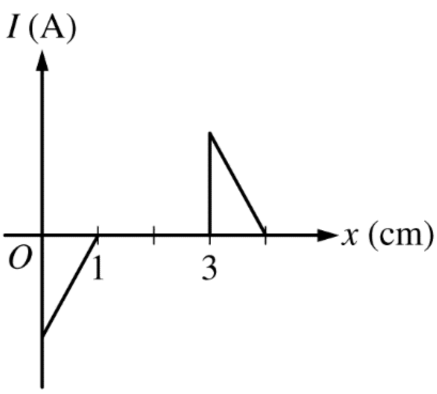
   II. The net charge enclosed by the surface is zero.

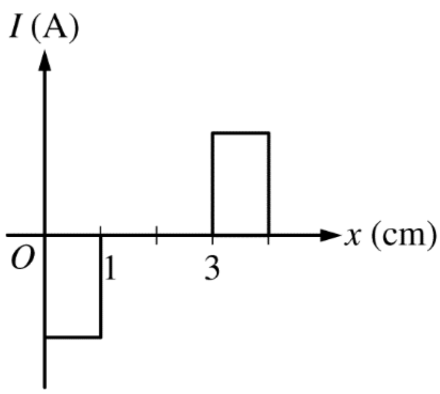
   III. The electric field is zero everywhere on the surface.

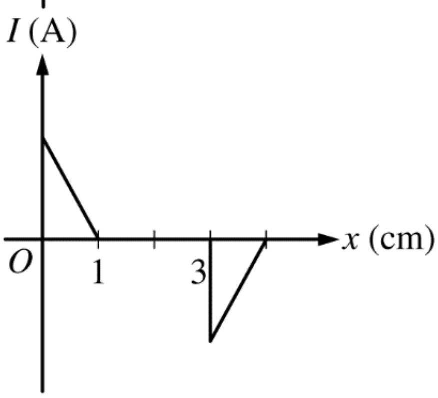
   (A) I only (B) II only (C) III only (D) I and II only (E) I, II, and III

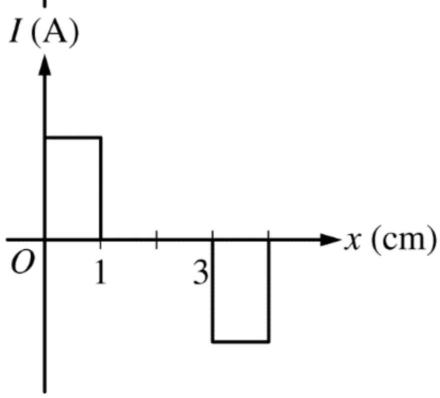


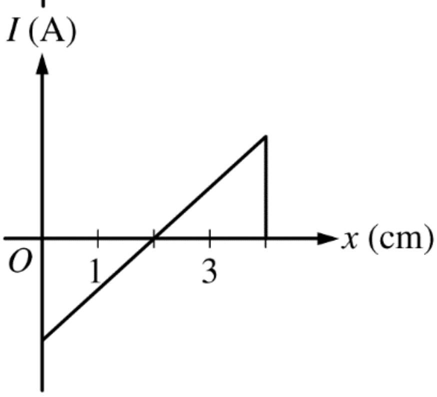
5. A square coil with sides of length 1.0 cm is moved through a region of uniform magnetic field at a constant speed, as shown in the figure above. Which of the following graphs best shows the current I in the coil as a function of the position x of the right edge as the coil moves through the magnetic field, where counterclockwise current is positive?

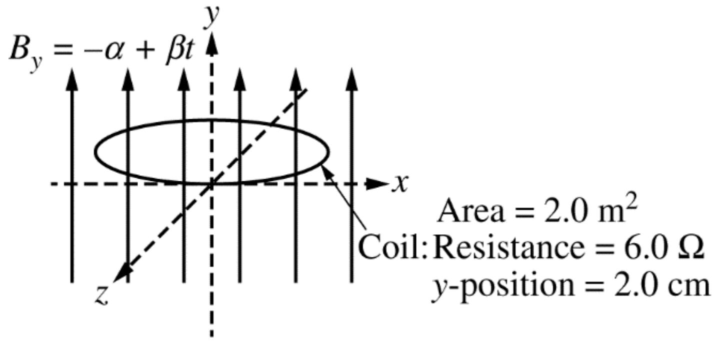
(A)


(B)


(C)


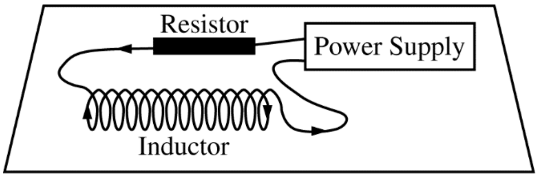
(D)


(E)




6. The y-component of the magnetic field B is given as a function of time t by the equation $B_y = -\alpha + \beta t$, where $\alpha = 4.0\,\mathrm{T}$ and $\beta = 3.0\,\mathrm{T/s}$. A coil of wire with an area of $2.0\,\mathrm{m}^2$ and a resistance of $6.0\,\Omega$ is placed in this field, parallel to the xz-plane at $y = 2.0\,\mathrm{cm}$. The current in the coil at time $t = 1.2\,\mathrm{s}$ is most nearly

(A) 0 (B) 0.6 A (C) 1.0 A (D) 3.6 A (E) 6.0 A



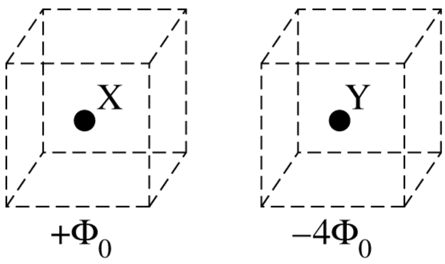
7. An inductor with inductance $L = 0.30\,\mathrm{H}$ is connected in series with a resistor and both are connected to a power supply, as shown above. The power supply generates a current I that is given as a function of time t by the equation $I = I_0(1 - t/k)$, where $I_0 = 4.0\,\mathrm{A}$ and $k = 2.0\,\mathrm{s}$. What is the magnitude of the potential difference across the inductor induced by the changing current?

(A) $0.15\,\mathrm{V}$ (B) $0.30\,\mathrm{V}$ (C) $0.60\,\mathrm{V}$ (D) $1.2\,\mathrm{V}$ (E) $2.4\,\mathrm{V}$

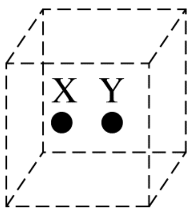
8. A parallel plate capacitor with air between the plates is charged and then disconnected from the source of emf. If the space between the plates is now filled with a dielectric, what happens to the capacitance of the capacitor and the magnitude of the electric field between the plates?

	Capacitance	Magnitude of the Electric Field
(A)	Increases	Increases
(B)	Increases	Remains constant
(C)	Increases	Decreases
(D)	Decreases	Increases
(E)	Decreases	Decreases

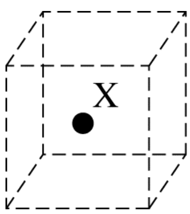
See the instruction for questions 9 to 11.



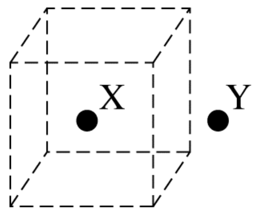
The figure above shows two charged spherical conductors, X and Y, which are equal in size. When each conductor is isolated and surrounded by a closed cubical surface, the total electric flux through the surfaces is $+\Phi_0$ for conductor X and $-4\Phi_0$ for conductor Y.



9. Conductor Y is brought into contact with conductor X and then separated. If the separation is small so that both conductors are inside the same closed cubical surface, as shown above, what is the total electric flux through the surface?
   (A) $-3\Phi_0$
   (B) $-\frac{5}{2}\Phi_0$
   (C) $-\frac{3}{2}\Phi_0$
   (D) $\frac{5}{2}\Phi_0$
   (E) It cannot be determined without knowing the distance separating the two conductors and the individual charges on each.



10. After being brought into contact with conductor X, conductor Y is moved a very large distance away from conductor X. What is the total electric flux through a closed cubical surface surrounding conductor X, as shown above?
    (A) $-3\Phi_0$ (B) $-\frac{3}{2}\Phi_0$ (C) $\frac{1}{2}\Phi_0$ (D) Φ_0 (E) $\frac{3}{2}\Phi_0$



11. Conductor Y is then moved closer to conductor X until it is just outside a closed cubical surface containing conductor X, as shown in the figure above. How would the total electric flux through the cubical surface change as conductor Y is moving?

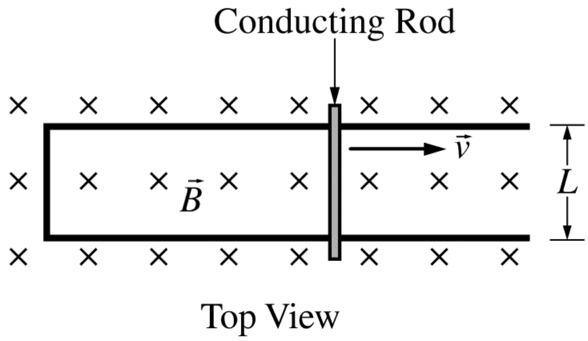
(A) It would increase.

(B) It would decrease.

(C) It would change sign.

(D) It would remain constant, with the flux through each side of the surface also remaining constant.

(E) It would remain constant, but the flux through each side of the cubical surface would change.



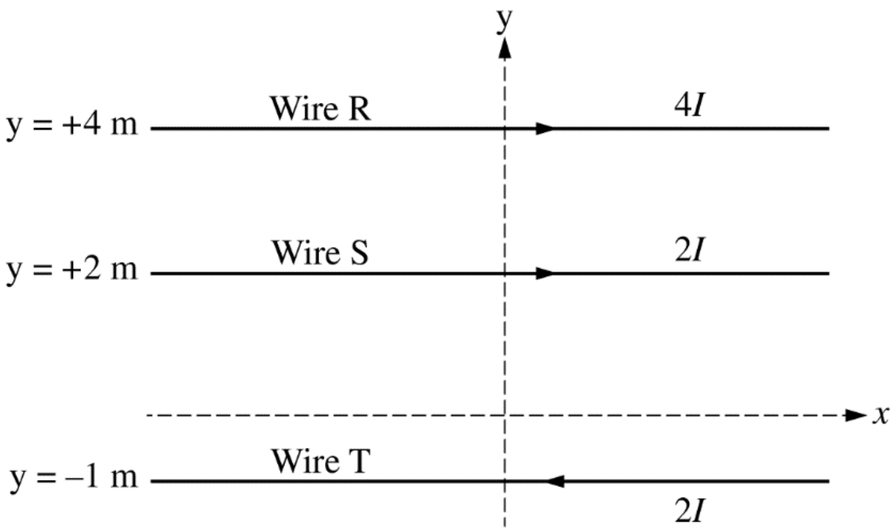
12. A conducting rod of resistance R is in electrical contact with a frictionless U-shaped rail of width L and negligible resistance. The rod is pulled to the right at a constant velocity $\vec{v}$. A magnetic field $\vec{B}$ is directed into the page, as shown in the figure above. Under these conditions, the electric power dissipated in the rod is P. If the velocity of the rod is doubled, the power dissipated in the rod is

(A) $P/4$ (B) $P/2$ (C) P (D) $2P$ (E) $4P$

13. Which of the following will increase the magnetic field on the axis of a long solenoid?

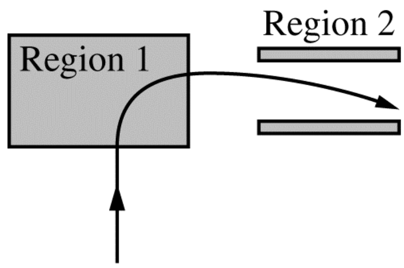
I. Increasing the current in the solenoid
II. Increasing the cross-sectional area of the solenoid
III. Inserting an iron core into the solenoid

(A) I only (B) III only (C) I and II only (D) II and III only (E) I, II, and III



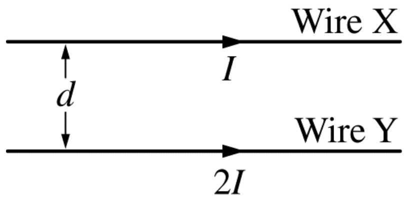
14. Three long wires, R, S, and T, are in the positions and carrying the currents indicated in the figure above. All currents are in the plane of the page and in the direction indicated. What are the magnitude and direction of the magnetic field at the origin?

	Magnitude	Direction
(A)	$\frac{\mu_0 I}{\pi}$	Into the page
(B)	$\frac{\mu_0 I}{\pi}$	Out of the page
(C)	$\frac{2\mu_0 I}{\pi}$	Into the page
(D)	$\frac{2\mu_0 I}{\pi}$	Out of the page
(E)	$\frac{4\mu_0 I}{\pi}$	Out of the page



15. A positively charged particle travels along the path shown in the figure above through region 1 and between two parallel plates in region 2. A magnetic field exists in region 1, and one of the plates in region 2 is at a higher potential than the other. What is the direction of the magnetic field in region 1, and which plate is at a higher potential in region 2?

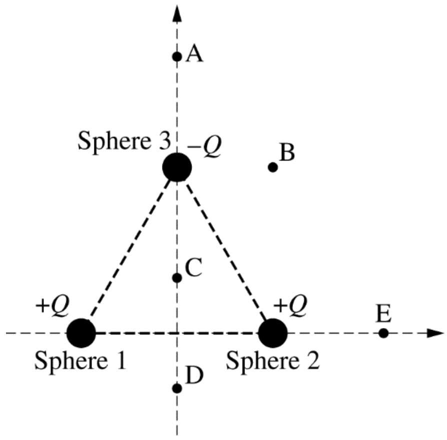
	Region 1	Plate at Higher Potential
(A)	Out of the page	Top plate
(B)	Out of the page	Bottom plate
(C)	Into the page	Top plate
(D)	Into the page	Bottom plate
(E)	To the right	Bottom plate



16. Two long, straight parallel wires X and Y are separated by a distance d and carry currents I and $2I$, as shown in the figure above. The force on wire X has magnitude F. If the current in each wire is both doubled and reversed in direction. which of the following is true of the magnitude and direction of the new force on wire X?

	Magnitude	Direction
(A)	F	Unchanged
(B)	$2F$	Reversed
(C)	$2F$	Unchanged
(D)	$4F$	Reversed
(E)	$4F$	Unchanged

See the instruction for questions 17 to 18.



Three identical spheres are equally spaced from one another. Spheres 1 and 2 have charge $+Q$, and sphere 3 has a charge of $-Q$, as shown in the figure above. Five different positions are labeled A, B, C, D, and E. Positions A, B, and C are all the same distance from sphere 3. Positions C, D, and E are all the same distance from sphere 2. All spheres and points lie in the same plane.

17. The electric potential is highest at position

(A) A (B) B (C) C (D) D (E) E

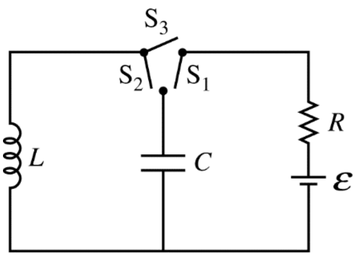
18. At which of the five positions are the horizontal and vertical components of the electric field directed toward the left and the top of the page, respectively?

(A) A (B) B (C) C (D) D (E) E

19. The magnetic field at a perpendicular distance r from a long, straight current-carrying wire is directly proportional to

(A) r (B) r^2 (C) $1/r$ (D) $1/r^2$ (E) $\ln(r)$

See the instruction for questions 20 to 21.



A circuit is constructed using a battery of emf $\mathcal{E}$, a resistor of resistance R, a capacitor of capacitance C, an inductor of inductance L, and three switches, as shown in the figure above. The three switches are labeled S_1, S_2, and S_3, and they can be operated independently.

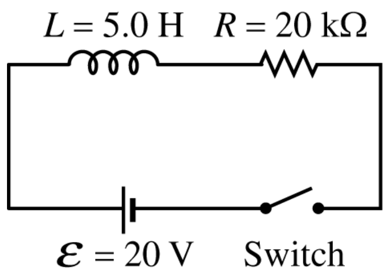
20. All switches are open, and there is no stored energy in the capacitor or the inductor. Switch S_3 is closed. What is the current in the inductor after steady state has been reached?

    (A) $\dfrac{\mathcal{E}}{LR}$ (B) $\dfrac{\mathcal{E}R}{L}$ (C) $\dfrac{\mathcal{E}L}{R}$ (D) $\dfrac{\mathcal{E}}{R}$ (E) Zero

21. All switches are open, and there is no stored energy in the capacitor or the inductor. Switch S_1 is closed. After the capacitor is fully charged, switch S_1 is opened and switch S_2 is closed. Which of the following expressions represents the maximum current in the LC circuit?

    (A) $\dfrac{\mathcal{E}}{R}$ (B) $\mathcal{E}\sqrt{\frac{C}{L}}$ (C) $\mathcal{E}\sqrt{\frac{L}{C}}$ (D) $\dfrac{\mathcal{E}C}{L}$ (E) $\dfrac{\mathcal{E}L}{C}$

See the instruction for questions 22 to 23.



After the switch is closed in the circuit above, the current in the circuit is given by $i = I\left(1 - e^{-t/\tau}\right)$, where I and τ are constants.

22. What is the value of I?

(A) 0 (B) 0.001 A (C) 0.80 A (D) 1.0 A (E) 4.0 A

23. What is the value of τ?

(A) 1.0×10^{-5} s (B) 2.5×10^{-4} s (C) 1.0 s (D) 4.0×10^{3} s (E) 1.0×10^{5} s

24. Two stationary point charges of unknown magnitude and sign are isolated from all other charges. If the electric field strength is zero at the midpoint of the line joining them, which of the following can be concluded about the charges?

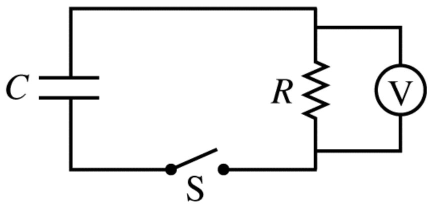
    (A) They are equal in magnitude but opposite in sign.

    (B) They are equal in magnitude and have the same sign.

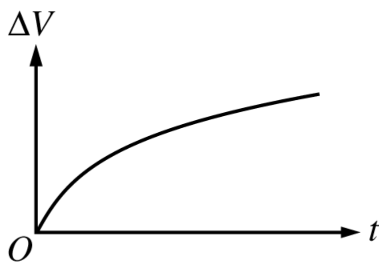
    (C) They are not necessarily equal in magnitude but have opposite signs.

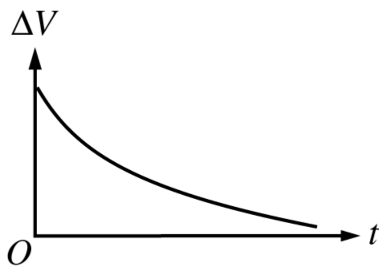
    (D) They are not necessarily equal in magnitude but have the same sign.

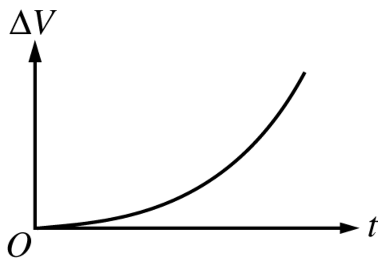
    (E) None of the above can be concluded without additional information.

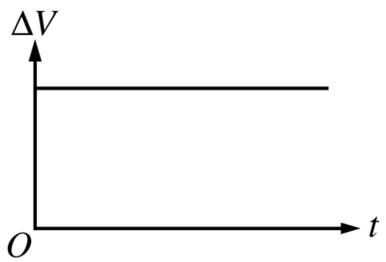


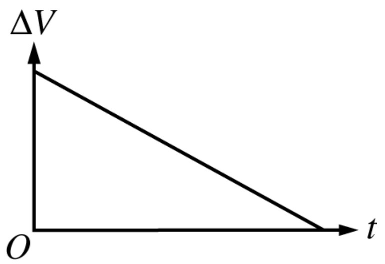
25. A charged capacitor C, resistor R, and switch S are connected in series. Voltmeter V is connected in parallel with the resistor, as shown in the figure above. At time $t = 0$, the switch is then closed. Which of the following shows the potential difference ΔV reading on the voltmeter as a function of time t after the switch is closed?

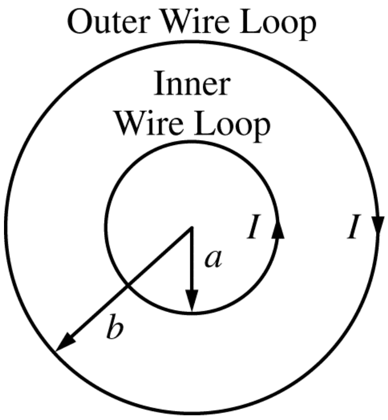
(A)


(B)


(C)


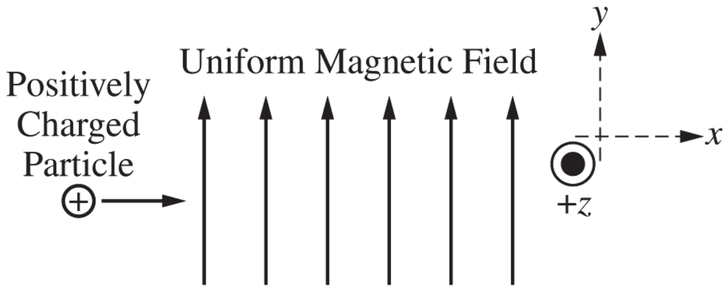
(D)


(E)




26. Two concentric circular wire loops carry equal currents I in opposite directions, as shown in the figure above. The inner loop has a radius a and carries a counterclockwise current. The outer loop has a radius b and carries a clockwise current. What is the magnitude and direction of the magnetic field at the center of the loops?

	Magnitude	Direction
(A)	$\frac{\mu_0 I}{2}\left(\frac{1}{a}-\frac{1}{b}\right)$	Out of the page
(B)	$\frac{\mu_0 I}{2}\left(\frac{1}{a}-\frac{1}{b}\right)$	Into the page
(C)	Zero	Undefined since magnitude is zero
(D)	$\frac{\mu_0 I}{2\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$	Out of the page
(E)	$\frac{\mu_0 I}{2\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$	Into the page



27. A positively charged particle moves in the positive x-direction in a uniform magnetic field directed in the positive y-direction. The net force on the particle could be zero if there is also an electric field present in the

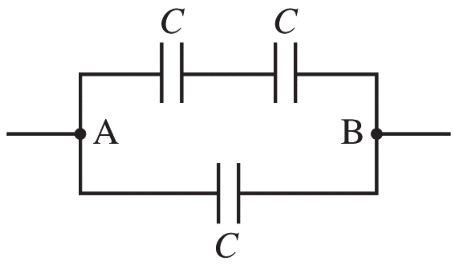
(A) positive z-direction

(B) negative z-direction

(C) positive x-direction

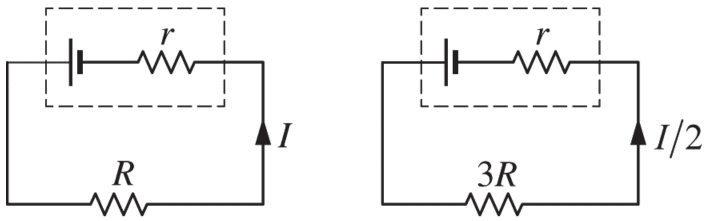
(D) negative x-direction

(E) negative y-direction



28. Three identical capacitors with capacitance C are arranged as shown above. What is the equivalent capacitance between points A and B?

(A) $C/3$ (B) $2C/3$ (C) C (D) $3C/2$ (E) $3C$



29. When a battery is connected to an external resistance R, as shown above on the left, there is a current I in the circuit. When the external resistance is changed to $3R$, the current changes to $I/2$, as shown above on the right. What is the internal resistance r of the battery?

(A) $R/4$ (B) $R/2$ (C) R (D) $2R$ (E) $4R$

30. The advantage of using a dielectric in a capacitor is that it

    (A) increases the capacitance of the capacitor

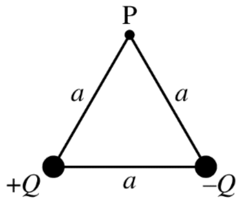
    (B) increases the conductivity of the capacitor

    (C) decreases the charging time of the capacitor

    (D) makes the capacitor dissipate less power

    (E) eliminates the electric field in the capacitor

See the instruction for questions 31 to 33.

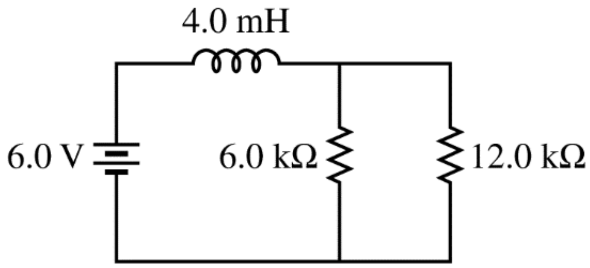


Two small spheres have charges $+Q$ and $-Q$ and are located at the bottom corners of an equilateral triangle, as shown in the figure above. The equilateral triangle has sides of length a, and point P is at the top corner of the triangle.

31. The potential energy stored in the charge configuration shown is
    (A) $\frac{Q^2}{4\pi\varepsilon_0 a}$ (B) $\frac{Q}{4\pi\varepsilon_0 a^2}$ (C) Zero (D) $-\frac{Q}{4\pi\varepsilon_0 a^2}$ (E) $-\frac{Q^2}{4\pi\varepsilon_0 a}$

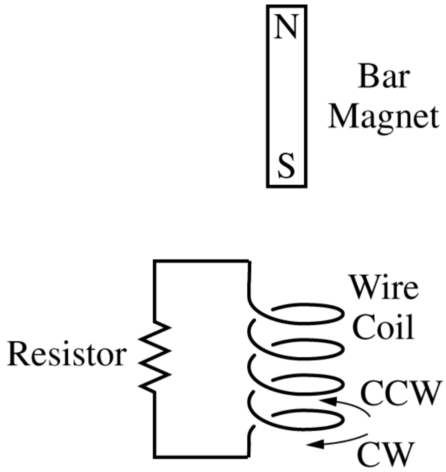
32. The electric potential at point P due to the two spheres is
    (A) Zero (B) $\frac{Q}{4\pi\varepsilon_0 a}$ (C) $\frac{Q}{4\pi\varepsilon_0 a^2}$ (D) $\frac{2Q}{4\pi\varepsilon_0 a}$ (E) $\frac{2Q}{4\pi\varepsilon_0 a^2}$

33. The direction of the electric field at point P due to the two spheres is
    (A) to the left
    (B) to the right
    (C) toward the bottom of the page
    (D) toward the top of the page
    (E) undefined, because the magnitude of the electric field at point P is zero



34. An inductor and two resistors are connected to an ideal battery, as shown in the figure above. What is the time constant for the circuit?

(A) $0.22\,\mu$s (B) $0.33\,\mu$s (C) $0.67\,\mu$s (D) $1.0\,\mu$s (E) $72\,\mu$s



35. A bar magnet with its south pole pointing down is released from rest and falls through a wire coil, as shown above. A resistor is connected across the two ends of the coil. What current would be produced in the coil, as observed by a person directly above the coil?

(A) A clockwise current only

(B) A counterclockwise current only

(C) A current that is first clockwise and then counterclockwise

(D) A current that is first counterclockwise and then clockwise

(E) No current would be produced.