		Name		Type
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List Number		e-mail		
Student ID		Signature		

ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

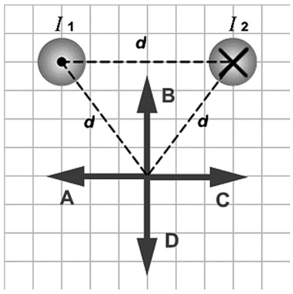
1. An electron moving in the direction of the (+x)-axis enters a magnetic field. If the electron experiences a magnetic deflection in the (-y) direction, the direction of the magnetic field in this region points in the direction of the

(a) (+y)-axis. (b) (+z)-axis. (c) (-z)-axis. (d) (-x)-axis. (e) (-y)-axis.

2. Ions having equal charges but masses of M and $2M$ are accelerated through the same potential difference and then enter a uniform magnetic field perpendicular to their path. If the heavier ions follow a circular arc of radius R, what is the radius of the arc followed by the lighter?

(a) $3R$ (b) $R/\sqrt{2}$ (c) $4R$ (d) $\sqrt{2}R$ (e) $R/2$

3. The figure shows two long wires carrying equal currents I_1 and I_2 flowing in opposite directions. Which of the arrows labeled A through 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) The magnetic field is zero at that point (b) D (c) A (d) B (e) C

4. Which of the following will reduce the time constant in an RC circuit?

(a) none of the above. (b) increasing the dielectric constant of the capacitor (c) adding an additional resistor in parallel with the first resistor (d) decreasing the voltage of the battery (e) increasing the voltage of the battery

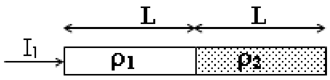
5. Kirchhoff's Junction Rule states that

(a) the algebraic sum of the potential changes around any closed loop in a circuit must be zero. (b) the algebraic sum of the currents at any junction in a circuit must be zero. (c) the current at a junction is given by the product of the resistance and the capacitance. (d) the current in a circuit with a resistor and a capacitor varies exponentially with time. (e) the time for the current development at a junction is given by the product of the resistance and the capacitance.

6. Which of the following has the same unit as the electromotive force (emf)?

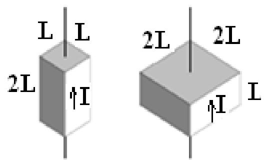
(a) electric field (b) electric power (c) none of the above (d) current (e) electric potential

7. A resistor consists of two segments of equal lengths and equal radii. Their resistivities differ, with $\rho_1 = 3\rho_2$. If the current in segment 1 is I_1, how big is the current in segment 2, I_2 ?



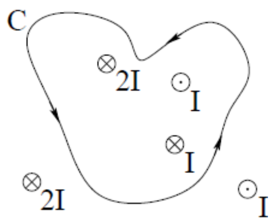
(a) $I_1 = I_2$ (b) $I_2 = I_1/3$ (c) $I_2 = I_1/2$ (d) $I_2 = 3I_1$ (e) $I_2 = 6I_1$

8. Two resistors are made out of the same material, but have different dimensions, as shown in the figures. The current through these two resistors is in the directions shown. What is the ratio of the resistances of the two wires R_A/R_B ?



(a) $R_A/R_B = 8$ (b) $R_A/R_B = 1/4$ (c) $R_A/R_B = 1/2$ (d) $R_A/R_B = 2$ (e) $R_A/R_B = 4$

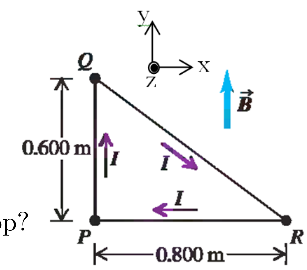
9. In the figure, long straight wires carry the currents indicated into or out of the page. The integral of $\vec{B}$ around the indicated curve C: $\oint_C \vec{B} \cdot d\vec{l}$ in the indicated direction is:



(a) $-\mu_0 I$ (b) $5\mu_0 I$ (c) $2\mu_0 I$ (d) $3\mu_0 I$ (e) $-2\mu_0 I$

Questions 10-12

The triangular loop of wire shown in Figure carries a current I= 5.00A in the direction shown. The loop is in a uniform magnetic field that has magnitude B = 3.00 T and the same direction as the current in side PQ of the loop.



10. What is the net force on the loop?

(a) 2.7N (b) 3N (c) 3.6N (d) 0.6N (e) 0

11. Calculate the magnetic moment of the loop.

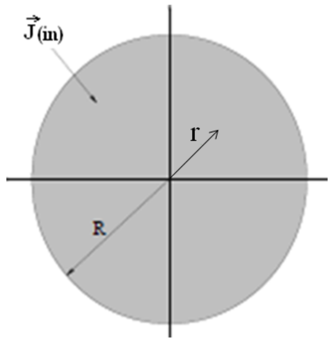
(a) $0.96\hat{\imath}$ A.m^2 (b) $2.16\hat{\imath}$ A.m^2 (c) -1.2$\hat{k}$ A.m^2 (d) $0.48\hat{k}$ A.m^2 (e) -0.72$\hat{k}$ A.m^2

12. The loop is pivoted about an axis that lies along side PR. What is the net initial torque on the loop?

(a) $2.16\hat{\imath}$ Nm (b) $3.6\hat{\imath}$ Nm (c) $0\hat{\imath}$ Nm (d) $0\hat{\jmath}$ Nm (e) $0.9\hat{\imath}$ Nm

Questions 13-15

A cylindrical long straight wire of radius R carries a uniform current density of magnitude $J=I/\pi R^2$ into the page as shown.(The coordinate r measures the distance from the axis of the cylinder. CW: clockwise, CCW: counter-clockwise)



13. For r<R how much current is encircled by a loop of radius r centered at origin?

(a) Ir^2/R^2 (b) none (c) πIr^2 (d) $\pi IR^2/r^2$ (e) $\pi Ir^2/R^2$

14. Find the magnetic field (magnitude and direction) for r<R (inside the wire).

(a) $\mu_0 I/2\pi R$, CW (b) $\mu_0 Ir/2R^2$, CCW (c) $\mu_0 Ir/2\pi R^2$, CW (d) $\mu_0 IR/2r^2$, CCW (e) $\mu_0 I/2\pi r$, CW

15. Find the magnetic field (magnitude and direction) for r > R (outside the wire).

(a) $\mu_0 Ir/2\pi R^2$, CW (b) $\mu_0 I/2r$, CCW (c) $\mu_0 I/2\pi r$, CW (d) $\mu_0 IR/2\pi r^2$, CW (e) $\mu_0 I/2\pi R$, CCW

Questions 16-18

An electrical conductor designed to carry large currents has a circular cross section 2 mm in diameter and is **21** m long. The resistance between its ends is 0.35 Ω. (take $\pi = 3$ and $e=1.6\text{x}10^{-19}$ C).

16. What is the resistivity of the material?

(a) $3.2 \times 10^{-6}\Omega$m (b) $2.5 \times 10^{-8}\Omega$m (c) $5.0 \times 10^{-8}\Omega$m (d) $4.6 \times 10^{-5}\Omega$m (e) $1.6 \times 10^{-7}\Omega$m

17. If the electric-field magnitude in the conductor is 2.0 V/m, what is the total current?

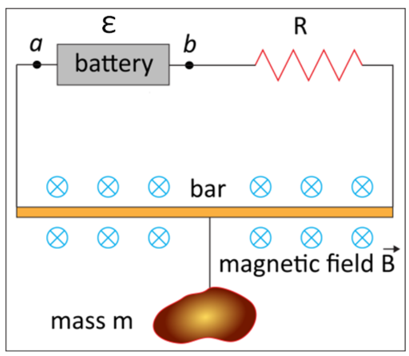
(a) 1.4×10^{-2} A (b) 2.3×10^{2} A (c) 0.45×10^{-5} A (d) 1.2×10^{2} A (e) 4.1×10^{3} A

18. If the material has 5 x 10^{28} free electrons per cubic meter, find the average drift speed under the conditions of the previous part.

(a) 1.80×10^{-3} m/s (b) 5.0×10^{-3} m/s (c) 3.2×10^{-2} m/s (d) 2.5×10^{-2} m/s (e) 8.5×10^{-4} m/s

Questions 19-21

The circuit shown in the figure is used to make a magnetic balance to weigh objects. The mass m to be measured is hung from the center of the bar that is in a uniform magnetic field of B= 2.0T, directed into the plane of the figure. The battery voltage (ε) can be adjusted to vary the current in the circuit. The horizontal bar is L=1.0 m long and is made of extremely light-weight material. It is connected to the battery by thin vertical wires that can support no appreciable tension; all the weight of the suspended mass m is supported by the magnetic force on the bar. A resistor with $R = 5\Omega$ is in series with the bar; the resistance of the rest of the circuit is much less than this. (take $g=10$ m/s^2)



19. Which point, a or b, should be the positive terminal of the battery?

(a) none (b) it does not matter (c) a (d) a and b should alternate every second (e) b

20. The magnetic force on the bar is given by

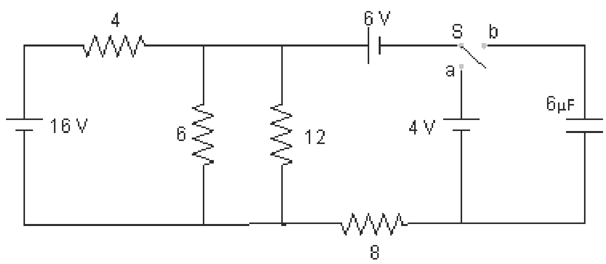
(a) εLB/R (b) $\varepsilon^2 B^2$L (c) LBε (d) εLBR (e) none

21. If the maximum terminal voltage of the battery is ε=140 V, what is the greatest mass m that this instrument can measure?

(a) 39.40 kg (b) 23.80 kg (c) 2.50 kg (d) 14.0 kg (e) 5.60 kg

Question 22-25

The numbers given in the figure for resistances are in units of ohm.



22. The equivalent resistance of 6 Ω and 12 Ω in parallel is

(a) 18 Ω (b) 20 Ω (c) 1/4 Ω (d) none (e) 4 Ω

23. Calculate the current in the 4 Ω, when switch S is in position a.

(a) 1.9 A (b) 0.80 A (c) 4.0 A (d) 0.40 A (e) 2.0 A

24. Calculate the current in the 8 Ω, when switch S is in position a.

(a) 2.0 A (b) 1.25 A (c) 0.04 A (d) 0.50 A (e) 0.20 A

25. Calculate the current in the 4 Ω resistor, when switch S is for a long time in position b.

(a) 2.0 A (b) 1.25 A (c) 2.5 A (d) 1.33 A (e) 4.0 A

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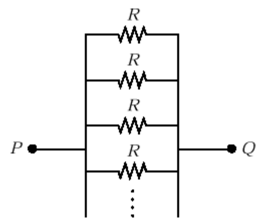
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account. Please take π=3, $m_{proton} \approx 1.6 \times 10^{-27} kg$, $q_{proton} \approx 1.6 \times 10^{-19} C$, $\mu_0 = 4\pi \times 10^{-7}$, $Sin53° = 0.8$, $Cos53° = 0.6$.

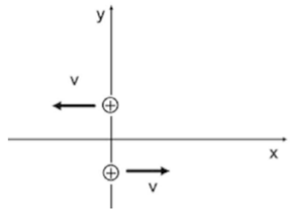


1. Points P and Q are connected to a battery of fixed voltage (see the figure). As more resistors R are added to the parallel circuit, what happens to the total current in the circuit?

(a) there is no current (b) increases (c) drops to zero (d) remains the same (e) decreases

2. Two protons move parallel to x- axis in opposite directions at the same speed v (see the figure). What is the direction of the magnetic force on the upper proton?

(a) out of the page (b) into the page (c) to the top of the page (d) to the right (e) to the left



3. Magnetic field produced at the centre of a current carrying circular wire loop is

(a) is zero. (b) directly proportional to the radius of the circular wire loop. (c) inversely proportional to the square of the radius of the circular wire loop. (d) inversely proportional to the radius of the circular wire loop. (e) directly proportional to the square of the radius of the circular wire loop.

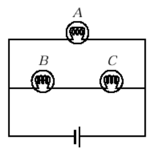
4. A current in a coil with N turns creates a magnetic field at the center of that coil. The field strength is directly proportional to:

(a) current and number of turns in the coil. (b) none of the above are valid. (c) current. (d) length of the coil. (e) number of turns in the coil.

5. The Weber (Wb) is the unit of

(a) magnetic flux. (b) eddy current intensity. (c) magnetic flux density. (d) the Hall effect. (e) none of these.

6. The three light bulbs in the circuit all have the same resistance of 1 Ω (see the figure). By how much is the brightness of bulb B greater or smaller than the brightness of bulb A? (brightness is related to power)

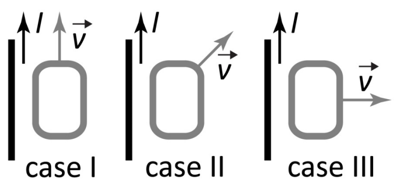


(a) the same (b) twice as much (c) 1/4 as much (d) 1/2 as much (e) 4 times as much

7. A freely suspended magnet will always come to rest in the direction

(a) South-West. (b) North-South. (c) East-North. (d) North-West. (e) East-South.

8. A long, straight wire carries a current I in the direction shown in the figure. A rectangular loop moves with a constant velocity v in the same plane as the wire as indicated. In which cases will the loop have an induced current?

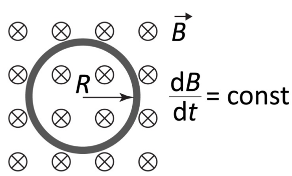


(a) Cases I and III (b) Cases I and II (c) None of the loops will have an induced current (d) Cases II and III (e) All of the loops will have an induced current

9. An airplane is flying at a constant height above the surface of Antarctica, where the magnetic field of the earth is directed upward, away from the ground. A passenger facing toward the front end of the plane will observe the following difference of electric potentials across the airplane:

(a) Lower potential at the left wing tip, higher potential at the right wing tip (b) Higher potential at the left wing tip, lower potential at the right wing tip (c) Lower potential at the front end, higher potential at the rear end (d) Higher potential at the front end, lower potential at the rear end (e) No potential difference will be observed

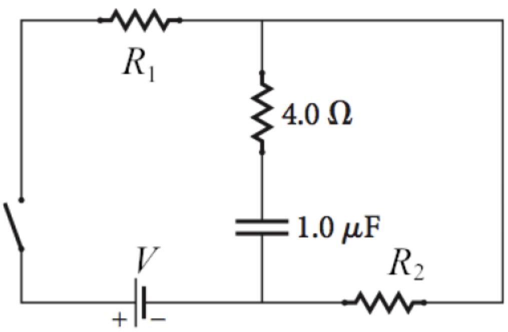
10. A metal ring with radius R lies in the plane perpendicular to a spatially uniform magnetic field B that points into the page and increases at a constant rate (see the figure). In this situation, electromotive force (emf) induced in the ring is $\mathcal{E}_1$ and magnitude of induced electric field is E_1. If the radius of the ring is doubled, the new values of the induced emf $\mathcal{E}_2$ and the induced electric field magnitude E_2 will be:



(a) $\mathcal{E}_2 = 4\mathcal{E}_1$ and $E_2 = 2E_1$ (b) $\mathcal{E}_2 = 4\mathcal{E}_1$ and $E_2 = 4E_1$ (c) $\mathcal{E}_2 = 2\mathcal{E}_1$ and $E_2 = 2E_1$ (d) $\mathcal{E}_2 = 2\mathcal{E}_1$ and $E_2 = 4E_1$ (e) $\mathcal{E}_2 = \mathcal{E}_1$ and $E_2 = E_1$

Questions 11-15

In the circuit in the figure, the capacitors are completely uncharged. The switch is then closed for a long time. As shown, $R_1 = 6\Omega$, $R_2 = 4\Omega$, $R_3 = 4\Omega$ and $V = 40V$.



11. Calculate the current through the $R_3 = 4\Omega$-resistor.

(a) 0 A (b) 2.5 A (c) 1.5 A (d) 1 A (e) 2 A

12. Find the potential difference across the $R_3 = 4\Omega$ -resistor.

(a) 8 V (b) 6 V (c) 0 V (d) 4 V (e) 10 V

13. Find the potential difference across the $R_1 = 6\ \Omega$-resistor.

(a) 32 V (b) 40 V (c) 30 V (d) 20 V (e) 24 V

14. Find the potential difference across the $R_2 = 4\ \Omega$-resistor.

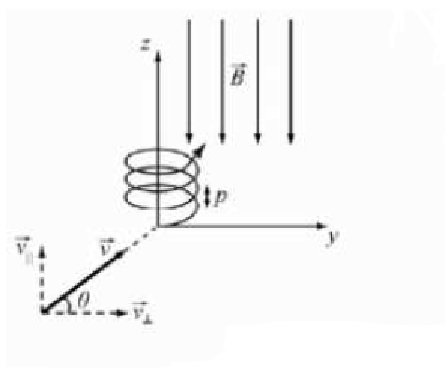
(a) 8 V (b) 16 V (c) 12 V (d) 10 V (e) 20 V

15. Find the potential difference across the 1.00 μF-capacitor.

(a) 10 V (b) 12 V (c) 20 V (d) 8 V (e) 16 V

Questions 16-20

A proton moving at speed v = 1 x 10^7 m/s enters a region in space where a magnetic field given by $\vec{B}$ = (-0.3 T) $\hat{z}$ exists. The velocity vector of the proton is at an angle $\Theta = 53°$ with respect to the positive z-axis.



16. Calculate the radius, r, of the trajectory projected onto a plane perpendicular to the magnetic field (in the xy-plane).

(a) 1 m (b) 0.2 m (c) 0.4 m (d) 2 m (e) 4 m

17. Calculate the period, T, of the motion in that plane.

(a) 200 s (b) 2×10^{-3} s (c) 2×10^{-7} s (d) 2×10^{5} s (e) 2 s

18. Calculate the frequency, f, of the motion in that plane.

(a) 5×10^{6} s (b) 5×10^{2} s (c) 5×10^{-6} s (d) 5×10^{-3} s (e) 0.5 s

19. Calculate the pitch of the motion (the distance traveled by the proton in the direction of the magnetic field in 1 period).

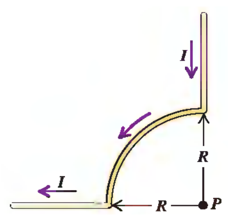
(a) 0.8 m (b) 0.4 m (c) 0.2 m (d) 3.2 m (e) 1.6 m

20. Calculate the energy change after one complete turn.

(a) 2×10^{-13} J (b) 3×10^{-13} J (c) 2×10^{-14} J (d) 3×10^{-14} J (e) 0 J

Questions 21-25

The wire in the figure carries current I in the direction shown. The wire consists of a very long, straight section, a quarter-circle with radius R, and another long, straight section.



21. What is the magnitude of the magnetic

(a) $\frac{\mu_0 I}{2R}$ (b) $\frac{\mu_0 I}{4R}$ (c) $\frac{\mu_0 I}{2\pi R}$ (d) $\frac{\mu_0 I}{4\pi R}$ (e) 0

22. What is the magnitude of the magnetic field at the center of the quarter-circle section (point P) due to the quarter-circle section?

(a) $\frac{\mu_0 I}{4R}$ (b) $\frac{\mu_0 I}{16R}$ (c) $\frac{\mu_0 I}{8R}$ (d) $\frac{\mu_0 I}{8\pi R}$ (e) $\frac{\mu_0 I}{4\pi R}$

23. What is the magnitude of the magnetic field at the center of the quarter-circle section (point P) due to the lower straight section?

(a) $\frac{\mu_0 I}{4\pi R}$ (b) 0 (c) $\frac{\mu_0 I}{4R}$ (d) $\frac{\mu_0 I}{2R}$ (e) $\frac{\mu_0 I}{2\pi R}$

24. What is the direction of the net magnetic field at the center of the quarter-circle section (point P) due to the whole wire?

(a) into the page (b) out of the page (c) none of the above (d) downwards (e) upwards

25. If all of the quantities for the above question are at the order of 1 (radius, current, total charge), what will be the ratio of the magnetic field to the electric field at point P?

(a) 0 (b) very big (c) order 1 (d) very small (e) currents produce magnetic field not electric field

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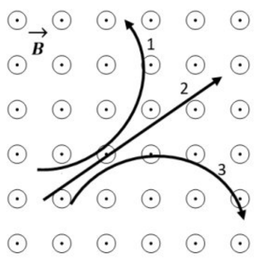
1. The unit of magnetic field Tesla and unit of magnetic flux Weber are related as

(a) Wb=T/m (b) Wb=T/m^2 (c) Wb=Tm (d) Wb=Tm^2 (e) Wb=T

2. An electron moving in the direction of the $+x$-axis enters a magnetic field. If the electron experiences a magnetic deflection in the $-y$ direction, the direction of the magnetic field in this region points in the direction of the

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

3. Three particles travel through a region of space where the magnetic field is out of the page, as shown in the figure. The electric charge of each of the three particles is, respectively.

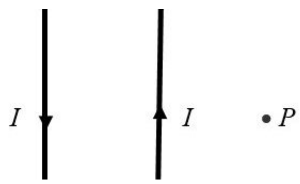


(a) 1 is positive, 2 is negative, and 3 is neutral. (b) 1 is negative, 2 is neutral, and 3 is positive. (c) 1 is positive, 2 is neutral, and 3 is negative. (d) 1 is neutral, 2 is negative, and 3 is positive. (e) 1 is neutral, 2 is positive, and 3 is negative.

4. Ions having equal charges but masses of M and $2M$ are accelerated through the same potential difference and then enter a uniform magnetic field perpendicular to their path. If the heavier ions follow a circular arc of radius R, what is the radius of the arc followed by the lighter?

(a) $\sqrt{2}R$ (b) $R/2$ (c) $4R$ (d) $R/\sqrt{2}$ (e) $3R$

5. Two wires lie as in Figure in the plane of the paper and carry equal currents in opposite directions, as shown in Figure. At a point P at the right of the two wire, the magnetic field



(a) points into the page. (b) points toward the bottom of the page (c) points toward the top of the page (d) is zero. (e) points out of the page

6. If in a solenoid the number of windings is doubled while the length and cross sectional area are constant the self induction coefficient is

(a) quartered (b) halved (c) quadrupled (d) not changed (e) doubled

7. Magnetic Gauss law states that;

(a) There is no electric charge. (b) There is no magnetic field. (c) There is no electric field. (d) The magnetic field is the gradient of a scalar potential. (e) There is no magnetic charge.

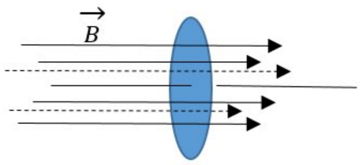
8. If there are electric and magnetic fields, the energy density u is given by;

(a) $\frac{\epsilon_0}{2}E^2 \times \frac{1}{2\mu_0}B^2$ (b) $\frac{\epsilon_0}{2}E^2 + \frac{1}{2\mu_0}B^2$ (c) $\frac{\epsilon_0}{2}E + \frac{1}{2\mu_0}B$ (d) $\frac{\epsilon_0}{2}E^2 - \frac{1}{2\mu_0}B^2$ (e) $(\frac{\epsilon_0}{2}E^2)/(\frac{1}{2\mu_0}B^2)$

9. When a capacitor is charged what is the form of the displacement current between the plates

(a) $\epsilon_0\frac{d\Phi_E}{dt}$ (b) $\mu_0\frac{d\Phi_E}{dt}$ (c) $\mu_0\epsilon_0\frac{d\Phi_E}{dt}$ (d) $\frac{1}{\mu_0\epsilon_0}\frac{dE}{dt}$ (e) $\frac{1}{\mu_0\epsilon_0}\frac{d\Phi_E}{dt}$

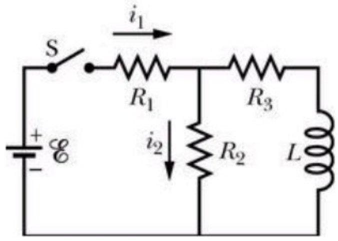
10. When an increasing magnetic field is applied through the surface of a coin as in the figure, which of the following will be true?



(a) Nothing happens (b) A current is created only along the outer edge of the circle (c) An induced magnetic field $\vec{B}'$ is created in the same direction of $\vec{B}$ (d) The coin starts to rotate around the axis (e) Currents are created in the shape of rings on the surface of the coin.

Questions 11-14

In the figure, $\mathcal{E} = 45$ V, $R_1 = 3\Omega$, $R_2 = 6\Omega$, $R_3 = 3\Omega$, and $L = 2$ mH. The switch is initially open as shown in figure. Find the values of i_1 and i_2 respectively,



11. immediately after the closing of switch S

(a) 5 A , 5 A (b) 7.5 A , 0 A (c) 3 A , 9 A (d) 7.5 A , 7.5 A (e) 0 A , 5 A

12. a long time later after the closing.

(a) 0 A , 5 A (b) 5 A , 5 A (c) 9 A , 3 A (d) 7.5 A , 0 A (e) 9 A , 6 A

13. immediately after the reopening of switch S

(a) 0 A , 6 A (b) 0 A , 3 A (c) 0 A , 9 A (d) 7.5 A , 0 A (e) 9 A , 6 A

14. a long time after the reopening.

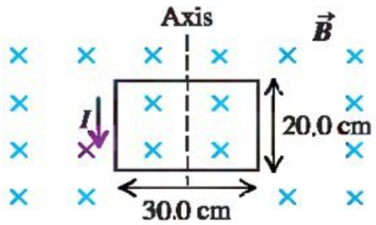
(a) 0 A , 0 A (b) 0 A , 3 A (c) 9 A , 6 A (d) 7.5 A , 0 A (e) 0 A , 6 A

15. What is the energy stored in the magnetic field inside the inductor before the switch is reopened?

(a) 36 mJ (b) 81 mJ (c) 0 mJ (d) 6 mJ (e) 9 mJ

Questions 16-19

A rectangular coil wire, 20 cm by 30 cm carrying a current of 1.5 A, is oriented with the plane of its loop perpendicular to a uniform 1.5 T magnetic field as shown in Figure.



16. What is the net force that the magnetic field exerts on the coil?

(a) 0.3 N (b) 0 N (c) 0.5 N (d) 0.9 N (e) 0.7 N

17. What is the torque that the magnetic field exerts on the coil?

(a) 0.32 Nm (b) 0.08 Nm (c) 0 Nm (d) 0.10 Nm (e) 0.16 Nm

18. What is the magnetic moment of the loop?

(a) 0.08 Am^2 (b) 0.09 Am^2 (c) 0.10 Am^2 (d) 0.06 Am^2 (e) 9 Am^2

19. The coil is rotated 30° about the axis shown, with the left side of the frame coming out of the plane. What is the net torque that the magnetic field exerts on the coil?

(a) 6.75 Nm (b) 0.0675 Nm (c) 0.125 Nm (d) 0.250 Nm (e) 0.675 Nm

Questions 20-25

A steady current $I = 10$ A flows through a solenoid with $N = 500$ turns. The solenoid has a length of $l = 30$ cm and a cross sectional area $A = 2$ cm^2. Take $\mu_0 = 1.2 \times 10^{-6}$ Tm/A.

20. To find the magnetic field inside the solenoid we use Ampere's law;

(a) $\oint \vec{B}d\vec{l} = d\vec{E}/dt$ (b) $\oint \vec{B}d\vec{l} = \mu_0 I_{enc}$ (c) $\oint \vec{E}d\vec{s} = Q/\mathcal{E}_0$ (d) $\oint \vec{B}d\vec{s} = Q/\mathcal{E}_0$ (e) $\oint \vec{E}d\vec{l} = \mu_0 I_{enc}$

21. The magnetic field inside the solenoid is;

(a) 2 T (b) 200 T (c) 20 mT (d) 0.002 mT (e) 0.2 T

22. The magnetic flux in the solenoid is

(a) 4×10^{-8} T (b) 0 (c) 1.2×10^{-6} T (d) 4×10^{-6} Wb (e) 1.2×10^{-4} Wb

23. If the current is time dependent $I = I_0 \sin \omega t$ the emf induced in a single loop of the solenoid is;

(a) $-(\mu_0 NAI_0\omega/l) \sin \omega t$

(b) $-(\mu_0 N^2 AI_0\omega/l) \cos \omega t$

(c) $-(\mu_0 NAI_0/(\omega l)) \sin \omega t$

(d) $-(\mu_0 NAI_0\omega/l) \cos \omega t$

(e) $-(\mu_0 NAI_0/(\omega l)) \cos \omega t$

24. The self induction coefficient of the solenoid L is;

(a) $\mu_0 A/l$ (b) $-\mu_0 N^2 A/l$ (c) $\mu_0 N^2 A/l$ (d) $-\mu_0 N^2 AI_0\omega/l$ (e) $\mu_0 N^2 AI_0\omega/l$

25. When $I = 10$ A is flowing through the solenoid the energy stored in it is;

(a) 10 J (b) 10 mJ (c) 10 mH (d) 10 T (e) 10 mT

		Name		Type
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Student ID		Signature		

ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

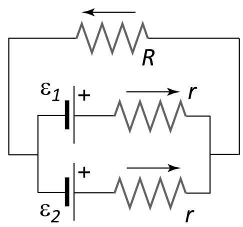
Please take $e = 1.6 \times 10^{-19}$**C,** $k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{N.m^2}{C^2}$

1. According to Kirchhoff's rules, which of the following statements about sign conventions is true?

(a) $+\mathcal{E}$ if the loop travel from (-) to (+), -IR if the loop travel in current direction (b) $-\mathcal{E}$ if the loop travel from (+) to (-), +IR if the loop travel in current direction (c) $+\mathcal{E}$ if the loop travel from (+) to (-), +IR if the loop travel in current direction (d) $-\mathcal{E}$ if the loop travel from (-) to (+), -IR if the loop travel in current direction (e) $+\mathcal{E}$ if the loop travel from (+) to (-), -IR if the loop travel opposite to current direction

Questions 2-3

Suppose two batteries, with electromotive forces $\varepsilon_1 = 2.00$ V and $\varepsilon_2 = 3.04$ V, are connected as shown in the figure. Each internal resistance is $r = 0.40\ \Omega$, and external resistance is $R = 4.00\ \Omega$.



2. What is the current through the branch of the circuit with smaller electromotive force ε_1 (the arrow indicates positive current direction)?

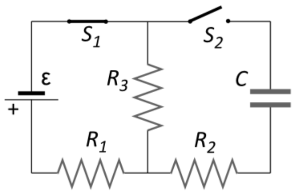
(a) 1.00 A (b) 2.10 A (c) 1.25 A (d) -1.00 A (e) -2.10 A

3. What is the voltage across the resistor R?

(a) 3.60 V (b) 2.40 V (c) 6.00 V (d) 4.80 V (e) 1.20 V

Questions 4-7

The circuit shown in the figure has a capacitor with capacitance $C = 800\,\mu$F connected to a battery with electromotive force $\varepsilon = 12$ V, two switches S_1, S_2, and three resistors $R_1 = 30\,\Omega, R_2 = 75\,\Omega, R_3 = 50\,\Omega$. Initially, the capacitor is completely discharged. The switch S_1 is closed, and switch S_2 is open.



4. Now, switch S_2 is closed. What is the total current flowing out of the battery immediately after switch S_2 has been closed?

(a) 150 mA (b) 100 mA (c) 75 mA (d) 0 mA (e) 200 mA

5. What is the energy stored in the capacitor long time after switch S_2 has been closed? Hint: you will first need to calculate the potential difference across the capacitor long time after switch S_2 has been closed.

(a) 100 mJ (b) 57.6 mJ (c) 45 mJ (d) 115.2 mJ (e) 22.5 mJ

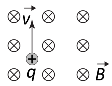
6. After switch S_2 has been closed for a long time, switch S_1 is opened and the capacitor starts discharging. How long will it take until the current in the resistor R_2 drops to 3 mA? In the calculation, take $\log 0.05 = -3$.

(a) 120 ms (b) 60 ms (c) 300 ms (d) 100 ms (e) 180 ms

7. After switch S_1 is opened, what is the total energy converted to heat in the resistor R_2 while the capacitor is discharging?

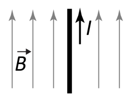
(a) 27 mJ (b) 9 mJ (c) 22.5 mJ (d) 18 mJ (e) 13.5 mJ

8. A positive charge enters a uniform magnetic field as shown. What is the direction of the magnetic force at the moment that the charge enters the magnetic field?



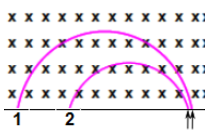
(a) into the page (b) downward (c) to the right (d) to the left (e) out of the page

9. A vertical wire carrying a current I is placed in a vertical magnetic field B. What is the direction of the magnetic force F on the wire?



(a) zero (b) out of the page (c) into the page (d) to the right (e) to the left

10. Two particles of the same mass enter a magnetic field with the same speed and follow the paths shown. Which particle has the bigger charge?

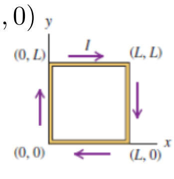


(a) Impossible to tell from the picture. (b) They have no mass. (c) Particle 2. (d) Particle 1. (e) Both charges are equal.

11. A particle of charge q moves in a circular path of radius r in a uniform magnetic field $\vec{B}$. If the magnitude of the magnetic field is doubled, and the kinetic energy of the particle remains constant, what happens to the momentum of the particle?(P_f is the final momentum, P_i is the initial momentum.)

(a) impossible to tell about the P (b) $P_f = 2P_i$ (c) $2P_f = P_i$ (d) $P_f = P_i$ (e) $4P_f = P_i$

12. A square conducting loop is placed in a nonuniform magnetic field. The loop has corners at $(0,0), (0,L), (L,L), (L,0)$ and carries a constant current I in the clockwise direction as shown. The magnetic field is non uniform and it is in z direction; $\vec{B} = (\frac{B_0 y}{L})\hat{k}$, where B_0 is a positive constant. Find the magnitude and direction of the net magnetic force on the loop.



(a) $\vec{F}_{net} = -IB_0L\hat{\jmath}$ (b) $\vec{F}_{net} = IB_0L\hat{\imath}$ (c) $\vec{F}_{net} = IB_0L\hat{k}$ (d) $\vec{F}_{net} = IB_0L\hat{\jmath}$ (e) $\vec{F}_{net} = -IB_0L\hat{k}$

Questions 13-14

A cyclotron in a magnetic field of 8.0 T is used to accelerate protons to 50% of the speed of light(Take c = 3.0×10^8 m/s, $\pi = 3.0$, q = 1.6×10^{-19}C, $m_{\text{proton}} = 1.6 \times 10^{-27}$kg).

13. What is the cyclotron frequency of these protons?

(a) 5.0×10^6Hz (b) 2.5×10^5Hz (c) 3.4×10^3Hz (d) 1.33×10^8Hz (e) 7.8×10^7Hz

14. What is the radius of their trajectory in the cyclotron?

(a) 0.188 m (b) 0.53 m (c) 1.07 m (d) 1.26 m (e) 0.45 m

Questions 15-17

A long solenoid has length L and radius a. It has n turns per unit length. The current in the solenoid is $I(t) = I_0 \sin \omega t$.

15. Find magnetic field inside the solenoid.

(a) 0 (b) $\mu_0 n I_0 \sin \omega t$ (c) $\mu_0 n I_0$ (d) $\mu_0 n I_0 \omega \sin \omega t$ (e) $\mu_0 n I_0 \omega \cos \omega t$

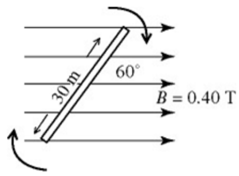
16. Find emf induced in one loop.

(a) $\pi a^2 \mu_0 n I_0 \omega \cos \omega t$ (b) $-2\pi a \mu_0 n I_0 \omega \cos \omega t$ (c) $-\pi a^2 \mu_0 n I_0 \omega \sin \omega t$ (d) $-\pi a^2 \mu_0 n I_0 \omega \cos \omega t$ (e) 0

17. Find induced E at radius a.

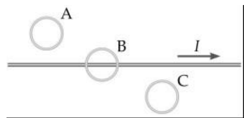
(a) $-a\mu_0 n I_0 \omega \cos \omega t/2$ (b) $-a^2 n I_0 \omega \cos \omega t/2$ (c) 0 (d) insufficient information (e) $-\pi a^2 \mu_0 n I_0 \omega \cos \omega t L$

18. Wire is wound on a square frame, 30 cm by 30 cm, to form a coil of 7 turns. The frame is mounted on a horizontal shaft through its center (perpendicular to the plane of the diagram), as shown in the figure. The coil is rotating clockwise, with a period of 0.060 s. A uniform, horizontal, magnetic field of magnitude 0.40 T is present. At a given instant, the plane of the coil forms a 60° angle with the horizontal, as shown. At that instant, what is the magnitude of the emf induced in the coil? Take $\pi = 3$.



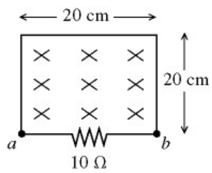
(a) 2.52 V (b) 6.3 V (c) 25.2 V (d) 1.26 V (e) 12.6 V

19. The long straight conducting wire in the figure carries a current I that is decreasing with time at a constant rate. The circular loops A, B, and C all lie in a plane containing the wire. The induced emf in each of the loops A, B, and C is such that



(a) no emf is induced in any of the loops. (b) loop A has a counter-clockwise emf, loops B and C have clockwise emfs. (c) loop A has a counter-clockwise emf, loop B has no induced emf, and loop C has a clockwise emf. (d) loop A has a clockwise emf, loop B has no induced emf, and loop C has a counterclockwise emf. (e) a counterclockwise emf is induced in all the loops.

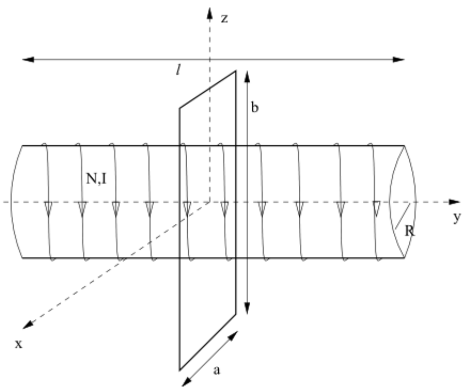
20. As shown in the figure, a wire and a 10 Ω resistor are used to form a circuit in the shape of a square, 20 cm by 20 cm. A uniform but non steady magnetic field is directed into the plane of the circuit. The magnitude of the magnetic field is decreased from 1.50 T to 0.50 T in a time interval of 100 ms. The average induced current and its direction through the resistor, in this time interval, are



(a) 40 mA, from a to b (b) 40 mA, from b to a. (c) 4 mA, from b to a. (d) 4 mA, from a to b. (e) 0.4 mA, from a to b.

Questions 21-25

A long solenoid with radius R, length l and number of turns N carries current I. A rectangular conducting loop with dimensions a and b is equicentered with the solenoid (a >> $2R$ and b >> $2R$) as shown in the figure. The loop is positioned in $x - z$ plane.



21. Determine the magnetic field inside and outside of the solenoid respectively.

(a) 0 and 0 (b) $\frac{\mu_0 IN}{2r}$ and 0 (c) $\frac{\mu_0 IN}{2R}$ and $\frac{\mu_0 I}{2r}$ (d) $\frac{\mu_0 IN}{l}$ and 0 (e) 0 and $\frac{\mu_0 IN}{2R}$

22. What is the magnetic flux through the rectangular loop?

(a) $\frac{\mu_0 IN}{2r}\pi R^2$ (b) $\frac{\mu_0 IN}{l}\pi R^2$ (c) $\frac{\mu_0 IN}{l}\pi R^2 + \frac{\mu_0 I}{2\pi r}\pi R^2$ (d) $\frac{\mu_0 IN}{2\pi r}\pi R^2$ (e) $\frac{\mu_0 IN}{l}ab$

23. What is the magnitude of the electromotive force (EMF) through the frame if the current in the solenoid changes as $I = I_0\ e^{-\alpha t}$ where I_0 and α are positive constants?

(a) $\frac{\alpha \mu_0 N I_0 e^{-\alpha t}}{2r}\pi R^2$ (b) $\frac{\alpha \mu_0 N I_0 e^{-\alpha t}}{2r}ab$ (c) $\frac{\alpha \mu_0 N I_0 e^{-\alpha t} ab}{l}$ (d) $\frac{\alpha \mu_0 N I_0 e^{-\alpha t} \pi R^2}{l}$ (e) 0

24. What is the direction of the induced current in the rectangular loop when it is viewed from right handside?

(a) in the direction of x (b) clockwise direction (c) in the direction of y (d) in the direction of z (e) counter clockwise direction

25. If the frame is rotated 90° about the z-axis, what is the magnitude of the EMF induced in the new position?

(a) twice as the original (b) half of the original (c) not enough information to answer it! (d) same with the original position (e) 0

		Name		Type
Group Number		Surname		A
List Number		e-mail		
Student ID		Signature		

ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

For all questions take: Speed of light $c = 3 \times 10^8$ m/s, $\pi = 3$, $\epsilon_0 = 9 \times 10^{-12}$ C^2/N.m^2, electron charge $e = 1.6\ 10^{-19}$ C.

1. Magnetic dipole moment is defined as $\vec{\mu} = I\vec{S}$. Here I is the current, $\vec{S}$ is the surface vector of the area enclosed by this current. Which of the following expressions gives the magnetic dipole moment of a single circling electron? (In the below expressions $\vec{l}$ is the angular momentum, e is the electron charge and m is the mass of the electron.)

(a) $\frac{4e}{m}\vec{l}$ (b) $\frac{2m}{e}\vec{l}$ (c) $\frac{e}{2m}\vec{l}$ (d) $\frac{e}{m}\vec{l}$ (e) $\frac{m}{e}\vec{l}$

2. A loop of area 0.1 m^2, carrying a current of 0.3 A with 200 windings is placed in a magnetic field of 0.1 T, making an angle of 60° with the normal of the loop. Which of the following is the potential energy of the system?

(a) -0.6 J (b) zero. (c) 0.6 J (d) 0.3 J (e) -0.3 J

3. An electron enters a magnetic field with a velocity $\vec{v}$ and follows a circular trajectory. Find the work done by the magnetic force on the electron for one period.

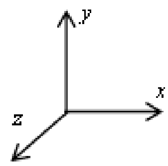
(a) $evBR$ (b) zero (c) $evB2\pi R$ (d) $e\frac{v^2}{R}B$ (e) ev^2BR

4. The magnetic field generated by a point-like charge q moving with a velocity $\vec{v}$, at a distance $\vec{r}$ from it, is given by

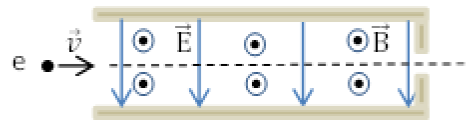
(a) $\frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$ (b) $\frac{4\pi}{\mu_0}\frac{q\vec{v}\times\hat{r}}{r^2}$ (c) $\frac{\mu_0}{4\pi}q\vec{v}\times\hat{r}$ (d) $\frac{\mu_0}{4\pi}\frac{q\vec{v}.\hat{r}}{r^2}$ (e) $\frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^3}$

5. An electron with a velocity $\vec{v} = v_1\hat{\imath} - v_2\hat{\jmath}$, where v_1 and $v_2$are some constants, enters the magnetic field given as $\vec{B} = -B_0\hat{\jmath}$. Which of the following is the trajectory that this electron will follow? (Answer the question on the basis of the reference frame given in figure.)

(a) A circle on the x-z plane in the counter-clockwise direction.
(b) A spiral with decreasing stepping in the $-z$ direction.
(c) A spiral with increasing stepping in the $+z$ direction.
(d) A spiral with equal stepping in the $+z$ direction.
(e) A circle on the x-y plane in the clockwise direction.

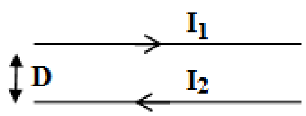


6. Only those electrons from the cathode that have a certain speed are required to pass through the hole at the right side of the instrument shown in figure. Electric field $\vec{E}$ (below direction) and magnetic field $\vec{B}$ (outside direction) are applied as shown in the figure. What is the speed of electrons which pass through the hole?



(a) $\vec{E}\times\vec{B}$ (b) $\vec{E}.\vec{B}$ (c) $E - B$ (d) E/B (e) B/E

7. Two parallel, straight and very long conducting wires carry currents I_1 and I_2 in opposite directions. The distance between them is D. What is the magnitude and direction of the force acting on a segment with length L of the wire carrying I_1 current?



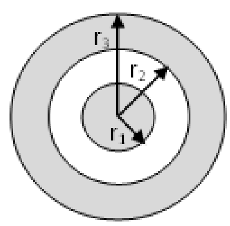
(a) $\frac{\mu_0 LI_1I_2}{2\pi D}$, up (b) $\frac{\mu_0 LI_1I_2}{2\pi D}$, to the right (c) $\frac{\mu_0 LI_1I_2}{2\pi D}$, to the left (d) $\frac{\mu_0 LI_1}{2\pi D}$, up
(e) $\frac{\mu_0 LI_2}{2\pi D}$, down

8. Which of the following statements refers to the displacement current, I_d?

(a) $\mu_0\frac{d}{dt}\int\vec{B}.d\vec{A}$ (b) $\epsilon_0\frac{d}{dt}\int\vec{E}.d\vec{A}$ (c) $\int\vec{E}.d\vec{A}$ (d) $\mu_0\frac{d}{dt}\int\vec{B}\times d\vec{A}$ (e) $\epsilon_0\frac{d}{dt}\int\vec{E}\times d\vec{A}$

Questions 9-12

A coaxial cable consists of a long cylindrical copper wire of radius r_1 surrounded by a cylindrical shell of inner radius r_2 and outer radius r_3. The wire and the shell carry equal and opposite currents I, uniformly distributed over their volumes. Find the magnitude of the magnetic field



9. in the region $r < r_1$.

(a) $\frac{\mu_0 I}{2\pi r}$ (b) 0 (c) $\frac{\mu_0 Ir}{2\pi r_1^2}$ (d) $\frac{\mu_0 Ir_1}{2\pi r^2}$ (e) $\frac{\mu_0 I}{2\pi r_1}$

10. in the region $r_1 < r < r_2$.

(a) $\frac{\mu_0 I(r_2-r_1)}{2\pi r^2}$ (b) $\frac{\mu_0 Ir}{2\pi r_1 r_2}$ (c) 0 (d) $\frac{\mu_0 Ir_1}{2\pi r^2}$ (e) $\frac{\mu_0 I}{2\pi r}$

11. in the region $r_2 < r < r_3$.

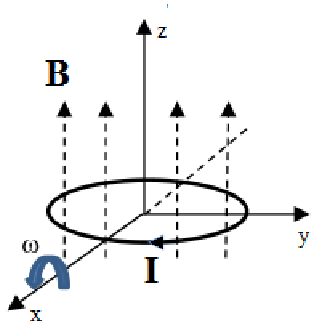
(a) $\frac{\mu_0 I}{2\pi(r_3^2-r_2^2)}(\frac{r_3^2-r^2}{r})$ (b) $\frac{\mu_0 Ir}{2\pi(r_3^2-r_2^2)}$ (c) $\frac{\mu_0 I}{2\pi(r_3^2-r_2^2)}(\frac{r^2-r_2^2}{r})$ (d) 0 (e) $\frac{\mu_0 Ir}{2\pi r_3^2}$

12. in the region $r > r_3$.

(a) $\frac{2\mu_0 I}{\pi r}$ (b) $\frac{\mu_0 I r^2}{\pi r_1 r_2 r_3)}$ (c) 0 (d) $\frac{\mu_0 I r}{\pi r_3^2}$ (e) $\frac{\mu_0 I}{\pi r}$

Questions 13-16

The axis of a ring carrying current I, is parallel to z-axis at time $t = 0$, as in figure. Then it starts to rotate around x-axis in the counterclockwise with an angular velocity $\omega = 2\pi/T$, where T is the period, as in figure. A homogeneous magnetic field is applied along the z-axis that passes through the whole area of the ring. The radius of ring is R.



13. What is the magnetic dipole moment of the ring at $t = 0$?

(a) 0 (b) $IR^2\omega\hat{\imath}$ (c) $-I\pi R^2\hat{k}$ (d) $-IR^2\omega\hat{\imath}$ (e) $I\pi R^2\hat{k}$

14. What is the magnetic dipole moment of the ring at $t = T/4$?

(a) $I\pi R^2\hat{\jmath}$ (b) $-I\pi R^2\frac{T}{4}\hat{\jmath}$ (c) 0 (d) $-I\pi R^2\hat{\jmath}$ (e) $I\pi R^2\frac{T}{4}\hat{\jmath}$

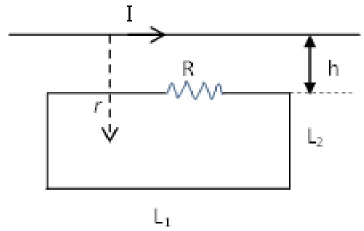
15. What is the tork on the ring at $t = T/4$?

(a) 0 (b) $-I2\pi RB\hat{k}$ (c) $I\pi R^2 B\hat{k}$ (d) $I\pi R^2 B\hat{\imath}$ (e) $-I\pi R^2 B\hat{\imath}$

16. What is the tork on the ring at $t = T/2$?

(a) $I\pi R^2 B\hat{\imath}$ (b) $-I2\pi RB\hat{k}$ (c) $-I2\pi RB\hat{\jmath}$ (d) $I\pi R^2 B\hat{\jmath}$ (e) 0

Questions 17-21



A rectangular loop of conducting wire of length L_1 and width L_2 lies near a very long wire carrying a current I, as shown in the figure. The loop and the current carrying wire are in the same plane, and the two long edges of the loop are parallel to the wire. The resistance of the loop is R.

17. What is the magnitude and direction of the magnetic field in the loop at a distance r from the current carrying wire?

(a) $\frac{\mu_0 I r}{2\pi}$, points out of the page (b) $\frac{\mu_0 I}{2\pi r}$, points into the page (c) $\frac{\mu_0 r}{2\pi I}$, points out of the page (d) $\frac{\mu_0 I r}{2\pi}$, points into the page (e) $\frac{\mu_0 I}{2\pi r}$, points out of the page

18. What is the magnetic flux through the loop?

(a) $\frac{\mu_0 I h}{2\pi}\ln(1+\frac{L_1}{L_2})$ (b) $\frac{\mu_0 I L_1}{2\pi}\ln(1+\frac{L_2}{h})$ (c) $\frac{\mu_0 I L_2}{2\pi}\ln(1+\frac{L_1}{h})$ (d) $\frac{\mu_0 I L_1 L_2}{2\pi h}$ (e) $\frac{\mu_0 I L_1 L_2}{2\pi}$

19. If the current in the wire changes as a function of time as $I = a + bt$, where a and b are positive constants, what is the induced emf $\mathcal{E}$ in the loop?

(a) $-\frac{\mu_0 a L_2}{2\pi}\ln(1+\frac{L_1}{h})$ (b) $\frac{\mu_0 b h}{2\pi}\ln(1+\frac{L_1}{L_2})$ (c) $\frac{\mu_0 b L_1 L_2}{2\pi h}$ (d) $\frac{\mu_0 b L_1 L_2}{2\pi}$ (e) $-\frac{\mu_0 b L_1}{2\pi}\ln(1+\frac{L_2}{h})$

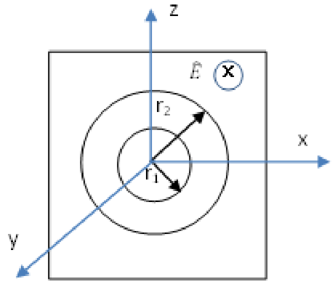
20. If the current in the wire changes as a function of time as $I = a + bt$, find the current and its direction in the loop?

(a) $\frac{\mu_0 b h}{2\pi R}\ln(1+\frac{L_1}{L_2})$, clockwise (b) $\frac{\mu_0 b L_1 L_2}{2\pi h R}$, counter-clockwise (c) $\frac{-\mu_0 a L_2}{2\pi R}\ln(1+\frac{L_1}{h})$, counter-clockwise (d) $\frac{\mu_0 b L_1 L_2}{2\pi R}$, clockwise (e) $\frac{\mu_0 b L_1}{2\pi R}\ln(1+\frac{L_2}{h})$, counter-clockwise

21. When the current in the wire, I, is constant and the loop moves away from the wire in the perpendicular direction with a constant speed, which of the following will be true?

(a) The tork on the loop decreases with time
(b) The magnetic flux through the loop increases with time
(c) The induced current does not change
(d) The induced current increases with time
(e) The magnetic flux through the loop decreases with time

Questions 22-25



In figure, a time dependent electric field, $\vec{E} = -E_0 t\hat{\jmath}$, is applied in the $-y$ direction (inside the page). ϵ_0 and μ_0, are the vacuum permittivity and the vacuum permeability, respectively.

22. Find the electric flux through a circular area of radius r_1 shown in figure.

(a) $\pi r_1^2 E_0 t$ (b) $\pi r_1 E_0 t$ (c) $\frac{4\pi}{3} r_1^3 E_0 t$ (d) $2\pi r_1 E_0 t$ (e) $\pi(r_2^2 - r_1^2)E_0 t$

23. Find the magnitude of the magnetic field at a distance r_2 shown in figure.

(a) $\frac{\mu_0 r_2 E_0}{\epsilon_0 r_1}$ (b) $\frac{\epsilon_0\mu_0 r_2 E_0}{2}$ (c) $\frac{\epsilon_0\mu_0(r_2 - r_1)E_0}{2\pi}$ (d) $\frac{\epsilon_0\mu_0\pi r_2^2 E_0}{2}$ (e) $\frac{\epsilon_0 r_1 E_0}{\mu_0 r_2}$

24. Find the electric flux in the region between r_1 and r_2 shown in figure.

(a) $\pi r_2^2 E_0 t$ (b) $\frac{\pi r_2^2 E_0 t}{r_1^2}$ (c) $\pi(r_2^2 - r_1^2)E_0 t$ (d) $2\pi(r_2 - r_1)E_0 t$ (e) $2\pi r_2 E_0 t$

25. Find the displacement current passing through the region between r_1 and r_2 shown in figure.

(a) $2\pi\epsilon_0\mu_0 r_2 E_0$ (b) $\frac{\epsilon_0}{\mu_0}\frac{\pi r_2^2 E_0}{r_1^2}$ (c) $\epsilon_0\mu_0\pi(r_2^2 - r_1^2)E_0$ (d) $\mu_0\pi r_2^2 E_0$ (e) $\frac{\epsilon_0}{\mu_0}\pi r_2^2 E_0$

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ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

For all questions take: Speed of light $c = 3 \times 10^8$ m/s, $\pi = 3$, $\epsilon_0 = 9 \times 10^{-12}$ $C^2/N.m^2$, electron charge $q_e = 1.6\ 10^{-19}$ C, electron mass $m_e = 9.11 \times 10^{-31}$ kg.

1. What is the SI unit of resistance ohm in terms of the basic (meter, kilogram, second, ampere) units?

(a) $kg.m^2/A^2$ (b) $kg.m^2/(A^2.s^3)$ (c) $kg.m/(A^2.s)$ (d) $m/(A.s)$ (e) $kg/(A^2.s^3)$

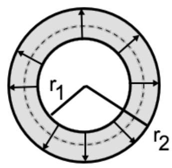
2. What is the resistance of a circular slab of radius r, thickness t, and resistivity ρ for current flowing through the slab along the thickness direction?

(a) $\rho/(\pi r^2)$ (b) $\pi r^2/(\rho t)$ (c) $\rho/(t\pi r^2)$ (d) $\rho t/(\pi r^2)$ (e) $\rho t/r^2$

3. Two wires, A and B, are made of the same metal and have equal length. The resistance of wire A is four times larger than the resistance of wire B. How do the diameters of the wires d_A and d_B compare?

(a) $d_A = d_B/2$ (b) $d_A = 2d_B$ (c) $d_A = d_B/4$ (d) $d_A = 4d_B$ (e) $d_A = d_B$

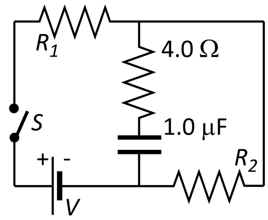
4. Determine the total resistance of a spherical shell made of material with conductivity σ, inner radius r_1, and outer radius r_2. Assume the current flows radially outward.



(a) $\frac{1}{4\pi\sigma}(\frac{r_2}{r_1})$ (b) $\frac{1}{4\pi\sigma}(\frac{1}{r_1 r_2})$ (c) $\frac{1}{4\pi\sigma}(\frac{r_1}{r_2})$ (d) $\frac{1}{4\pi\sigma}(\frac{1}{r_1} - \frac{1}{r_2})$ (e) $\frac{1}{4\pi\sigma}(\frac{1}{r_2} - \frac{1}{r_1})$

Questions 5-6

In the circuit shown in the figure, the capacitor is initially completely uncharged. The switch is then closed for a long time. Assume $R_1 = 7.0\,\Omega$, $R_2 = 3.0\,\Omega$, and V = 9.0 V.



5. Find the final potential difference across the resistor R_1.

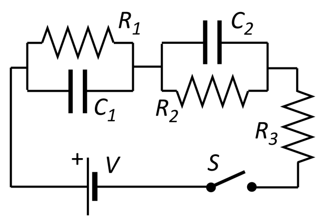
(a) 4.9 V (b) 0 (c) 6.8 V (d) 6.3 V (e) 2.0 V

6. Find the final potential difference across the 1.0 μF-capacitor.

(a) 2.7 V (b) 4.9 V (c) 6.3 V (d) 2.4 V (e) 0

Questions 7-10

An electric circuit is given in the figure where $R_1 = 20\,\Omega$, $R_2 = 40\,\Omega$, $R_3 = 60\,\Omega$, $C_1 = 4\,\mu F$, $C_2 = 2\,\mu F$ and $V = 12$ V. The capacitors have initially no charge.



7. What is the current in the circuit right after the switch is closed ($t = 0$)?

(a) 0.2 A (b) 0.5 A (c) 0.1 A (d) 0.4 A (e) 0

8. What is the current in the circuit long time after the switch is closed ($t \to \infty$)?

(a) 0.1 A (b) 0.2 A (c) 0.5 A (d) 0.4 A (e) 0

9. What is the energy stored in C_1 during the charging process (when the capacitor is fully charged)?

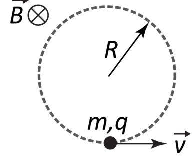
(a) 16 μJ (b) 2 μJ (c) 8 μJ (d) 32 μJ (e) 4 μJ

10. After the equilibrium is reached, the switch is opened again. What is the ratio of currents I_1 to I_2 through resistors R_1 and R_2 at all times?

Hint : Charged capacitors should discharge independently via the resistors connected to them.

(a) 4 (b) 1/4 (c) 2 (d) 1/2 (e) 1

11. A uniform magnetic field $\vec{B}$ is directed into the plane of the page as shown in the figure. The particle of charge q, mass m, and speed v is following a circular path with a radius R. If you double the mass of the charged particle in the figure while keeping the magnitude of the magnetic field the same (as well as the charge and the speed of the particle), how does this effect the radius of the circular trajectory and the time required for one complete circular orbit?



(a) The radius and the time become four times larger. (b) The radius and the time become two times smaller. (c) The radius becomes two times larger and the time remains the same. (d) The radius and the time become two times larger. (e) The radius and the time do not change.

12. Which of the following statements is false?

(a) Magnetic force on a moving charged particle is always perpendicular to the magnetic field $\vec{B}$.

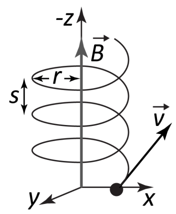
(b) Magnetic force does zero work on a moving charged particle.

(c) A charged particle can move through a magnetic field without experiencing any magnetic force.

(d) A current loop with an area A and a current I in a uniform magnetic field $\vec{B}$ will experience zero net force, but can experience a non-zero torque.

(e) Magnetic moment of a planar current loop depends on the shape of the loop, the area of the loop and the current in the loop.

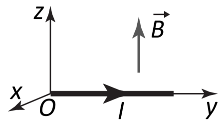
13. A particle with a positive charge q and mass m is traveling through a region with a uniform magnetic field $\vec{B} = B_0(-\hat{k})$ where B_0 is a constant. The velocity of the particle is given as $\vec{v} = v_0\hat{\imath} - 2v_0\hat{k}$ where v_0 is a constant. The path of the particle will be a helix. What is the distance s traveled along the axis of helix (-z axis) during the time needed to complete one full revolution around the helix (distance between the neighboring helix turns)?



(a) $\frac{2v_0\pi m}{qB_0}$ (b) $\frac{4v_0\pi}{qmB_0}$ (c) $\frac{2v_0\pi}{qmB_0}$ (d) $\frac{\sqrt{2}v_0\pi m}{qB_0}$ (e) $\frac{4v_0\pi m}{qB_0}$

Questions 14-15

A long conducting wire placed along the y-axis carries a current I in the positive y-direction. A magnetic field $\vec{B}$ is applied on this wire in the $+z$-direction that varies linearly with y as $\vec{B} = B_0 y\hat{k}$. Here, B_0 is a constant.



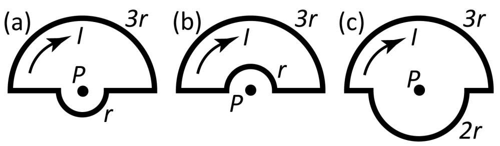
14. What is the magnitude and the direction of the net force on a segment of length L of this wire starting at the origin O?

(a) $2IB_0L$ along the -x axis (b) $2IB_0L^2$ along the -x axis (c) $IB_0L^2/2$ along the $+x$ axis (d) 0 (e) IB_0L along the $+x$ axis

15. Now, if this wire is placed along the $+x$ axis instead of $+y$ axis and it still carries the same current I, what will be the magnitude and the direction of the net force on a wire segment of length L?

(a) IB_0L along the $+x$ axis (b) 0 (c) $2IB_0L$ along the -y axis (d) $IB_0L^2/2$ along the $+y$ axis (e) $2IB_0L^2$ along the -x axis

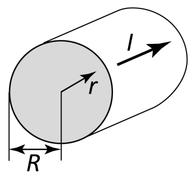
16. The three circuits shown in the figure consist of straight radial segments and concentric circular arcs (half-circles of radii r, $2r$, or $3r$). The circuits carry the same current I in the indicated direction. Rank the circuits according to the magnitude of the magnetic field produced at point P at the center of curvature, greatest first.



(a) $a = b > c$ (b) $b > c > a$ (c) $a > c > b$ (d) $a > b > c$ (e) $c > a > b$

Questions 17-18

The current density in a cylindrical conductor of radius R shown in the figure varies with the distance from the cylinder axis as $J(r) = J_0 r/R$ (in the region from zero to R). The total current flowing along the cylinder axis is I.



17. What is the value of J_0 in terms of the total current I and conductor radius R?

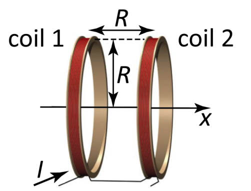
(a) $I/(\pi R^2)$ (b) $3I/(\pi R^2)$ (c) $2I/(\pi R^2)$ (d) $I/(3\pi R^2)$ (e) $3I/(2\pi R^2)$

18. What is the magnitude of the magnetic field at a distance r in the region $r < R$?

(a) $\mu_0 J_0 R^2/(3r)$ (b) $\mu_0 J_0 r/R$ (c) $\mu_0 J_0 r/3$ (d) $\mu_0 J_0 r^2/(3R)$ (e) $2\mu_0 J_0 \pi R^2/r$

Questions 19-21

Two coils each with 2000 turns have both radius $R = 0.1$ m. They are placed parallel to each other and are on the same axis as shown in the figure. The distance between the coils is equal to R. The first coil carries a current $I = 1$ A. There is initially no current in the second coil. (Take $\mu_0 = 4\pi \times 10^{-7}$ Tm/A)



19. What is the magnitude of the magnetic field $\vec{B}$ at the center of coil 1?

(a) $4\pi \times 10^{-3}$ T (b) $4\pi \times 10^{3}$ T (c) 4π T (d) 0 (e) $4\pi \times 10^{-4}$ T

20. What is the magnitude of the magnetic field $\vec{B}$ on the axis of the current-carrying coil 1 at the position $x = R/2$, halfway between the two coils?

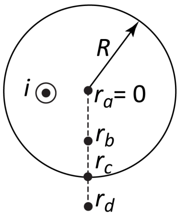
(a) $[16\pi/(5\sqrt{5})] \times 10^{-3}$ T (b) $[32\pi/(5\sqrt{5})] \times 10^{-3}$ T (c) $[4\pi/(5\sqrt{5})] \times 10^{-3}$ T (d) $[8\pi/(5\sqrt{5})] \times 10^{-3}$ T (e) 0

21. Now both coils are energized and carry the same current $I = 1$ A in the same direction. What is the magnitude of the magnetic field $\vec{B}$ on their axis at the position $x = R/2$, halfway between the two coils?

(a) $[16\pi/(5\sqrt{5})] \times 10^{-3}$ T (b) 0 (c) $[64\pi/(5\sqrt{5})] \times 10^{-3}$ T (d) $[32\pi/(5\sqrt{5})] \times 10^{-3}$ T (e) $[8\pi/(5\sqrt{5})] \times 10^{-3}$ T

Questions 22-25

The figure shows a cross section across the diameter of a long, solid, cylindrical conductor. The radius of the cylinder is $R = 8.00$ cm. A current $i = 1.00$ A is uniformly distributed through the conductor and is flowing out of the page. Calculate the magnitude of the magnetic field: (Take $\pi = 3$)



22. at $r_a = 0.00$ cm

(a) 0.25 T (b) Incalculable (c) 0 (d) $10^{-3}/32$ T (e) 2.5×10^{-6} T

23. at $r_b = 3.20$ cm

(a) 0.25 T (b) 6.25×10^{-5} T (c) 25 T (d) 10^{-6} T (e) $10^4/32$ T

24. at $r_c = 8.00$ cm

(a) Incalculable (b) 2.5×10^{-6} T (c) 2.5×10^{-10} T (d) 1/64 T (e) 6.25×10^{-5} T

25. at r_d=10.00 cm

(a) 2.0×10^{-3} T (b) 2.0×10^{-6} T (c) 1.56×10^{-2} T (d) 6.25×10^{-5} T (e) 0

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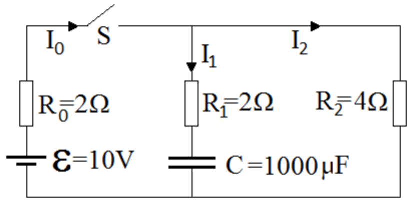
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

Questions 1-4

The capacitor in the figure is initially uncharged and the switch is open.



1. Immediately after the switch is closed, what is the current I_1 through resistor R_1?

(a) 2 A (b) 3 A (c) 5 A (d) 1 A (e) 4 A

2. What will be the potential difference across the capacitor a long time after the switch is closed?

(a) 3 V (b) 4 V (c) $\frac{15}{4}$ V (d) $\frac{10}{3}$ V (e) $\frac{20}{3}$ V

3. After a very long time, the switch is reopened. What is the current through resistor R_1 immediately after the switch is reopened?

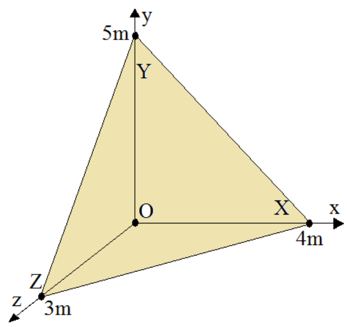
(a) $\frac{5}{4}$ A (b) $\frac{10}{7}$ A (c) $\frac{3}{2}$ A (d) $\frac{5}{7}$ A (e) $\frac{10}{9}$ A

4. What is $I_2(t)$, the current through the resistor R_2 after the switch is reopened at $t = 0$?

(a) $\frac{10}{9}e^{-(500t/3)}$ A (b) $\frac{3}{2}e^{-(250t/3)}$ A (c) $\frac{5}{4}e^{-(400t/3)}$ A (d) $\frac{10}{7}e^{-(200t/3)}$ A (e) $\frac{5}{7}e^{-(100t/3)}$ A

Questions 5-7

The magnetic field B in a certain region is given by $\vec{B} = 8\hat{\jmath} + 3\hat{k}$ in units of tesla. (Unit vectors pointing along the x, y and z axes are $\hat{\imath}$, $\hat{\jmath}$ and $\hat{k}$ respectively.)



5. What is the magnetic flux across the surface OYZ in the figure?

(a) −75 Wb (b) 0 Wb (c) −30 Wb (d) −60 Wb (e) −15 Wb

6. What is the magnetic flux across the surface OXY?

(a) −75 Wb (b) 0 Wb (c) +15 Wb (d) −30 Wb (e) +30 Wb

7. What is the net flux through all four surfaces that enclose the shaded volume?

(a) +75 Wb (b) −30 Wb (c) 0 Wb (d) +60 Wb (e) −15 Wb

8. An insulator in the shape of a circular loop of radius R has uniformly distributed total charge of Q. It rotates with a constant angular speed ω about an axis perpendicular to the plane of the loop and passing through its center. What is current produced in the loop?

(a) $\frac{3Q\omega}{4\pi}$ (b) $\frac{5Q\omega}{4\pi}$ (c) $\frac{Q\omega}{2\pi}$ (d) $\frac{7Q\omega}{5\pi}$ (e) $\frac{Q\omega}{3\pi}$

9. An insulator in the shape of a circular loop of radius R has uniformly distributed total charge of Q. It rotates with a constant angular speed ω about an axis perpendicular to the plane of the loop and passing through its center. What is the magnetic field at the center of the loop?

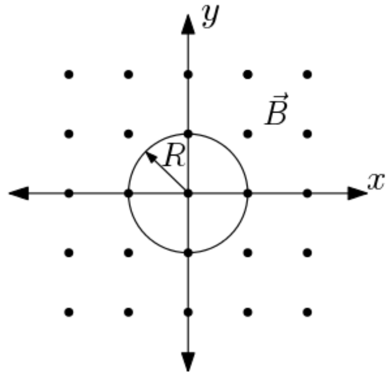
(a) $\frac{5\mu_0 Q\omega}{4\pi R}$ (b) $\frac{\mu_0 Q\omega}{4\pi R}$ (c) $\frac{7\mu_0 Q\omega}{5\pi R}$ (d) $\frac{\mu_0 Q\omega}{2\pi R}$ (e) $\frac{3\mu_0 Q\omega}{4\pi R}$

10. A thin disk of insulating material of radius R has a total charge Q distributed uniformly over its surface. It rotates with a constant angular speed ω about an axis perpendicular to the surface of the disk and passing through its center. What is the magnetic field at the center of the disk?

(a) $\frac{\mu_0 Q\omega}{2\pi R}$ (b) $\frac{5\mu_0 Q\omega}{4\pi R}$ (c) $\frac{7\mu_0 Q\omega}{5\pi R}$ (d) $\frac{\mu_0 Q\omega}{4\pi R}$ (e) $\frac{3\mu_0 Q\omega}{4\pi R}$

Questions 11-14

A circular conducting ring of radius R with an average resistance of r is located in the xy-plane, as shown in the figure, in a region of magnetic field $\vec{B} = \alpha t \hat{k}$, where B is in Tesla, t is in seconds, and α is a positive constant.



11. What is the SI unit of the constant α?

(a) $\frac{\mathrm{N \cdot s}}{\mathrm{A \cdot m}}$ (b) $\frac{\mathrm{N \cdot m}}{\mathrm{A \cdot s}}$ (c) $\frac{\mathrm{N}}{\mathrm{A \cdot s \cdot m}}$ (d) $\frac{\mathrm{N}}{\mathrm{A \cdot m}}$ (e) $\frac{\mathrm{N}}{\mathrm{A \cdot s}}$

12. What is the magnitude and the direction of the induced current on the ring?

(a) $\frac{3\alpha\pi R^2}{2r}$, clockwise (b) $\frac{\alpha\pi R^2}{r}$, clockwise (c) $\frac{\alpha\pi R^2}{2r}$, counterclockwise
(d) $\frac{\alpha\pi R^2}{2r}$, clockwise (e) $\frac{\alpha\pi R^2}{r}$, counterclockwise

13. What is the induced electric field at point $(x, y) = (0, R/2)$?

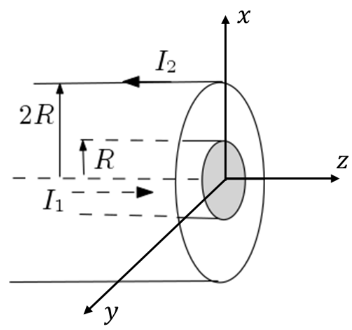
(a) $-3\frac{\alpha R}{4}\hat{\imath}$ (b) $-\frac{\alpha R}{2}\hat{\imath}$ (c) $\frac{\alpha R}{4}\hat{\imath}$ (d) $\frac{\alpha R}{3}\hat{\imath}$ (e) $-\frac{\alpha R}{4}\hat{\imath}$

14. If the magnetic field were of the form $\vec{B} = \alpha(y\hat{k} + z\hat{\jmath})$ what would be the induced current on the conducting ring?

(a) $\frac{\alpha\pi R^2}{3r}$ (b) 0 (c) $\frac{\alpha\pi R^2}{r}$ (d) $\frac{\alpha\pi R^2}{2r}$ (e) $3\frac{\alpha\pi R^2}{4r}$

Questions 15-17

A very long cylinder of radius R carries a uniform current I_1 in the z-direction and a uniform current I_2 flows in opposite direction on a very thin cylindrical shell of radius $2R$, as shown in the figure.



15. What is the magnetic field $\vec{B}(x = R/2, y = 0, z = 0)$?

(a) $\frac{\mu_0 I_1}{4\pi R}\hat{\jmath}$ (b) $\frac{\mu_0 I_1}{8\pi R}\hat{\jmath}$ (c) $-\frac{\mu_0 I_1}{4\pi R}\hat{\jmath}$ (d) $\frac{\mu_0 I_1}{4\pi R}\hat{\imath}$ (e) $\frac{\mu_0 I_1}{16\pi R}\hat{\jmath}$

16. What is the magnetic field $\vec{B}(x = 0, y = 3R/2, z = 0)$?

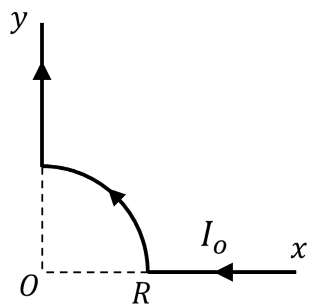
(a) $\frac{\mu_0 I_1}{6\pi R}\hat{\imath}$ (b) $\frac{\mu_0 I_1}{4\pi R}\hat{\imath}$ (c) $-\frac{\mu_0 I_1}{12\pi R}\hat{k}$ (d) $-\frac{\mu_0 I_1}{6\pi R}\hat{\jmath}$ (e) $-\frac{\mu_0 I_1}{3\pi R}\hat{\imath}$

17. What is the magnetic field $\vec{B}(x = 3R, y = 0, z = R)$?

(a) $\frac{\mu_0(I_1 - I_2)}{12\pi R}\hat{\jmath}$ (b) $\frac{\mu_0(I_1 - I_2)}{6\pi R}\hat{\imath}$ (c) $\frac{\mu_0(I_1 + I_2)}{6\pi R}\hat{\jmath}$ (d) $\frac{\mu_0(I_1 + I_2)}{4\pi R}\hat{\jmath}$ (e) $\frac{\mu_0(I_1 - I_2)}{6\pi R}\hat{\jmath}$

Questions 18-20

18. A constant current I_0 flows through the wire as shown in the figure What is the magnetic field at the origin, $\vec{B}(x = 0, y = 0, z = 0)$?



(a) 0 (b) $\frac{\mu_0 I_0}{8\pi R}\hat{k}$ (c) $-\frac{\mu_0 I_0}{16\pi R}(\hat{\imath} + \hat{\jmath})$ (d) $\frac{\mu_0 I_0}{8R}\hat{k}$ (e) $-\frac{\mu_0 I_0}{8R}\hat{k}$

19. What is the magnetic force on a particle of charge q at the moment it passes the origin with velocity $\vec{V} = V_x\hat{\imath} + V_z\hat{k}$?

(a) $\frac{q\mu_0 I_0 V_x}{8R}\hat{\jmath}$ (b) $-\frac{q\mu_0 I_0 V_x}{8R}\hat{\jmath}$ (c) $\frac{q\mu_0 I_0(V_x\hat{\imath} + V_y\hat{\jmath})}{16\pi R}$ (d) $-\frac{q\mu_0 I_0 V_x}{4R}\hat{\jmath}$ (e) $-\frac{q\mu_0 I_0 V_x}{8\pi R}\hat{\imath}$

20. If a particle of charge q passes the origin at $t = 0$ with a velocity $\vec{V} = V_x\hat{\imath} + V_z\hat{k}$ what is the work done on the charge by the magnetic force in the time interval $t = 0$ to $t = t_1$?

(a) 0 (b) $-\frac{q\mu_0 I_0 V_x V_y t_1}{16R}$ (c) $\frac{q\mu_0 I_0 V_y^2 t_1}{8R}$ (d) $-\frac{q\mu_0 I_0 V_x^2 t_1}{16R}$ (e) $-\frac{q\mu_0 I_0 V_x t_1}{16R}$

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ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

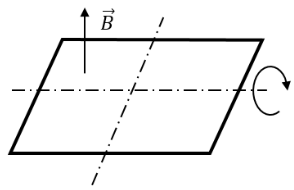
1. A metal wire has resistance R. What will be the resistance of this wire in terms of R if it is stretched to 4 times of its original length, assuming that the volume and resistivity of the material do not change when the wire is stretched?

(a) R (b) $8R$ (c) $4R$ (d) $16R$ (e) $2R$

2. An electron that has velocity $\vec{v} = (10^6\,\mathrm{m/s})\hat{\imath}$ enters into a region with magnetic field $\vec{B} = (0.050\,\mathrm{T})\hat{\imath} - (0.20\,\mathrm{T})\hat{\jmath}$. What is the force on the electron acted by the magnetic field? The charge of an electron is $q_e = -1.6 \times 10^{-19}\,\mathrm{C}$.

(a) $(-0.16 \times 10^{-13}\,\mathrm{N})\hat{k}$ (b) $(0.32 \times 10^{-13}\,\mathrm{N})\hat{k}$ (c) $(-3.2 \times 10^{-13}\,\mathrm{N})\hat{k}$ (d) $(-0.32 \times 10^{-13}\,\mathrm{N})\hat{k}$ (e) $(3.2 \times 10^{-13}\,\mathrm{N})\hat{k}$

3. An electric generator consists of 50 turns of wire formed into a rectangular loop of side lengths 20 cm by 10 cm, placed entirely in a uniform magnetic field with magnitude $B = 2.0\,\mathrm{T}$. What is the maximum value of the electromotive force ($\mathcal{E}$) produced when the loop is spun at 1000 rev/min about an axis perpendicular to B? (Take $\pi = 3$.)



(a) 200 V (b) 24 V (c) 2400 V (d) 240 V (e) 1200 V

4. Which one of the following defines the displacement current in empty space (vacuum)?

(a) $\mu_o \epsilon_o \frac{d\phi_B}{dt}$ (b) $-\mu_o \frac{d\phi_E}{dt}$ (c) $-\epsilon_o \frac{d\phi_B}{dt}$ (d) $\epsilon_o \mu_o \frac{d\phi_E}{dt}$ (e) $\epsilon_o \frac{d\phi_E}{dt}$

Questions 5-8

Time dependent current flowing through a cylindrical wire given in units of amperes is $I = 20\, sin(100\pi t)$, where t is measured in seconds.

5. What is the amount of charge that passes through this wire between t=0 s and t=0.01 s in units of coulombs.

(a) $\frac{5\pi}{2}$ (b) 0.2 (c) $\frac{2}{5\pi}$ (d) $\frac{1}{5\pi}$ (e) π

6. If the cross section of this wire is circular, its radius is 1mm and the current is uniformly distributed through its cross section, what is the charge density at t=1/200 s in $\mathrm{A/m^2}$?

(a) $\frac{\pi \times 10^7}{2}$ (b) $\pi \times 10^7$ (c) $2\pi \times 10^7$ (d) $\frac{2 \times 10^7}{\pi}$ (e) $4\pi \times 10^7$

7. If density of the charge carriers is n=10^{27} 1/m^3, what is the drift speed of the charge carriers at t=1/200 s in m/s units? ($|q_e| = 1.6 \times 10^{-19}$ C).

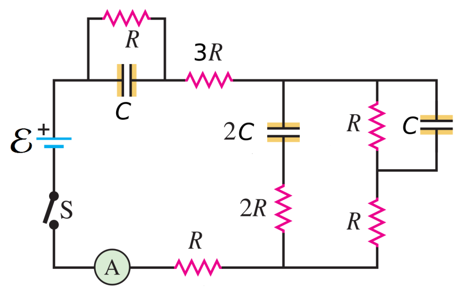
(a) $\frac{\pi}{16}$ (b) $\frac{1}{16\pi}$ (c) $\frac{1}{8\pi}$ (d) $\frac{\pi}{8}$ (e) $\frac{1}{32\pi}$

8. If the resistance of 10 meters of this wire is 10 Ω, what is the magnitude of the electric field at t=1/200 s inside the wire in V/m?

(a) 0.05 (b) 10 (c) 0.1 (d) 2 (e) 20

Questions 9-11

All the capacitors are initially uncharged in the circuit given in the figure. The battery has no internal resistance and the ammeter is ideal. Here $\mathcal{E} = 11\,\mathrm{V}$, $C = 2\,\mu\mathrm{F}$ and $R = 1\,\Omega$.



9. What is the reading of the ammeter, in ampere units, just after the switch S is closed?

(a) 11/7 (b) 4 (c) 2/3 (d) 3/2 (e) 33/14

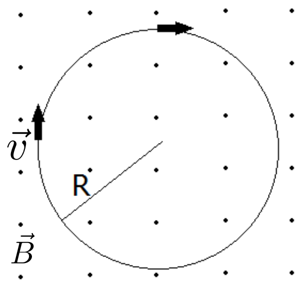
10. What is the reading of the ammeter, in ampere units, long time after the switch has been closed?

(a) 11/7 (b) 7/4 (c) 4/7 (d) 6/11 (e) 11/6

11. What is the charge on the capacitor, in μC unit, closest to the battery long time after the switch has been closed?

(a) 11/6 (b) 11/3 (c) 22/7 (d) 3/11 (e) 2/7

Questions 12-13



A charged particle enters a uniform magnetic field and moves in a circular path perpendicular to the direction of magnetic field in an experiment. It takes 3×10^{-6}s for the particle to make one revolution. Magnitude of magnetic feld used in this experiment is 0.1T. Take $\pi = 3$.

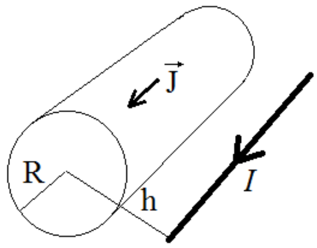
12. What is the charge/mass ratio of this particle in C/kg unit?

(a) 3×10^7 (b) 8×10^7 (c) 4×10^7 (d) 2×10^7 (e) 10^7

13. If the radius of the circular path is 0.5 m, what is the speed of this particle in m/s?

(a) 8×10^5 (b) 2×10^4 (c) 5×10^6 (d) 10^6 (e) 10^8

Questions 14-16



A very long solid cylinder has a current density J = αr and is parallel to a thin and very long wire which carries current I. Currents in both conductors flow in the same direction, α is a constant and r is the radial distance from the cylinder axis. The wire is h away from the cylinder axis.

14. What is the net current flowing through the cylinder?

(a) $\frac{2\alpha\pi R^3}{3}$ (b) $2\alpha\pi R$ (c) $\frac{3\alpha\pi R^4}{2}$ (d) $\alpha\pi R^2$ (e) $\alpha\pi R^3$

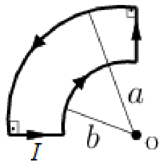
15. What is the magnetic field created by the cylinder at the position of the wire?

(a) $\frac{\mu_o\pi\alpha R^3}{3h}$ (b) $\frac{\alpha\pi R^3}{h}$ (c) $\frac{\mu_o\alpha h}{3R^3}$ (d) $3\mu_o\alpha\pi R^3$ (e) $\frac{\mu_o\alpha R^3}{3h}$

16. What is the magnitude of the magnetic force that the wire exerts on the unit length of the cylinder?

(a) $\frac{\mu_o\alpha R^3 I}{3h}$ (b) $3\mu_o\alpha\pi R^3 I$ (c) $\frac{\mu_o\alpha h I}{3R^3}$ (d) $\frac{\alpha\pi R^3 I}{h}$ (e) $\frac{\mu_o\pi\alpha R^3 I}{3h}$

Questions 17-18



A wire carrying current I is bent to make a quarter circular current loop as shown in the figure. The radius of the inner circle is b and of the outer circle is a.

17. What is the magnetic moment of this current loop?

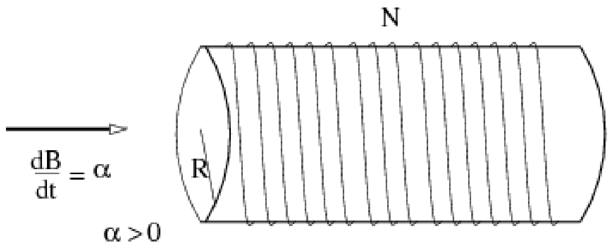
(a) $\frac{I\pi(a^2+b^2)}{2}$ (b) $\frac{I\pi(a^2-b^2)(a^2+b^2)}{4ab}$ (c) $\frac{I\pi(a^2-b^2)}{4}$ (d) $\frac{I\pi(a^2-b^2)}{2}$ (e) $\frac{I\pi(a^2+b^2)}{4}$

18. What is the magnitude of the magnetic field generated by this loop at the center position, O?

(a) $\frac{\mu_0 I(a+b)}{8ab}$ (b) $\frac{\mu_0 I(a-b)}{8ab}$ (c) $\frac{\mu_0 I(a^2-b^2)}{8ab}$ (d) $\frac{\mu_0 I(a^2+b^2)}{8ab}$ (e) $\frac{\mu_0 I(a^2-b^2)}{4ab}$

Questions 19-20

A solenoid with radius R and number of turns N is in a uniform magnetic field along its axis. The magnetic field is time dependent and is given as $\frac{dB}{dt} = \alpha$ where α is a positive constant. Magnitude of the magnetic field is zero at t=0.



19. What is the magnitude of the magnetic flux through one of the windings of the solenoid?

(a) $N\pi\alpha R^2 t$ (b) $\pi\alpha R^2 t$ (c) $N\pi\alpha R^2$ (d) $N^2\pi\alpha R^2 t$ (e) $\pi\alpha R^2$

20. What is the magnitude of the electromotive force (emf) in the solenoid?

(a) $2\pi\alpha^2$ (b) $N\pi\alpha R^2$ (c) $2N^2\pi\alpha R^2$ (d) $N^2\pi\alpha R^2$ (e) $2\pi R\alpha$

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Questions 1-2

A silver wire 2.0 mm in diameter transfers a charge of 432 C in 50 minutes. Silver contains, 6×10^{28} free electrons per cubic meter. (Take $\pi = 3$, magnitude of the charge of the electron: 1.6×10^{-19} C)

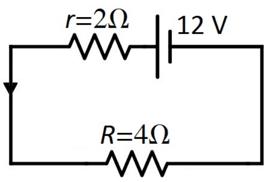
1. What is the current in the wire?

(a) 83.4 mA (b) 144 mA (c) 525 mA (d) 0 (e) 432 mA

2. What is the magnitude of the drift velocity, in units of μm/s, of the electrons in the wire?

(a) 5.6 (b) 0 (c) 5.0 (d) 14.4 (e) 2.4

Questions 3-4



The internal resistance of the battery $r = 2\,\Omega$ for the circuit shown in the figure.

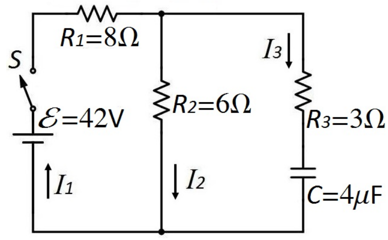
3. What is the rate of dissipation of electrical energy in the internal resistance of the battery?

(a) 20 W (b) 0 (c) 8 W (d) 24 W (e) 12 W

4. What is the rate of dissipation of electrical energy in the external resistor, R?

(a) 0 (b) 16 W (c) 72 W (d) 48 W (e) 24 W

Questions 5-7



The capacitor in the figure is initially uncharged and the switch is open.

5. Immediately after the switch is closed, find the current I_1 through the resistor R_1.

(a) 0 (b) 4.2 A (c) 3 A (d) 9 A (e) 6 A

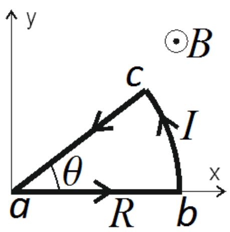
6. After the switch has been closed for a long time, find the current I_3 through the resistor R_3.

(a) 5 A (b) 3 A (c) 4.2 A (d) 0 A (e) 1 A

7. After the switch has been closed for a long time, find charge on the capacitor.

(a) 72 μC (b) 4 μC (c) 30 μC (d) 0 (e) 16.8 μC

Questions 8-12



The pie shaped current loop shown in the figure subtends an angle of $\theta = 36^o$ and lies in the xy-plane. The radius $R = 20$ cm and the current $I = 4.0$ A. The loop is in a uniform magnetic field with $B = 0.5$ T parallel to the z-axis. Take $\cos 36^o = 0.8$, $\sin 36^o = 0.6$, $\cos 53^o = 0.6$, $\sin 53^o = 0.8$ and $\pi = 3$.

8. What is the magnetic force on the segment a-b?

(a) $(+0.2\hat{j})$ N (b) $(-0.2\hat{j})$ N (c) $(-0.4\hat{j})$ N (d) $(+0.4\hat{j})$ N (e) $(-0.32\hat{j})$ N

9. What is the magnetic force on the segment b-c?

(a) $(0.24\hat{i} - 0.08\hat{j})$ N (b) $(0.4\hat{i} + 0.32\hat{j})$ N (c) $(0.24\hat{i} + 0.08\hat{j})$ N (d) $(0.4\hat{i} - 0.32\hat{j})$ N (e) 0

10. What is the magnetic moment of the loop in units of A.m^2?

(a) $(48 \times 10^{-2}\hat{k})$ (b) $(24 \times 10^{-2}\hat{k})$ (c) $(60 \times 10^{-3}\hat{k})$ (d) $(-24 \times 10^{-3}\hat{k})$ (e) $(48 \times 10^{-3}\hat{k})$

(for questions of 11 and 12) When the plane of the loop makes an angle of 53^o relative to the xy-plane,

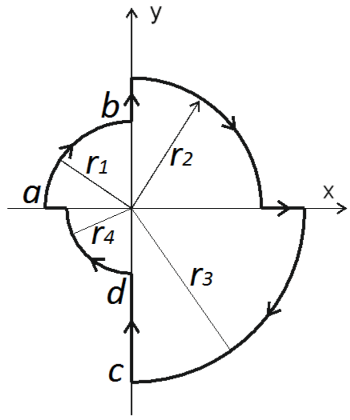
11. What is the magnetic potential energy of the loop?

(a) $+24\,\text{mJ}$ (b) $7.2\,\text{mJ}$ (c) $-9.6\,\text{mJ}$ (d) $19.2\,\text{mJ}$ (e) $-14.4\,\text{mJ}$

12. What is the magnitude of the net torque that the magnetic field exerts on the loop?

(a) $9.6\times10^{-3}\,\text{N.m}$ (b) $19.2\times10^{-3}\,\text{N.m}$ (c) $14.4\times10^{-3}\,\text{N.m}$ (d) $24\times10^{-3}\,\text{N.m}$ (e) $7.2\times10^{-3}\,\text{N.m}$

Questions 13-15



A wire consist of four quarter circles with radii $r_1 = 4\,\text{cm}$, $r_2 = 6\,\text{cm}$, $r_3 = 10\,\text{cm}$, $r_4 = 3\,\text{cm}$ and straight sections as shown in the figure. The wire carries a current $I = 2\,\text{A}$ in the direction shown. Take $\mu_o = 12 \times 10^{-7}\,\text{T.m/A}$.

13. What is the magnitude of the magnetic field at the origin due to the part of a-b?

(a) $6\,\mu\text{T}$ (b) $10\,\mu\text{T}$ (c) $2.5\,\mu\text{T}$ (d) $30\,\mu\text{T}$ (e) $7.5\,\mu\text{T}$

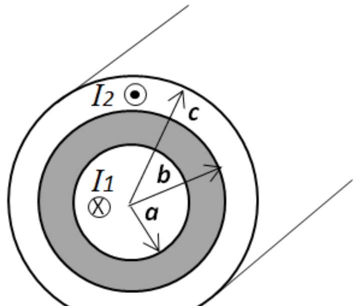
14. What is the magnitude of the magnetic field at the origin due to the part of c-d?

(a) $0\,\text{T}$ (b) $6\,\mu\text{T}$ (c) $13.3\,\mu\text{T}$ (d) $17.1\,\mu\text{T}$ (e) $7.5\,\mu\text{T}$

15. What is the magnitude of the total magnetic field at the origin?

(a) $25.5\,\mu\text{T}$ (b) $12.5\,\mu\text{T}$ (c) $102\,\mu\text{T}$ (d) $40\,\mu\text{T}$ (e) $22\,\mu\text{T}$

Questions 16-17



The figure shows the cross-section of a very long coaxial cable. The radius of the inner conductor part of the cable is a, the outer radius of the insulator is $b = 2a$ and the outer radius of the conductor part is c, $2a < c < 3a$. The current density in both conductive regions is constant. The internal current, $I_1 = I$, flows into the plane of the page and the current in the outer part, $I_2 = 2I$, flows out of the page plane. (take $\pi = 3$).

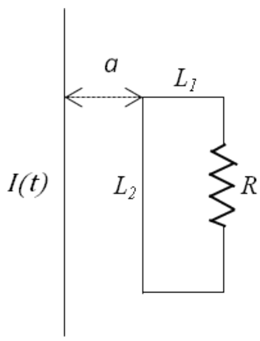
16. What is the magnitude of the magnetic field, in terms of μ_o, I and a, generated by these currents at the point $r = \frac{a}{2}$?

(a) $\frac{\mu_o I}{12a}$ (b) $\frac{\mu_o I}{24a}$ (c) $\frac{\mu_o I}{54a}$ (d) $\frac{\mu_o I}{18a}$ (e) $\frac{\mu_o I}{2a}$

17. What is the magnitude of the magnetic field, in terms of μ_o, I and a, generated by these currents at the point $r = 3a$?

(a) $\frac{\mu_o I}{3a}$ (b) $\frac{\mu_o I}{54a}$ (c) $\frac{\mu_o I}{27a}$ (d) $\frac{\mu_o I}{12a}$ (e) $\frac{\mu_o I}{18a}$

Questions 18-20



A rectangular conductive loop is placed near a long, straight wire at a distance a carrying an alternating current of $I(t) = I_o \sin(\omega_o t)$. Here, $\omega_o = \frac{2\pi}{T}$, $T = 0.02\,\text{s}$ is the period of the alternating current. Both the wire and the loop are in the same plane. The side lengths of the loop are $L_1 = a$ and $L_2 = 2a$, and the resistance $R = 20\,\Omega$ is connected between the two open ends of the loop (take $ln2 = 0.6$ and $\pi = 3$).

18. What is the magnetic flux, in terms of μ_o, I_o and a, passing through the loop at $t = T/4$?

(a) $10a\mu_o I_o$ (b) $0.1a\mu_o I_o$ (c) $2a\mu_o I_o$ (d) $0.2a\mu_o I_o$ (e) $3a\mu_o I_o$

19. What is the voltage, in terms of μ_o, I_o and a, between the ends of the resistor at $t = T/2$?

(a) $12a\mu_o I_o$ (b) $50a\mu_o I_o$ (c) $180a\mu_o I_o$ (d) $60a\mu_o I_o$ (e) $6a\mu_o I_o$

20. What is the current, in terms of μ_o, I_o and a, passing through resistance at $t = T/2$?

(a) $a\mu_o I_o$ (b) $9a\mu_o I_o$ (c) $5a\mu_o I_o$ (d) $3a\mu_o I_o$ (e) $4a\mu_o I_o$

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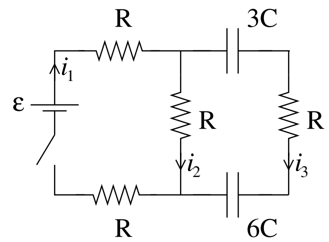
ATTENTION: Each question has only one correct answer. Make sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. Which of the following combination cannot be a unit of the magnetic field?
(N: Newton, J: Joule, W: Watt, C: Coulomb, A: Ampere)

(a) $N \cdot s/(A \cdot m)$ (b) $N \cdot s/(C \cdot m)$ (c) $W \cdot s^2/(C \cdot m^2)$ (d) $J \cdot s/(C \cdot m^2)$ (e) $kg/(A \cdot s^2)$

Questions 2-3

Consider the circuit shown in the figure on the right. Both capacitors are uncharged and the switch is closed at time $t = 0$.



2. Find the currents i_1, i_2, i_3 in units of ε/R at $t = 0$, immediately after the switch is closed.

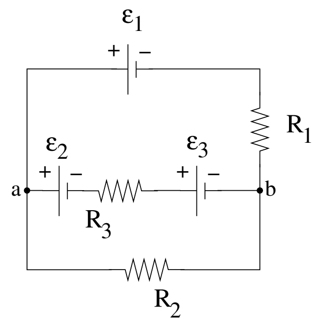
(a) $1/2, 1/4, 1/4$ (b) $2/5, 1/5, 1/5$ (c) $1/3, 1/3, 0$ (d) $0, 0, 0$ (e) $2/3, 1/3, 1/3$

3. Find the currents i_1, i_2, i_3 in units of ε/R when $t \to \infty$.

(a) $2/3, 1/3, 1/3$ (b) $2/5, 1/5, 1/5$ (c) $0, 0, 0$ (d) $1/2, 1/4, 1/4$ (e) $1/3, 1/3, 0$

Questions 4-5

Consider the circuit shown in the figure on the right. Take $\varepsilon_1/2 = \varepsilon_2 = \varepsilon_3 = \varepsilon$ and $R_1/2 = R_2 = R_3 = R$.



4. What is the magnitude of the current through the resistor R_3?

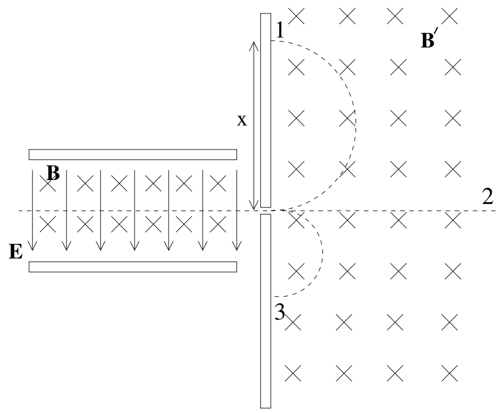
(a) 0 (b) $4\varepsilon/5R$ (c) $2\varepsilon/3R$ (d) $2\varepsilon/5R$ (e) $\varepsilon/5R$

5. What is the the potential difference $V_b - V_a$ between points a and b.

(a) 0 (b) $6\varepsilon/5$ (c) $-6\varepsilon/5$ (d) -2ε (e) $2\varepsilon/3$

Questions 6-8

In a mass spectrometer particles pass a velocity selector and enter a region of uniform magnetic field where they move in circular orbits. E, B are the strengths of the uniform fields in the velocity selector and B' is the magnetic field in the second part.



6. What is the speed of the particles that move in a straight line in the velocity selector part?

(a) $(E/2B)^2$ (b) E/B (c) $\sqrt{2E/B}$ (d) $E/2B$ (e) $2E/B$

7. What are the charges of the particles that have paths 1, 2, 3?
(positive: +, neutral: 0, negative −)

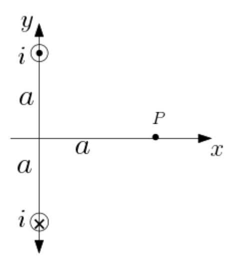
(a) +, 0, − (b) 0, 0, 0 (c) −, 0, + (d) −, 0, − (e) +, 0, +

8. Find the expression for the mass of particle 1 with charge q, given in terms of the variables shown in the figure. (x is the distance of its final point from the entering point in the second region.)

(a) $qxBB'/(2E)$ (b) $qxE/(BB')$ (c) $qxEB'/(2B)$ (d) $2qxBB'/E$ (e) $2qxEB'/B$

Questions 8-9

Two very long parallel wires, each carrying a current i in opposite directions, are located perpendicular to the xy-plane, as shown in the figure.



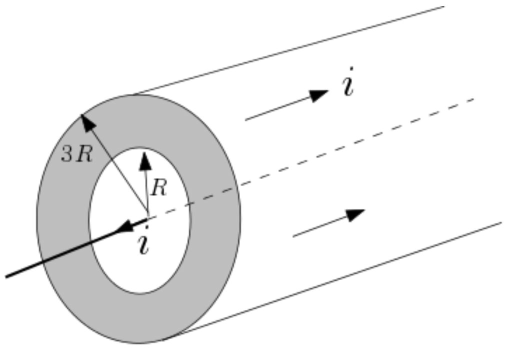
9. What is the net magnetic field vector at point P?

(a) $\frac{\mu_0 i}{2\pi a}\hat{k}$ (b) $\frac{\mu_0 i}{3\pi a}\hat{i}$ (c) $\frac{\mu_0 i}{2\pi a}\hat{i}$ (d) $-\frac{\mu_0 i}{3\pi a}\hat{j}$ (e) $\frac{\mu_0 i}{2\pi a}\hat{j}$

10. A point charge q moving in the xy-plane has the velocity $\vec{v} = v\hat{j}$ at the instant when it is passing through point P. What is the magnetic force on the point charge at this instant?

(a) $\frac{\mu_0 iqv}{2\pi a}\hat{j}$ (b) $\frac{\mu_0 iqv}{2\pi a}\hat{i}$ (c) $-\frac{\mu_0 iqv}{3\pi a}\hat{k}$ (d) $-\frac{\mu_0 iqv}{4\pi a}\hat{j}$ (e) $-\frac{\mu_0 iqv}{2\pi a}\hat{k}$

Questions 11-13



A very long conducting wire carrying a current i is coaxial with a very long solid conducting cylinder of inner radius R and outer radius $3R$, as shown in the figure. The solid cylinder is also carrying a uniform current i but the current is in the opposite direction to the current of the wire.

11. What is the magnitude of the magnetic field at $r = R/2$?

(a) $\frac{\mu_0 i}{4\pi R}$ (b) $\frac{\mu_0 i}{\pi R}$ (c) $\frac{2\mu_0 i}{\pi R}$ (d) $\frac{2\mu_0 i}{3\pi R}$ (e) $\frac{\mu_0 i}{2\pi R}$

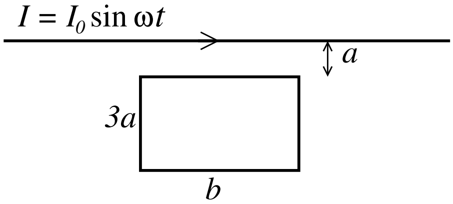
12. What is the magnitude of the magnetic field at $r = 2R$?

(a) $\frac{5\mu_0 i}{24\pi R}$ (b) $\frac{2\mu_0 i}{15\pi R}$ (c) $\frac{4\mu_0 i}{15\pi R}$ (d) $\frac{5\mu_0 i}{32\pi R}$ (e) $\frac{7\mu_0 i}{24\pi R}$

13. What is the magnitude of the magnetic field at $r = 4R$?

(a) $\frac{2\mu_0 i}{3\pi R}$ (b) $\frac{2\mu_0 i}{\pi R}$ (c) 0 (d) $\frac{\mu_0 i}{2\pi R}$ (e) $\frac{\mu_0 i}{4\pi R}$

Questions 14-15



A current in the form $I = I_0 \sin(\omega t)$ flows through a long straight wire, where ω is a constant angular frequency. There is a rectangular ring with edge lengths $3a$ and b at a distance a from the long wire, as shown in the figure. The resistance of this ring is R.

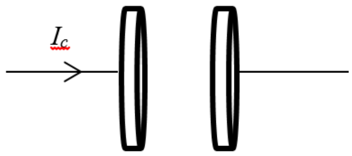
14. What is the magnetic flux (into the page) passing through the rectangular ring?

(a) $\frac{\mu_0 b I_0 \sin(\omega t)}{2\pi} \ln 2$ (b) $\frac{\mu_0 b I_0 \cos(\omega t)}{2\pi} \ln 4$ (c) $\frac{\mu_0 I_0 \sin(\omega t)}{\pi} \ln 4$ (d) $\frac{\mu_0 b I_0 \sin(\omega t)}{2\pi} \ln 4$ (e) $\frac{\mu_0 b I_0}{\pi} \ln 4$

15. What is the maximum value of the induced current in the rectangular ring?

(a) $\frac{\mu_0 \omega I_0}{\pi R} \ln 4$ (b) $\frac{\mu_0 \omega I_0}{2\pi R} \ln 4$ (c) $\frac{\mu_0 b I_0}{2\pi R} \ln 4$ (d) $\frac{\mu_0 b \omega I_0}{2\pi R} \ln 2$ (e) $\frac{\mu_0 b \omega I_0}{2\pi R} \ln 4$

Questions 16-18



A parallel-plate, air filled capacitor is being charged. The circular plates have the radius 5.0 cm. At a particular instant the conduction current I_c in the wire is 0.5 A. (Take $\pi \approx 3$, the electric permittivity of the air as ϵ_0, and the magnetic permeability μ_0.)

16. What is the magnitude of the displacement current density between the plates?

(a) $\frac{1}{15} \times 10^3\ A/m^2$ (b) $\frac{1}{5} \times 10^2\ A/m^2$ (c) $\frac{4}{7} \times 10^3\ A/m^2$ (d) $\frac{1}{3} \times 10^4\ A/m^2$ (e) $10^5\ A/m^2$

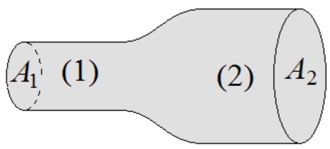
17. What is the rate at which the electric field between the plates is changing?

(a) $\frac{1}{3\epsilon_0} \times 10^4\ \frac{N}{C \cdot s}$ (b) $10^5 \epsilon_0\ \frac{N}{C \cdot s}$ (c) $\frac{1}{5\epsilon_0} \times 10^2\ \frac{N}{C \cdot s}$ (d) $\frac{4}{7\epsilon_0} \times 10^3\ \frac{N}{C \cdot s}$ (e) $\frac{1}{15\epsilon_0} \times 10^3\ \frac{N}{C \cdot s}$

18. What is the induced magnetic field between the plates at a distance of 2.00 cm from the axis?

(a) $\frac{4\mu_0}{25}\ T$ (b) $\frac{4\mu_0}{15}\ T$ (c) $\frac{4\mu_0}{3}\ T$ (d) $\frac{2\mu_0}{3}\ T$ (e) $\frac{\mu_0}{3}\ T$

Questions 19-20



Wire section (1) of cross sectional area $A_1 = 3\,\text{mm}^2$ and wire section (2) of cross sectional area $A_2 = 4\,\text{mm}^2$ are connected by a tapered section as shown in the figure. The number density of conduction electrons in the wire is $10^{30}\ e/\text{m}^3$, electronic charge $e = -1.6 \times 10^{-19}\,\text{C}$ and resistivity of the wire $\rho = 2 \times 10^{-6}\,\Omega\,\text{m}$. Assume that the current is uniformly distributed across any cross-sectional area through the wire's width. Magnitude of electric field in wire section (2) is $3\,\text{V/m}$.

19. What is the current flowing in the wire?

(a) 4 A (b) 1 A (c) 6 A (d) 2 A (e) 8 A

20. What is the drift speed of conduction electrons in wire section (1)?

(a) $2.5 \times 10^{-5}\,\text{m/s}$ (b) $6 \times 10^{-6}\,\text{m/s}$ (c) $1.5 \times 10^{-5}\,\text{m/s}$ (d) $12.5 \times 10^{-6}\,\text{m/s}$ (e) $25 \times 10^{-6}\,\text{m/s}$