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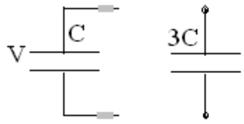
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. A point charge Q is located a short distance from a point charge $3Q$, and no other charges are present. If the electrical force on Q is $\vec{F}$, what is the electrical force on $3Q$?

(a) $-\vec{F}$ (b) $\vec{F}/3$ (c) $\vec{F}/\sqrt{3}$ (d) $3\vec{F}$ (e) $\sqrt{3}\vec{F}$

2. Consider a capacitor of capacitance C that is initially charged to a potential difference V. If this is then connected in parallel with a second initially uncharged capacitor of capacitance 3C, what is the final potential difference across its plates?

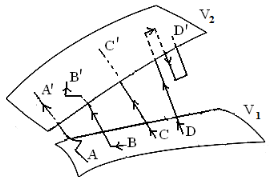


(a) V/8 (b) 4V (c) V/4 (d) 3V/4 (e) V/3

3. Consider a spherical Gaussian surface of radius R centered at the origin. A charge Q is placed inside the sphere. To maximize the magnitude of the flux of the electric field through the Gaussian surface, the charge should be located

(a) at x=R/2, y=0, z=0 (b) The charge can be located anywhere, since flux does not depend on the position of the charge as long as it is inside the sphere. (c) at the origin (d) at x=0, y=R/2, z=0 (e) at x=0, y=0, z=R/2

4. The figure shows two equipotential surfaces whose potentials are V_1 and V_2. The lines represent four paths (A → A′, B→ B′, C→C′, D → D′) along which equal test charges are moved. The work involved, can be said to be



(a) the greatest for path C → C′ (b) the greatest for path A → A′ (c) the greatest for path B → B′ (d) the same for all paths (e) the greatest for path D → D′

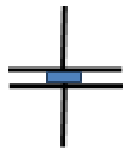
5. A free proton is placed midway between points A and B. The potential at point A is -20 V, and the potential at point B is +20 V. The potential at the midpoint is 0 V. The proton will

(a) move toward point B with constant velocity. (b) remain at rest. (c) move toward point A with constant velocity. (d) accelerate toward point A. (e) accelerate toward point B.

6. Which of the following angles between an electric dipole moment and an applied electric field will result in the most stable state?

(a) π rad (b) 0 rad (c) -π/2 rad (d) The electric dipole moment is not stable under any condition in an applied electric field. (e) π/2 rad

7. A dielectric with a dielectric constant $\chi = 4$ is inserted into a parallel plate capacitor, filling 1/3 of the volume, as shown in the figure. If the capacitance of the capacitor without the dielectric is C, what is the capacitance of the capacitor with the dielectric?



(a) 6C (b) 2C (c) C (d) 0.75C (e) 4C

8. The electric potential of a region of space is given by V= 7x^{2}y in SI units. Which of the following statements is false?

(a) The electric field has both x and y components apart origin. (b) The x-component of the electric field depends on both x and y. (c) The z-component of the electric field is zero everywhere in this region. (d) The magnitude of the electric field at the origin is zero. (e) The y-component of the electric field is proportional to y.

9. X and Y are two uncharged metal spheres on insulating stands, and are in contact with each other. A positively charged rod R is brought close to X as shown in Figure (a). Sphere Y is now moved away from X, as in Figure (b). What are the final charge states of X and Y?

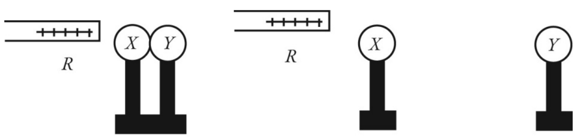


Figure (a) Figure (b)

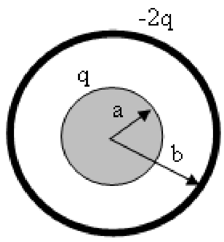
(a) X is positive and Y is neutral. (b) X is neutral and Y is positive. (c) X is negative and Y is positive. (d) Both X and Y are negative. (e) Both X and Y are neutral.

10. Consider a hollow spherical conductor with total charge +5e. The outer and inner radii are a and b, respectively. A charge of -3e is placed at the center of the sphere. Which of the following statements is true?

(a) The charge on the outer surface of the sphere is +5e. (b) The charge on the inner surface of the sphere is -3e. (c) The total net charge of the sphere is +8e. (d) The total net charge of the sphere +2e. (e) The charge on the inner surface of the sphere is +3e.

Question 11-15

A very long conducting cylinder (length L) carrying a total charge +q, is surrounded by a conducting cylinder shell (also of length L) with total charge -2q as shown in the figure. (The coordinate r measures the distance from the axis of the cylinders and $\hat{\mathbf{r}}$ is the unit vector in the radial direction).



11. What is the electric field inside the conducting cylinder?

(a) $q\hat{\mathbf{r}}/\varepsilon_0$ (b) $q\hat{\mathbf{r}}/4\pi\varepsilon_0 a^2$ (c) $q\hat{\mathbf{r}}/2\pi\varepsilon_0 La$ (d) 0 (e) $-q\hat{\mathbf{r}}/4\pi\varepsilon_0 La^2$

12. What is the electric field in the region between the cylinders?

(a) $q\hat{\mathbf{r}}/(2\pi\varepsilon_0 Lr)$ (b) $3q\hat{\mathbf{r}}/(2\pi\varepsilon_0 Lr)$ (c) $-2q\hat{\mathbf{r}}/(2\pi\varepsilon_0 La)$ (d) $2kq\hat{\mathbf{r}}/(\varepsilon_0 aL)$ (e) $-q\hat{\mathbf{r}}/(2\varepsilon_0 Lr)$

13. What is the charge on the inner surface of the shell?

(a) +q (b) 0 (c) -q (d) -2q (e) -3q

14. What is the charge on the outer surface of the shell ?

(a) -2q (b) -3q (c) -q (d) +q (e) 2q

15. What is the electric field at points outside the conducting shell ?

(a) $-2q\hat{\mathbf{r}}/(2\pi\varepsilon_0 Lr)$ (b) $q\hat{\mathbf{r}}/(2\pi\varepsilon_0 Lr)$ (c) $q\hat{\mathbf{r}}/(4\pi\varepsilon_0 r)$ (d) $q\hat{\mathbf{r}}/(4\pi\varepsilon_0 r^2)$ (e) $-q\hat{\mathbf{r}}/(2\pi\varepsilon_0 Lr)$

Question 16-20

A parallel plate capacitor with air in the gap between the plates is connected to a 6.00 V battery. Each of the plates has an area of 50.0 cm^2. After charging, the energy stored in the capacitor is 78.0 nJ. Without disconnecting the capacitor from the battery, a dielectric is inserted into the gap and the energy of the capacitor increases by 312 nJ. (Take $k = \frac{1}{4\pi\varepsilon_0} = 9.00 \cdot 10^9$ N.m^2/C^2 and $\pi = 3$)

16. What is the dielectric constant of the dielectric?

(a) 4.00 (b) 1.25 (c) 5.00 (d) 3.00 (e) 2.50

17. What is the charge on the positive plate of the capacitor after the dielectric has been inserted?

(a) 26.0 nC (b) 32.5 nC (c) 130 nC (d) 78.0 nC (e) 65.0 nC

18. What is the charge on the positive plate of the capacitor before the dielectric has been inserted?

(a) 26 nC (b) 130 nC (c) 78.0 nC (d) 32.5 nC (e) 65.0 nC

19. What is the magnitude of the electric field between the plates before the dielectric is inserted?

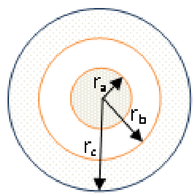
(a) $5.62 \cdot 10^5$ N/C (b) $2.81 \cdot 10^6$ N/C (c) $2.00 \cdot 10^5$ N/C (d) $1.40 \cdot 10^6$ N/C (e) $1.69 \cdot 10^6$ N/C

20. What is the magnitude of the electric field between the plates after the dielectric is inserted?

(a) $1.69 \cdot 10^6$ N/C (b) $1.40 \cdot 10^6$ N/C (c) $2.00 \cdot 10^5$ N/C (d) $5.62 \cdot 10^5$ N/C (e) $2.81 \cdot 10^6$ N/C

Question 21-23

A solid metal sphere with radius $r_a = 1$ cm is supported on an insulating stand at the center of a hollow, metal spherical shell with inner radius $r_b = 2$ cm and outer radius $r_c = 3$ cm. There is charge of q = +1 nC on the solid sphere and total charge of -3q on the spherical shell. (Take $k = 9 \cdot 10^9 \text{V} \cdot \text{m/C}$)



21. Calculate the potential V(r) in the region $r_b < r < r_c$,

(a) 0 V (b) -200 V (c) $\frac{9}{r}$ V (d) $-\frac{9}{r}$ V (e) -600 V

22. Calculate the potential V(r) in the region $0 < r < r_a$,

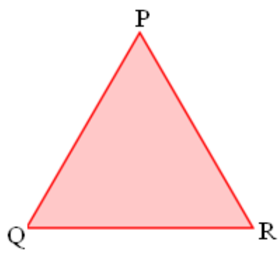
(a) -150 V (b) 0 V (c) 900 V (d) $-\frac{9}{r}$ V (e) $\frac{9}{r}$ V

23. What is the potential difference between the solid metal sphere and spherical metal shell $\Delta V = V(r_a) - V(r_b)$?

(a) 1100 V (b) 600 V (c) 200 V (d) 700 V (e) 450 V

Question 24-25

Three charges, q_1 =2 pC, q_2 = 3 pC, and q_3 = 4 pC, are located at the corners of an equilateral triangle with side length of L =1 m. (Take $k = 9 \cdot 10^9 \text{V} \cdot \text{m/C}$)



24. What is the work done to bring the third particle, q_3 to R from infinity?

(a) 15.0×10^{-14}J (b) 18.0×10^{-14}J (c) 5.4×10^{-14}J (d) 1.8×10^{-15}J (e) 11.4×10^{-14}J

25. What is the total potential energy stored in the final configuration of q_1, q_2, and q_3?

(a) 10.8×10^{-14}J (b) 1.8×10^{-14}J (c) 23.4×10^{-14}J (d) 12.6×10^{-14}J (e) 2.1×10^{-15}J

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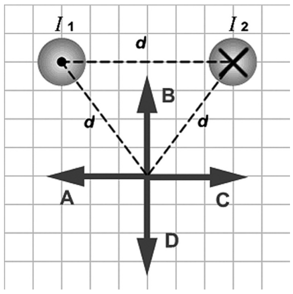
1. An electron moving in the direction of the (+x)-axis enters a magnetic field. If the electron experiences a magnetic deflection in the (-y) direction, the direction of the magnetic field in this region points in the direction of the

(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

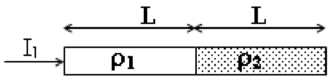
5. Kirchhoff's Junction Rule states that

(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)?

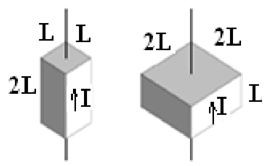
(a) electric field (b) electric power (c) none of the above (d) current (e) electric potential

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 ?



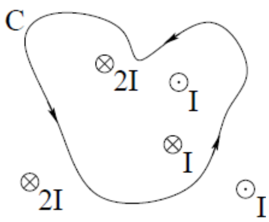
(a) $I_1 = I_2$ (b) $I_2 = I_1/3$ (c) $I_2 = I_1/2$ (d) $I_2 = 3I_1$ (e) $I_2 = 6I_1$

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) $R_A/R_B = 4$

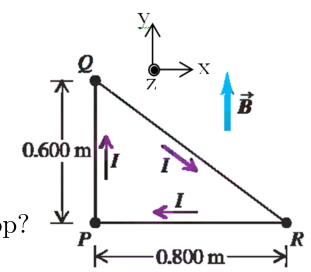
9. In the figure, long straight wires carry the currents indicated into or out of the page. The integral of $\vec{B}$ around the indicated curve C: $\oint_C \vec{B} \cdot d\vec{l}$ in the indicated direction is:



(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.

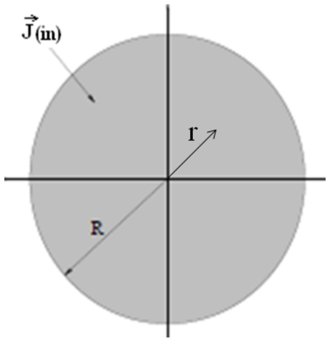
(a) $0.96\hat{\imath}$ A.m^2 (b) $2.16\hat{\imath}$ A.m^2 (c) $-1.2\hat{k}$ A.m^2 (d) $0.48\hat{k}$ A.m^2 (e) $-0.72\hat{k}$ A.m^2

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=1.6x10^{-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?

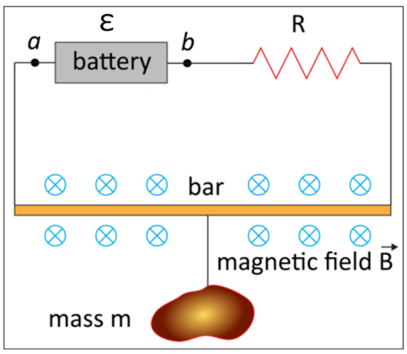
(a) 1.4×10^{-2} A (b) 2.3×10^{2} A (c) 0.45×10^{-5} A (d) 1.2×10^{2} A (e) 4.1×10^{3} A

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

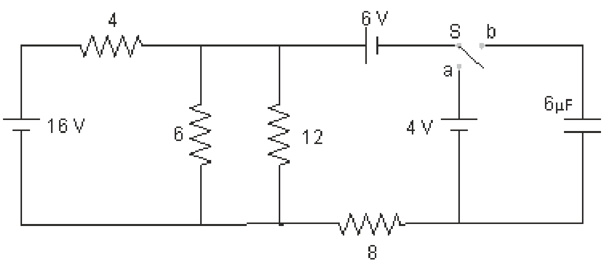
(a) εLB/R (b) ε^2B^{2}L (c) LBε (d) εLBR (e) none

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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1. Two long, straight wires are parallel to each other. The wires carry currents of different magnitudes. If the amount of current flowing in each wire is doubled, the magnitude of the force between the wires will be

(a) twice the magnitude of the original force. (b) half of the magnitude of the original force. (c) eight times the magnitude of the original force. (d) four times the magnitude of the original force. (e) the same as the magnitude of the original force.

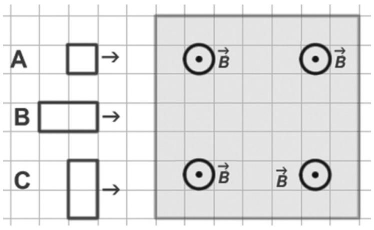
2. The number of turns in a solenoid is doubled, and its length is halved. How does its magnetic field change?

(a) it triples. (b) it is halved. (c) it quadruples. (d) it doubles. (e) it remains unchanged.

3. A solid cylinder carries a current that is uniform over its cross section. Where is the magnitude of the magnetic field the greatest?

(a) none of the above. (b) at the center of the cylinder's cross section (c) outside (d) at the surface (e) in the middle of the cylinder

4. The figure shows three metal loops labeled A, B, and C heading towards a region where a uniform static magnetic field exists. The loops move with the same constant velocity and all have the same resistance. Their relative sizes are indicated by the background grid. As they enter the magnetic field the loops will have an induced electric current in them. For which loop will the current be the greatest?



(a) B (b) C (c) A (d) The current is the same in all three cases since all the loops move with the same velocity. (e) There is no induced current in any of the loops since they move at constant velocity.

5. Inductors of value L, $2L$ and $3L$ are connected in series. What is the equivalent inductance?

(a) $11L/6$ (b) $3L$ (c) $6L$ (d) $6L/11$ (e) $3L/11$

6. The intensity of an EM wave propagating in vacuum is given as I. If the amplitude of the electric field component of this wave is doubled, what would be the new intensity?

(a) $I/2$ (b) $2I$ (c) $I/4$ (d) $4I$ (e) I

7. Inductors of value L, $2L$ and $3L$ are connected in parallel. What is the equivalent inductance?

(a) $3L$ (b) $11L/6$ (c) $6L$ (d) $6L/11$ (e) $6L/5$

8. There are no currents and permanent magnets present, but there is a non-zero magnetic field. What else must be present?

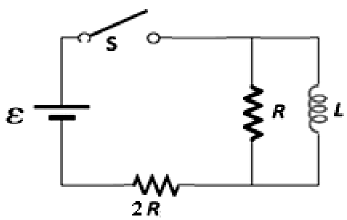
(a) none of them (b) electric charge (c) it is imposible to have a magnetic field, without a current (d) constant electric field (e) changing electric field

9. A circular loop of wire lies in the plane of the paper. An increasing magnetic field points out of the paper. What is the direction of the induced current in the loop?

(a) There is no current induced in the loop. (b) counter-clockwise then clockwise (c) clockwise then counter-clockwise (d) counter-clockwise (e) clockwise

Questions 10-13

In the circuit in the figure, the emf of the battery is ε, the resistances are R and $2R$, and the inductance is L. For questions 10-11 consider the time $t = 0$ immediately after the switch S is closed.



10. What is the current in the inductor L?

(a) 0 (b) $\varepsilon/3R$ (c) $\varepsilon/2R$ (d) ∞ (e) ε/R

11. What is the current in resistor $2R$?

(a) $\varepsilon/3R$ (b) ∞ (c) ε/R (d) $\varepsilon/2R$ (e) 0

For questions 12-13 consider the time $t \to \infty$, long after the switch is closed.

12. What is the current in the resistor $2R$?

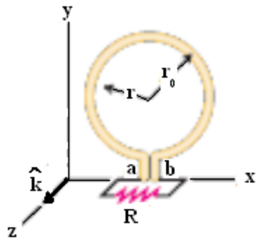
(a) $\varepsilon/2R$ (b) $\varepsilon/3R$ (c) $2\varepsilon/R$ (d) 0 (e) ε/R

13. What is the energy stored in the inductor L?

(a) $L(\varepsilon/R)^2$ (b) 0 (c) $\frac{1}{8}L(2\varepsilon/3R)^2$ (d) $\frac{1}{2}L(\varepsilon/2R)^2$ (e) $\frac{1}{8}L(\varepsilon/R)^2$

Questions 14-16

A circular conducting ring with radius r_0 lies in the xy-plane in a region of uniform magnetic field $B(t) = B_0[1 - 3(t/t_0)^2 + 2(t/t_0)^3]$ in z-direction as shown in figure. In this expression, t_0 and B_0 are constants and t is time. At points a and b there is a small gap in the ring with wires leading to an external circuit of resistance R. There is no magnetic field at the location of the external circuit. Neglect the internal resistance of the ring. (r is the distance of any point from the center of the ring. CW: clockwise, CCW: counter-clockwise).



14. Derive an expression, as a function of time, for the total magnetic flux through the ring.

(a) $\Phi_B = B_0\pi r_0^2\left[1 - 3(\frac{t}{t_0})^2 + 2(\frac{t}{t_0})^3\right]$ (b) $\Phi_B = B_0\pi(r_0^2 - r^2)$ (c) $\Phi_B = B_0\pi(r_0^2 - r^2)\left[1 - 3(\frac{t}{t_0})^2 + 2(\frac{t}{t_0})^3\right]$
(d) $\Phi_B = \pi(r^2 - r_0^2)\left[3(\frac{t}{t_0})^2 + 2(\frac{t}{t_0})^3\right]$ (e) $\Phi_B = 3B_0\pi r^2\left[1 - 3(\frac{t}{t_0}) + 2(\frac{t}{t_0})^2\right]$

15. Determine the emf induced in the ring.

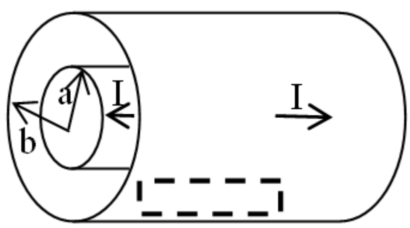
(a) $\varepsilon = \frac{B_0\pi r_0^2}{t_0}\left[1 - (\frac{t}{t_0})^2 - (\frac{t}{t_0})\right]$ (b) $\varepsilon = -B_0\pi r^2\left[(\frac{t}{t_0}) - (\frac{t}{t_0})^2\right]$ (c) $\varepsilon = \frac{B_0 r^2}{t_0}\left[(\frac{t}{t_0})^3 - (\frac{t}{t_0})^2\right]$ (d) $\varepsilon = \frac{-B_0\pi r_0^2}{t_0}(\frac{t}{t_0})^2$
(e) $\varepsilon = \frac{-6B_0\pi r_0^2}{t_0}\left[(\frac{t}{t_0})^2 - (\frac{t}{t_0})\right]$

16. Determine the magnitude and direction of the induced current in the ring at time $t = 2t_0$.
(take $\pi = 3$, $r_0 = 0.05\,\mathrm{m}$, $t_0 = 0.01\,\mathrm{s}$, $B_0 = 0.100\,\mathrm{T}$, $R = 10.0\,\Omega$).

(a) 1.5×10^{-2} A, CCW (b) 9×10^{-2} A, CW (c) 0.5 A, CW (d) 2.5 A, CW (e) 1.0 A, CCW

Questions 17-21

A long coaxial cable consists of two concentric thin walled cylinderical shells with radii a and b. Their length is ℓ. The inner and outer cylinders carry equal currents I in opposite directions as shown in the figure.(r is the distance from the axis of the cylinder)



17. Find the magnetic field for $r < a$ (inside the inner cylinder).

(a) $B = \mu_0 I\ell/2\pi(b^2 - a^2)$ (b) $B = \mu_0 I/2\pi a$ (c) $B = \mu_0 I/2\pi r^2$ (d) $B = \mu_0 I/4\pi r$
(e) $B = 0$

18. Find the magnetic field for $a < r < b$ (between the cylinders).

(a) $B = \mu_0 I/2\pi r$ (b) $B = \mu_0 I/2\pi r^2$ (c) $B = \mu_0 I/2\pi a$ (d) $B = \mu_0 I/4\pi r$ (e) $B = \mu_0 I/2\pi(b - a)$

19. Calculate the energy density in the region between the cylinders ($a < r < b$).

(a) $\mu_0 I^2/8\pi^2 r^2$ (b) $I^2/4\pi^2(a + b)^2\mu_0$ (c) $I^2/2\mu_0\ell(a + b)$ (d) $\ell I^2/4\pi^2 r^2\mu_0$ (e) $\left(\mu_0 I^2/4\pi^2\ell(b^2 - a^2)\right)\ln(b/a)$

20. What is the flux between the cylinders in a section of this system of length ℓ ?

(a) $\Phi = \mu_0 I\ell\pi(b^2 - a^2)/(a + b)$ (b) $\Phi = 2\mu_0 I\ell\pi(b + a)$ (c) $\Phi = (\mu_0 I\ell/2\pi)\ln(b/a)$ (d) $\Phi = (\mu_0 I^2/2\pi)\ln(b/a)$
(e) $\Phi = (\mu_0 I/\pi)\ln(b/a)$

21. What is the inductance of the cable?

(a) $L = (\mu_0 I/4\pi\ell)\ln(b/a)$ (b) $L = 2\mu_0 I\pi(b^2 - a^2)$ (c) $L = (\mu_0\ell/2\pi)\ln(b/a)$ (d) $L = \mu_0 I\pi(b^2 - a^2)/(a + b)$
(e) $L = (\mu_0 I/\pi\ell)\ln(b/a)$

Questions 22-25

Suppose that charges on a dipole antenna oscillate slowly at a rate of 1 cycle/s, and antenna radiates electromagnetic waves in a region of space.

22. If someone measured the time-varying magnetic field in the region and found its maximum to be 0.00120 T, what would be the maximum electric field, E, in units of volts per meter? (Take $c = 3.0 \times 10^8$ m/s, $\pi = 3.0$, $\mu_0 = 4\pi \times 10^{-7}$ T.m/A)

(a) 2.5×10^{-5} (b) 4.1×10^{-4} (c) 0.36 (d) 3.6×10^5 (e) 1.2×10^5

23. What is the period of the charge oscillation.

(a) 6 s (b) 1 s (c) 4.5 s (d) 2 s (e) 3 s

24. What is the wavelength of the wave?

(a) 6.0×10^8 m (b) 3.0×10^8 m (c) 2.4×10^5 m (d) 1.4×10^5 m (e) 12×10^{-8} m

25. What is the magnitude of the poynting vector?

(a) $1.0 \times 10^3\,\mathrm{W/m^2}$ (b) $4.3 \times 10^{10}\,\mathrm{W/m^2}$ (c) $3.6 \times 10^8\,\mathrm{W/m^2}$ (d) $3.0 \times 10^{11}\,\mathrm{W/m^2}$ (e) $6.3 \times 10^{11}\,\mathrm{W/m^2}$

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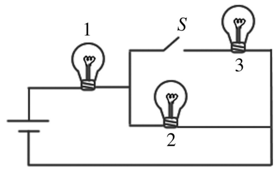
List Number		e-mail		
Student ID		Signature		

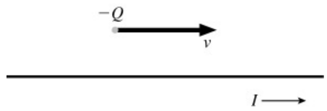
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. The figure shows three identical light bulbs connected to a battery having a constant voltage across its terminals. What happens to the brightness of light bulb 1 when the switch S is closed?



(a) The brightness remains the same as before the switch is closed. (b) The brightness decreases permanently. (c) The brightness will increase momentarily then return to its previous level. (d) The brightness increases permanently. (e) The brightness will decrease momentarily then return to its previous level

2. A negatively charged particle is moving to the right, directly above a wire having a current flowing to the right, as shown in the figure. In which direction is the magnetic force exerted on the particle?



(a) The magnetic force is zero since the velocity is parallel to the current. (b) out of the page (c) downward (d) upward (e) into the page

3. A solenoid with 200 turns and a cross-sectional area of 60 cm^2 has a magnetic field along its axis. If the field is confined within the solenoid and changes at a rate of 0.20 T/s, the magnitude of the induced potential difference in the solenoid will be

(a) 0.02 V (b) 0.002 V (c) 0.24 V (d) 0.3 V (e) 0.001 V

4. If the amplitude of the $\vec{B}$ field of an EM wave is 2.5×10^{-7} T, what is the amplitude of the $\vec{E}$ field?

(a) 75 V/m (b) 8 V/m (c) 1.02 V/m (d) 25 V/m (e) 90 V/m

5. Which of the following will induce a current in a loop of wire in a **uniform** magnetic field?

(a) all of these (b) none of these (c) rotating the loop about an axis parallel to the field (d) moving the loop within the field (e) decreasing the strength of the field

6. Which of the following statements concerning electromagnetic waves are incorrect?
i) Electromagnetic waves in vacuum travel at the speed of light.
ii) The magnitudes of the electric field and the magnetic field in SI units are equal.
iii) Only the electric field vector is perpendicular to the direction of the waves propagation.
iv) Both the electric field vector and the magnetic field vector are perpendicular to the direction of propagation.
v) An electromagnetic wave carries energy only when electric field vector is parallel to magnetic field vector.

(a) (i), (iii) (b) (ii), (v) (c) (i), (ii), (iv) (d) (ii), (iii), (v) (e) (iii), (v)

7. Which of the following statements is ***false***?

(a) Electric field starts from a positive charge and ends at a negative charge. (b) Magnetic field starts at the north pole and ends at the south pole. (c) Electric field lines due to an electric dipole and magnetic field lines due a magnetic dipole far from the dipoles have similar configuration. (d) Magnetic poles always occur in pairs. (e) static magnetic fields result from the flow of charges.

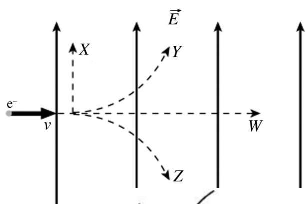
8. The current i through an ideal inductor with inductance L and zero resistance depends on time t according to $i(t) = Kt^2$, where K is a positive constant. The magnitude of the voltage across the inductor is

(a) Kt^2/L (b) $2KLt$ (c) KLt (d) KLt^2 (e) $KLt/2$

9. The charge on the square plates of a parallel-plate capacitor is Q. The potential across the plates is maintained with constant voltage by a battery as they are pulled apart to twice their original separation, which is small compared to the dimensions of the plates. The amount of charge on the plates is now equal to

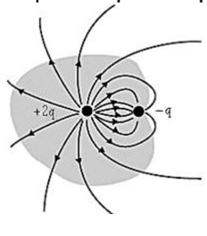
(a) $4Q$ (b) $2Q$ (c) $Q/2$ (d) $Q/4$ (e) Q

10. An electron is initially moving to the right when it enters in a uniform electric field directed upwards. Which trajectory shown in Figure will the electron follow?



(a) trajectory W (b) none of them (c) trajectory X (d) trajectory Y (e) trajectory Z

11. The figure shows a surface enclosing the charges $2q$ and $-q$. The net flux through the surface surrounding the two charges is



(a) zero (b) q/ε_0 (c) $2q/\varepsilon_0$ (d) $-q/\varepsilon_0$ (e) None of these is correct

Questions 12-15

An air capacitor is made by using two flat plates, each with area A, separated by a distance d. Then a metal slab having thickness a (less than d) and the same shape and size as the plates is inserted between them, parallel to the plates and not touching either plate .

12. When the metal slab is not present, what is the capacitance of this arrangement, C_0?

(a) $C_0 = A/4\pi\varepsilon_0 Ad$ (b) $C_0 = \varepsilon_0 A/d$ (c) $C_0 = \varepsilon_0 A/a$ (d) $C_0 = 4\pi\varepsilon_0 A/d$ (e) $C_0 = 4\pi\varepsilon_0 dA$

13. When the metal slab is present, what is the capacitance of this arrangement?

(a) $C = 4\pi\varepsilon_0 A/(d-a)$ (b) $C = 2\varepsilon_0 A/(d-a)$ (c) $C = 4\varepsilon_0 A/(d-a)$ (d) $C = \varepsilon_0 A/(d-a)$ (e) $C = 8\pi\varepsilon_0 A/(d-a)$

14. What happens to the capacitance in the limits $a \to 0$

(a) $C = 0$ (b) $C = \varepsilon_0 A/d$ (c) $C = \infty$ (d) $C = 2\varepsilon_0 A/d$ (e) $C = \varepsilon_0 d/A$

15. What happens to the capacitance in the limits $a \to d$

(a) $C = 0$ (b) $C = \infty$ (c) $C = \varepsilon_0 d/A$ (d) $C = \varepsilon_0 A/d$ (e) $C = -\infty$

Questions 16-20

The pointing vector of an electromagnetic wave in vacuum is

$$\vec{S} = -\left(10\frac{W}{m^2}\right)\cos^2\left[\left(12\frac{rad}{m}\right)z + \left(3.6\times 10^9\frac{rad}{s}\right)t\right]\hat{?}$$

(Take $\pi = 3$, $\mu_0 = 4\pi \times 10^{-7}$ Tm/A, and $c = 3 \times 10^8$ m/s).

16. Find the propagation direction of the wave.

(a) $-\hat{k}$ (b) $+\hat{k}$ (c) $-\hat{\imath}$ (d) $-\hat{\jmath}$ (e) $+\hat{\imath}$

17. Find the wavelength of the wave.

(a) 1 m (b) 4 m (c) 2 m (d) 3 m (e) 0.5 m

18. Find the frequency of the wave.

(a) 600 MHz (b) 100 MHz (c) 300 MHz (d) 2 GHz (e) 1 GHz

19. Find the intensity of the wave.

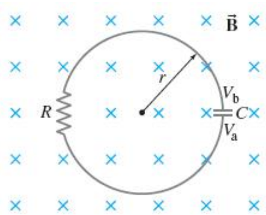
(a) 5 W/m^2 (b) 20 W/m^2 (c) 2.5 W/m^2 (d) 10 W/m^2 (e) 2 W/m^2

20. Find the maximum electric field component.

(a) 60 V/m (b) 90 V/m (c) 120 V/m (d) 1200 V/m (e) 30 V/m

Questions 21-23

A circular-shaped circuit of radius r, containing a resistance R and capacitance C, is situated with its plane perpendicular to the spatially uniform magnetic field within which it is immersed. The magnetic field ($\vec{B}$) is directed into the page as shown. Starting at time $t = 0$, the voltage difference $V_{ba} = V_b - V_a$ across the capacitor plates is observed to increase with time according to $V_{ba} = V_0(1 - e^{-t/\tau})$ where V_0 and τ (τ is time constant) are positive constants.



21. Find the current in the loop?

(a) $I = 0$ (b) $I = \frac{V_0}{R}$ (c) $I = \frac{V_0}{R}(1 - e^{-t/\tau})$ (d) $I = \frac{V_0}{R}e^{-1}$ (e) $I = \frac{V_0}{R}e^{-t/\tau}$

22. Find the emf in the loop?

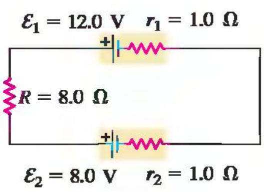
(a) $\varepsilon = V_0(1 - e^{-t/\tau})$ (b) $\varepsilon = V_0$ (c) $\varepsilon = V_0(1 - e^{-1})$ (d) $\varepsilon = V_0 e^{-t/\tau}$ (e) $\varepsilon = V_0(2e^{-t/\tau} - 1)$

23. Determine $d\Phi_B/dt$, the rate at which the magnetic flux changes with time.

(a) $-V_0 e^{-t/\tau}$ (b) V_0 (c) $V_0(1 - e^{-t/\tau})$ (d) $-V_0$ (e) $2V_0 e^{-1}$

Questions 24-25

In the circuit shown in the figure



24. find the current through the 8.0-ohm resistor

(a) 1.2 A (b) 0.40 A (c) 0.5 A (d) 2 A (e) 0.8 A

25. the total rate of dissipation of electrical energy in the 8.0-ohm resistor and in the internal resistance of the batteries.

(a) 2.25 W (b) 4 W (c) 1.6 W (d) 14.4 W (e) 6.4 W

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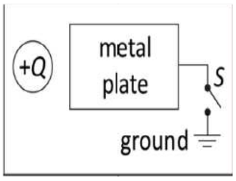
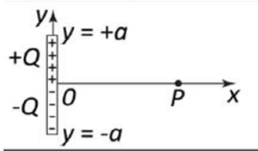
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account. The following identities are helpful: $\int_0^x \frac{y^2}{y-a}dy = \frac{x^2}{2} + ax + a^2\ln(1-\frac{x}{a})$, $\sin(x) \approx x$ **for small x**

1. A metal plate is connected by a conductor to the ground through a switch S. The switch is initially closed. A charge +Q is brought close to the plate without touching it, and then the switch is opened. After the switch is opened, the charge +Q is removed. What is the final charge on the plate?



(a) The plate is negatively charged (b) The plate is uncharged (c) Not enough information to decide (d) The plate could be either positively or negatively charged, depending on the charge it had before +Q was brought near (e) The plate is positively charged

2. A line of charge centered at point O and oriented along the y-axis has charge +Q distributed uniformly between y = 0 and y = +a and charge -Q distributed uniformly between y = 0 and y = -a (see figure). In this situation, the electric field at point P located on the x-axis as shown in the figure is directed:



(a) Along the positive x-axis (b) Along the negative x-axis (c) Along the positive y-axis (d) Along the negative y-axis (e) Electric field is zero

3. A cubical Gaussian box contains a negatively charged particle with charge -Q, and another positively charged particle with charge +Q lies outside the box. What can you say about the net electric flux through the box?

(a) The net electric flux is less than zero. (b) None of these, because flux is a vector. (c) The net electric flux is greater than zero. (d) The net electric flux is equal zero. (e) The net electric flux cannot be determined without more information.

4. There is a negative surface charge density in a certain region on the surface of a spherical solid conductor. Just beneath(under) the surface of this region, the electric field

(a) points inward, away from the surface of the conductor. (b) is zero. (c) points outward, toward the surface of the conductor. (d) not enough information given to decide. (e) points parallel to the surface.

5. Which of the following(s) is(are) **wrong** for a positive unit charge moving radially outward?

I) Potential difference near a positive charge located at the center is negative so electric force does positive work.
II) Potential difference near a positive charge located at the center is positive so electric force does negative work.
III) Potential difference near a negative charge located at the center is negative so electric force does positive work.
IV) Potential difference near a negative charge located at the center is positive so electric force does negative work.
V) Potential difference is zero means that electric force does no work.

(a) only I (b) II and III (c) I and IV (d) only V (e) only III

6. Which of the following(s) is/are true?

I) Equipotential surfaces for both positive and negative point charge form a sphere.
II) Equipotential surfaces for only positive point charge form a sphere.
III) Equipotential surfaces are planes for uniform electric field.
IV) On a given equipotential surface, the electric field E has the same value at every point..

(a) I and IV (b) only IV (c) I and III (d) II and III (e) only I

7. The capacitance of a spherical capacitor with inner radius a and outer radius b is proportional to:

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

8. The capacitance of a cylindrical capacitor can be increased by:

(a) decreasing the radius of the inner cylinder and increasing the radius of the outer cylindrical shell. (b) decreasing both the radius of the inner cylinder and the length. (c) increasing both the radius of the inner cylinder and the length. (d) only by decreasing the length. (e) increasing the radius of the outer cylindrical shell and decreasing the length.

9. Which term describes the rate at which electrical energy is used?

(a) Resistance (b) Voltage (c) Amper (d) Current (e) Power

10. What is the name for the flow of electrons in an electric circuit?

(a) Current (b) Inductance (c) Resistance (d) Capacitance (e) Voltage

Questions 11-15

A solid sphere has a volume charge density $\rho(r) = \frac{A}{r+c}$ where A and c are two constants, r is the radial distance from the center of the sphere.

11. What is the unit of A?

(a) $\frac{1}{m^2}$ (b) $\frac{C}{m^3}$ (c) $\frac{C^2}{m^3}$ (d) $\frac{C}{m^2}$ (e) $\frac{1}{m^3}$

12. If the total charge is Q, what is the magnitude of the electric field at $r > R$?

(a) $\frac{Q}{4\pi\epsilon_0(r+c)^2}$ (b) $\frac{Q}{4\pi\epsilon_0(r-c)^2}$ (c) $\frac{Q}{4\pi\epsilon_0 r^2}$ (d) $\frac{Q}{4\pi\epsilon_0 R^2}$ (e) $\frac{Qr}{4\pi\epsilon_0(r+c)^3}$

13. If the total charge is Q, what is the magnitude of the electric potential at $r > R$?

(a) $\frac{Qr}{4\pi\epsilon_0(r+c)^2}$ (b) $\frac{Q}{4\pi\epsilon_0(r+c)}$ (c) $\frac{Q}{4\pi\epsilon_0 r}$ (d) $\frac{Q}{4\pi\epsilon_0 R}$ (e) $\frac{Q}{4\pi\epsilon_0(r-c)}$

14. Express the total charge Q in terms of A,R,c.

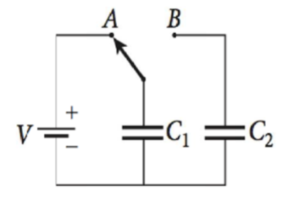
(a) $2\pi AR^2(1 + \frac{2c}{R} + \frac{2c^2}{R^2}\ln(1 - \frac{c}{R}))$
(b) $2\pi AR^2(1 - \frac{2c}{R} + \frac{2c^2}{R^2}\ln(1 + \frac{R}{c}))$ (c) $4\pi AR^2(1 + \frac{2c}{R} + \frac{2c^2}{R^2}\ln(1 - \frac{R}{2c}))$ (d) $4\pi AR^2(1 - \frac{2c}{R} + \frac{2c^2}{R^2}\ln(1 + \frac{c}{2R}))$
(e) $4\pi AR^2(1 + \frac{2c}{R} + \frac{2c^2}{R^2}\ln(1 + \frac{2R}{c}))$

15. Express the total charge at Q in the case where $c >> R$

(a) $\frac{4\pi}{3R}Ac^3$ (b) $\frac{4\pi}{3c}A(R+c)^3$ (c) $\frac{2\pi}{3R}cA^3$ (d) $\frac{2\pi}{3R}Ac^3$ (e) $\frac{4\pi}{3c}AR^3$

Questions 16-20

The figure shows a circuit with V=10 V, $C_1 = 2$ nF, and $C_2 = 3$ nF. The switch is closed, to A, and the capacitor C_1 is fully charged.



16. Find the energy delivered by the battery.

(a) 300 nJ (b) 100 nJ (c) 150 nJ (d) 200 nJ (e) 250 nJ

17. Find the energy stored in C_1.

(a) 200 nJ (b) 250 nJ (c) 150 nJ (d) 300 nJ (e) 100 nJ

18. Then the switch is thrown to B and the circuit is allowed to reach equilibrium. Find the total energy stored at C_1.

(a) 16 nJ (b) 30 nJ (c) 24 nJ (d) 12 nJ (e) 20 nJ

19. Find the total energy stored at C_2 after the switch is thrown to B and the circuit is allowed to reach equilibrium.

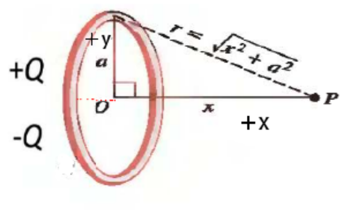
(a) 45 nJ (b) 30 nJ (c) 36 nJ (d) 18 nJ (e) 24 nJ

20. Find the total energy stored at $C_1 + C_2$ after the switch is thrown to B and the circuit is allowed to reach equilibrium.

(a) 40 nJ (b) 30 nJ (c) 60 nJ (d) 75 nJ (e) 50 nJ

Questions 21-23

A circular loop(ring), with a radius a is charged with +Q at the upper part and -Q at the lower part as shown in the figure.



21. What is the direction of the electric field at point P?

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

22. Calculate the potential V(r) at point P.

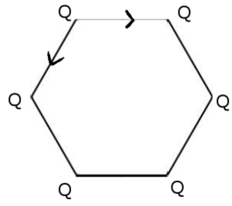
(a) $\frac{kQx}{(a^2+x^2)}$ (b) $\frac{2kQ}{(a^2+x^2)^{\frac{1}{2}}}$ (c) $\frac{2kQx}{(a^2+x^2)}$ (d) 0 (e) $\frac{2kQa}{(a^2+x^2)}$

23. Calculate the magnitude of the electric field at the middle of the ring.

(a) $\frac{2kQ}{\pi a^2}$ (b) 0 (c) $\frac{4kQ}{\pi a^2}$ (d) $\frac{kQ}{4\pi a^2}$ (e) $\frac{kQ}{2\pi a^2}$

Questions 24-25

Now take a positively charged regular hexagon wire with a side length of L. It is placed horizontally on a table. The positive charges at the corners repel each other and create a tension on the wire.



24. Express the tension T on the wire in terms of Q and length L.

(a) $\frac{kQ^2}{24L^2}(2\sqrt{3} + 5)$ (b) $\frac{kQ^2}{12L^2}(2\sqrt{3} + 5)$ (c) $\frac{kQ^2}{24L^2}(4\sqrt{3} + 15)$ (d) $\frac{kQ^2}{12L^2}(4\sqrt{3} + 15)$
(e) $\frac{kQ^2}{6L^2}(2\sqrt{3} + 5)$

25. Assume that the metal wire barely holds against the electric force. If one doubles the side lengths of the loop, what is the maximum **total** charge that one can have on the wire without breaking it?

(a) 4Q (b) 3Q (c) 6Q (d) Q/2 (e) 12Q

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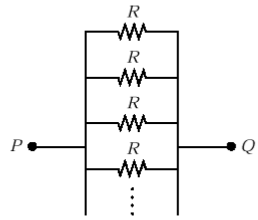
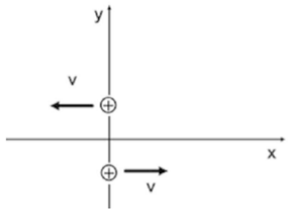


1. Points P and Q are connected to a battery of fixed voltage (see the figure). As more resistors R are added to the parallel circuit, what happens to the total current in the circuit?

(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.

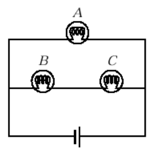
4. A current in a coil with N turns creates a magnetic field at the center of that coil. The field strength is directly proportional to:

(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)

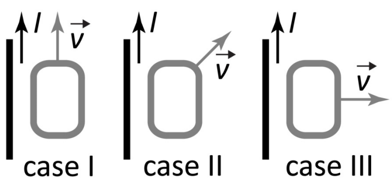


(a) the same (b) twice as much (c) 1/4 as much (d) 1/2 as much (e) 4 times as much

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?

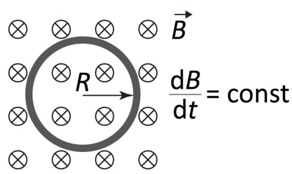


(a) Cases I and III (b) Cases I and II (c) None of the loops will have an induced current (d) Cases II and III (e) All of the loops will have an induced current

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

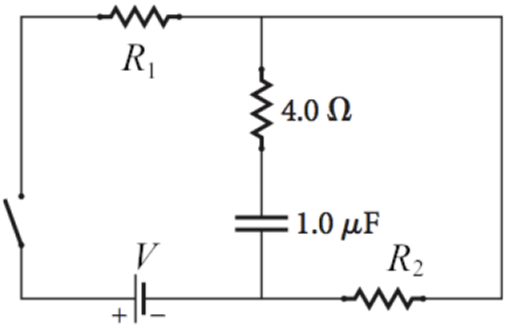
10. A metal ring with radius R lies in the plane perpendicular to a spatially uniform magnetic field B that points into the page and increases at a constant rate (see the figure). In this situation, electromotive force (emf) induced in the ring is $\mathcal{E}_1$ and magnitude of induced electric field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

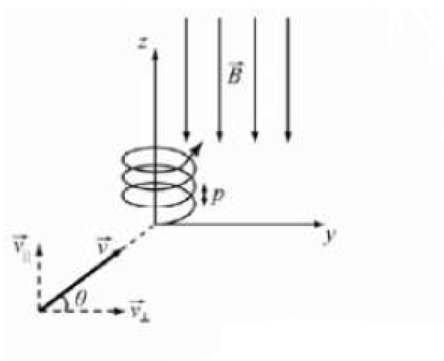
(a) 8 V (b) 16 V (c) 12 V (d) 10 V (e) 20 V

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).

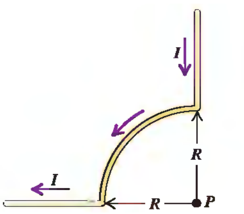
(a) 0.8 m (b) 0.4 m (c) 0.2 m (d) 3.2 m (e) 1.6 m

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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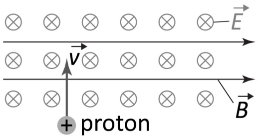
1. A proton moves with velocity $\vec{v}$ perpendicularly to crossed electric and magnetic fields $\vec{E}$ and $\vec{B}$ as shown in the figure. What is the direction of the net force acting on the proton?



(a) Into the page (b) Out of the page (c) Toward the left (d) Not enough information given to decide (e) Toward the right

2. An electromagnetic wave propagates in a dielectric medium with permittivity $\epsilon = K\epsilon_0$ and permeability $\mu = K_m\mu_0$ where K is the dielectric constant of the medium and K_m is the relative permeability of the medium. In this medium, energy density of electric field of the wave is $u_E = \frac{1}{2}\epsilon E^2$ and energy density of magnetic field of the wave is $u_B = \frac{1}{2\mu}B^2$. What is the ratio of u_E/u_B?

(a) K_m/K (b) $\frac{1}{\sqrt{KK_m}}$ (c) K/K_m (d) 1 (e) $\sqrt{KK_m}$

3. Which of the following statements concerning propagating electromagnetic waves are incorrect?

i) Electric and magnetic fields of the wave oscillate with the same phase

ii) Mutual orientation of electric and magnetic field in the wave is random

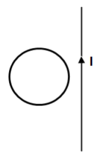
iii) When the wave moves between two media with different permittivity, frequency of the wave changes

iv) When the wave moves between two media with different permittivity, wavelength of the wave changes

v) Ratio of magnitudes of electric and magnetic field of the wave is an arbitrary number

(a) i, ii, iii (b) ii, iv, v (c) ii, iii, v (d) ii, iii, iv (e) i, iii, v

4. A steady current, I, flows through a straight wire. A circular loop of wire is placed next to the straight wire as shown in the figure. Which of the following will not produce an induced current in the loop?



(a) Move the loop away from the wire. (b) Move the loop toward the wire. (c) Decrease the electric current in the wire. (d) Move the loop in parallel to the wire. (e) Increase the electric current in the wire.

5. The principle or law that says "an induced emf in a closed circuit loop produces a current whose magnetic field opposes further change of magnetic flux" is credited to:

(a) Volta (b) Faraday (c) Coulomb (d) Lenz (e) Ampere

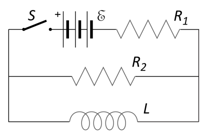
6. What is the unit of Poynting vector?

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

Questions 7-9

In the circuit shown in the figure, the switch S is initially opened. It is then closed, and remains closed for a long time. The inductor L has negligible resistance. Express your answers in terms of L, the battery emf $\mathcal{E}$ and the values of the resistors R_1,R_2.

7. Determine the currents through R_1,R_2, L a long time after the switch is closed.



(a) $I_{R_2} = 0$ and $I_{R_1} = 0$ and $I_L = \mathcal{E}/R_1$ (b) $I_{R_2} = \mathcal{E}/R_2$ and $I_{R_1} = \mathcal{E}/R_1$ and $I_L = \mathcal{E}/(R_1 + R_2)$ (c) $I_{R_2} = 0$ and $I_{R_1} = I_L = \mathcal{E}/R_1$ (d) $I_{R_2} = I_{R_1} = I_L = 0$ (e) $I_{R_2} = 0$ and $I_{R_1} = \mathcal{E}/R_1$ and $I_L = 0$

For question 8 and 9

After switch has been closed for a very long time t, it is then opened.

8. What is the time constant of this circuit?

(a) zero (b) t (c) $L/(R_1 + R_2)$ (d) L/R_1 (e) L/R_2

9. Determine $I_L(t)$, the current in the inductor as a function of time after the switch is opened.

(a) $I_L = \frac{\mathcal{E}}{R_1}e^{(\frac{-(R_1+R_2)t}{L})}$ (b) $I_L = \frac{\mathcal{E}}{R_1}e^{(\frac{-R_2 t}{L})}$ (c) $I_L = \frac{\mathcal{E}}{R_1}e^{-t}$ (d) $I_L = \frac{\mathcal{E}}{R_1}e^{(\frac{-R_1 t}{L})}$ (e) $I_L = \frac{\mathcal{E}}{R_1}$

Questions 10-14

A solenoid of square cross section $a \times a$ is of length $l (l \gg a)$. It has N windings (sarım). The time dependent current through the solenoid is given as $I = I_0 \sin(\omega t)$ where ω is a constant.

10. The magnetic field in the solenoid at t=0 is;

(a) $\mu_0 I_0$ (b) 0 (c) $\mu_0 I_0 a^2/l$ (d) $\mu_0 I_0 N/l$ (e) $\mu_0 I_0 l/a^2$

11. The magnetic field in the solenoid when $\omega t = \pi/2)$ is;

(a) 0 (b) $I_0 N a^2 \mu_0/l$ (c) $I_0 N \mu_0/l$ (d) $I_0 l \mu_0/a^2$ (e) $2I_0 N \mu_0/l$

12. The magnetic flux in the solenoid when $\omega t = \pi/2)$ is;

(a) 0 (b) $I_0 l \mu_0/a^2$ (c) $I_0 N a^2 \mu_0/2l$ (d) $I_0 N \mu_0/2a^2 l$ (e) $I_0 N a^2 \mu_0/l$

13. The self induction coefficient of the solenoid is

(a) $I_0 l \mu_0/a^2$ (b) $I_0 N a^2 \mu_0/l$ (c) $N a^2 \mu_0/l$ (d) 0 (e) $2I_0 N \mu_0/a^2 l$

14. The emf of the solenod at time t=0 is;

(a) $\frac{N\mu_0 a^2}{l}\omega I_0$ (b) $\frac{N\mu_0 a^2}{l}\frac{dI_0}{dt}$ (c) 0 (d) $\frac{N\mu_0 a^2}{l} t\omega$ (e) $\frac{N\mu_0 a^2}{l} t$

Questions 15-17

Suppose that charges on a dipole antenna oscillate slowly at a rate of 2 cycle/s, and the antenna radiates sinusoidal electromagnetic waves in a region of space.

15. If someone measured the time-varying magnetic field in the region and found its maximum B_{max} to be 2×10^{-6} T, what would be the maximum electric field, E_{max}, in the region, in units of volts per meter?

(a) 600 (b) 800 (c) 200 (d) 1000 (e) 400

16. What is the period of the charge oscillation?

(a) 2 s (b) 0.5 s (c) 1 s (d) 0.25 s (e) 4 s

17. What is the minimum value of the magnitude of the Poynting vector?

(a) $\frac{2E_{max}B_{max}}{\mu_0}$ (b) 0 (c) $\frac{E_{max}B_{max}}{2\mu_0}$ (d) $\frac{E_{max}B_{max}}{4\mu_0}$ (e) $\frac{E_{max}B_{max}}{\mu_0}$

Questions 18-19

At the surface of the Earth, the Sun delivers an estimated 3 W/m^2 of energy. Suppose the light is incident perpendicular to a 10 m by 20 m roof.

18. Estimate the total power incident on the roof in Watts.

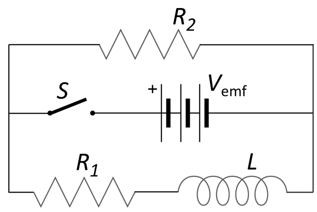
(a) 800 (b) 1000 (c) 600 (d) 400 (e) 200

19. Find the radiation pressure on the roof in μPa. (Assume the roof is black and totally absorbs the sunlight!)

(a) 0.01 (b) 0.06 (c) 0.04 (d) 0.02 (e) 0.03

Questions 20-25

In the circuit shown in the figure, a battery supplies $V_{emf} = V$ and resistances are R_1, R_2, and inductance is L.



20. Calculate the magnitude of the current through R_1 immediately after the switch is closed.

(a) $\frac{V}{R_2}$ (b) $\frac{V}{R_1}$ (c) $\frac{V}{R_1+R_2}$ (d) 0 (e) $V(\frac{R_1 \times R_2}{R_1+R_2})$

21. Calculate the magnitude of the potential difference across L immediately after the switch is closed.

(a) $V\frac{R_2}{R_1}$ (b) $V(\frac{R_1}{R_1+R_2})$ (c) $V\frac{R_1}{R_2}$ (d) V (e) 0

22. Calculate the rate of current change across R_1 immediately after the switch is closed.

(a) $\frac{2V}{L}$ (b) $\frac{V}{L}$ (c) $\frac{V}{2L}$ (d) $\frac{V}{4L}$ (e) $\frac{4V}{L}$

23. Calculate the power across R_1 at time $t = \frac{L}{R_1} ln(2)$.

(a) $\frac{2V^2}{R_1}$ (b) $\frac{V^2}{R_1}$ (c) $\frac{4V^2}{R_1}$ (d) $\frac{V^2}{2R_1}$ (e) $\frac{V^2}{4R_1}$

24. Calculate the power across R_2 as time $t \to \infty$.

(a) $\frac{V^2}{R_2}$ (b) $\frac{V^2}{4R_2}$ (c) $\frac{4V^2}{R_2}$ (d) $\frac{V^2}{2R_2}$ (e) $\frac{2V^2}{R_2}$

25. Calculate the power across R_1 as time $t \to \infty$.

(a) $\frac{V^2}{4R_2}$ (b) $\frac{4V^2}{R_2}$ (c) $\frac{V^2}{2R_2}$ (d) $\frac{V^2}{R_1}$ (e) $\frac{2V^2}{R_2}$

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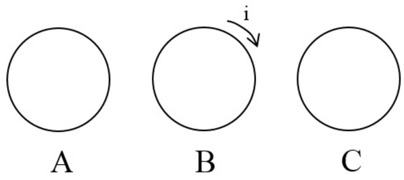
1. Three conducting loops are situated side-by-side in the plane of the page. A clockwise current flows in the center loop B, and its magnitude is decreasing in time. The induced currents in loops A and C



(a) both flow clockwise. (b) flow in opposite directions (A clockwise, C counterclockwise). (c) there will be no induced current. (d) flow in opposite directions (A counterclockwise, C clockwise). (e) both flow counterclockwise.

2. An electron travels towards north through a vacuum in a region of uniform magnetic field that is also directed towards north. It will:

(a) slow down (b) speed up (c) follow a left-handed corkscrew path (d) follow a right-handed corkscrew path (e) be unaffected by the field

3. A magnet moves inside a coil. Consider the following factors; which of the following(s) can affect the emf induced in the coil?

I) strength of the magnet

II) number of turns in the coil

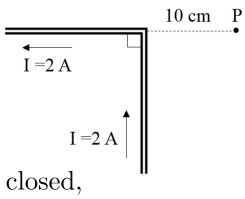
III) speed at which the magnet moves

(a) I only (b) II only (c) I and II only (d) III only (e) I,II,III

4. The magnetic force on a moving charged particle is in the direction of its velocity if:

(a) it is moving opposite to the direction of the field (b) never (c) it is moving perpendicular to the field (d) it is moving in the direction of the field (e) it is moving in some other direction

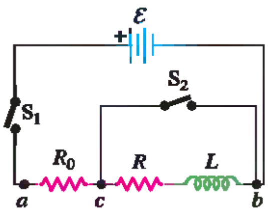
5. An infinitely long wire carrying a current of $2A$ is bent at a right angle as shown in the Figure. What is the magnetic field magnitude in Tesla a point P, 10 cm from the corner?



(a) $2\mu T$ (b) $3\mu T$ (c) $1\mu T$ (d) $4\mu T$ (e) $5\mu T$

Questions 6-10

Consider the circuit shown in the figure. Switch S_1 is closed and switch S_2 is left open. Just after S_1 is closed,



6. what is the current I_{R_0} through R_0?

(a) 0 (b) $\mathcal{E}/R$ (c) $\mathcal{E}/R_0$ (d) $\mathcal{E}/(R+R_0)$ (e) $\mathcal{E}/(R-R_0)$

7. what is the potential difference V_{ac}?

(a) $\mathcal{E}\frac{R}{R+R_0}$ (b) $\mathcal{E}\frac{R_0}{R}$ (c) $\mathcal{E}\frac{R}{R_0}$ (d) 0 (e) $\mathcal{E}$

8. what is the potential differences V_{cb}?

(a) 0 (b) $\mathcal{E}\frac{R}{R_0}$ (c) $\mathcal{E}$ (d) $\mathcal{E}\frac{R}{R+R_0}$ (e) $\mathcal{E}\frac{R_0}{R}$

9. After S_1 has been closed a long time (S_2 is still open) so that the current has reached its final, steady value, what is the current I_{R_0} through R_0?

(a) $\mathcal{E}/(R+R_0)$ (b) $\mathcal{E}/(R-R_0)$ (c) 0 (d) $\mathcal{E}/R$ (e) $\mathcal{E}/R_0$

10. If one waits for a long time, the current becomes steady. Then switch S_1 is opened and S_2 is closed. Just after S_2 is closed what is the current through R?

(a) $\mathcal{E}/(R-R_0)$ (b) $\mathcal{E}/R$ (c) 0 (d) $\mathcal{E}/(R+R_0)$ (e) $\mathcal{E}/R_0$

Questions 11-18

The electric field of a plane electromagnetic wave propagating in vacuum is given by : $\vec{E} = E_0 \sin(\frac{2\pi}{5}x - \omega t)\hat{j}$; where x is the amount of distance along the x axis and has a unit of meters.

11. What is the wave number (k) of the electromagnetic wave in units of m^{-1}?

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

12. What is the wavelength λ of the electromagnetic wave in meters?

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

13. What is the the direction of propagation of the electromagnetic wave?

(a) $\hat{k}$ (b) $\hat{i}$ (c) $\hat{i}+\hat{j}$ (d) $\hat{j}$ (e) $\hat{j}+\hat{k}$

14. What is the direction of the magnetic field component $\vec{B}$ of the electromagnetic wave?

(a) $\hat{i}$ (b) $\hat{k}$ (c) $\hat{i}+\hat{j}$ (d) $\hat{j}$ (e) $\hat{j}+\hat{k}$

15. What is the maximum value of the magnetic field component $\vec{B}$ of the electromagnetic wave at a given location?

(a) E_0/c (b) $2cE_0$ (c) 0 (d) cE_0 (e) $2E_0/c$

16. What is the average value of the magnitude of the Poynting vector $\vec{S}$?

(a) $B^2_{max}/c\mu_0$ (b) $B^2_{max}\mu_0/2c$ (c) $cB^2_{max}/2\mu_0$ (d) B^2_{max}/μ_0^2 (e) B^2_{max}/μ_0

17. What is the frequency (f) of the electromagnetic wave in Hz?

(a) 7.5×10^7 (b) 6×10^7 (c) 1×10^8 (d) 1.5×10^8 (e) 3×10^8

18. Find the radiation pressure if this wave is totally reflected from a surface.

(a) B^2_{max}/μ_0 (b) $B^2_{max}/c\mu_0^2$ (c) $B^2_{max}/c^2\mu_0$ (d) cB^2_{max}/μ_0 (e) $B^2_{max}/c\mu_0$

Questions 19-25

A solenoid of circular cross section is of radius a and length $l(l \gg a)$. It has N windings (sarım). The time dependent current through the solenoid is given as $I = I_0 e^{(-t/\tau)}$ where τ is a constant.

19. The magnetic field in the solenoid at $t = 0$ is

(a) $\mu_0 I_0$ (b) $\mu_0 I_0 l/a^2$ (c) $\mu_0 I_0 N/l$ (d) 0 (e) $\mu_0 I_0 a^2/l$

20. The magnetic field in the solenoid when $t \to \infty$ is

(a) $I_0 l\mu_0/a^2$ (b) $I_0 N\mu_0/l$ (c) 0 (d) $2I_0 N\mu_0/l$ (e) $I_0 Na^2\mu_0/l$

21. The magnetic flux in the solenoid when $t = 0$ is

(a) 0 (b) $\pi I_0 N\mu_0/2a^2 l$ (c) $\pi I_0 l\mu_0/a^2$ (d) $\pi I_0 Na^2\mu_0/2l$ (e) $\pi I_0 Na^2\mu_0/l$

22. The self induction coefficient of the solenoid L is

(a) $\pi N^2 a^2\mu_0/l$ (b) $2\pi N\mu_0/a^2 l$ (c) $\pi I_0 l\mu_0/a^2$ (d) 0 (e) $\pi I_0 Na^2\mu_0/l$

23. The emf of the solenoid at time t=0 is;

(a) $\pi\mu_0 I_0 tNl^2/a\tau^2$ (b) 0 (c) $\frac{N\mu_0 a^2}{l}\frac{dI_0}{dt}$ (d) $\pi\mu_0 I_0 Na^2/l\tau$ (e) $\pi\mu_0 I_0 Nl^2/a\tau$

24. The energy density u inside the solenoid at $t = 0$ is

(a) $\mu_0(I_0N)^2/2$ (b) $2\mu_0(I_0N)^2/l^2$ (c) 0 (d) $\mu_0(I_0N)^2/2l^2$ (e) $2(\mu_0 I_0 N)^2/l^2$

25. The total energy of the solenoid as $t \to \infty$ is

(a) $2\mu_0(aI_0N)^2/l^2$ (b) 0 (c) $\mu_0 a(lI_0N)^2/2$ (d) $2(\mu_0 aI_0N)^2/l$ (e) $\mu_0 a(I_0N)^2/2$

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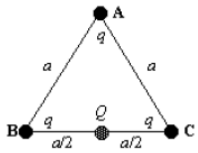
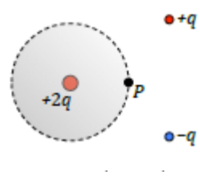
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. Three identical charges each with charge, q, are placed at the corners of an equilateral triangle. A fourth charge, Q, is placed midway between two of the charges as shown. Is it possible to choose a value for the charge Q such that the force on it due to the three corner charges is zero?
(a) No, because an additional charge would be needed to cancel the force on Q due to the charge at point A. (b) Yes, because it is centered between identical charges at points B and C. (c) No, because the forces on Q due to the charges at points B and C are in the same direction (d) No, because three force vectors can never add to zero. (e) None of them.

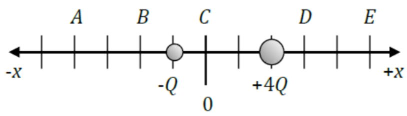


2. Suppose an electric field exists in a certain region of space. A test charge moves from point A to point B in the field. The work done by the field during this process is equal to
(a) the potential difference between points A and B. (b) the difference in the potential energy of the charge at point A and at point B. (c) none of them. (d) the difference between the value of the electric field at point A and at point B. (e) zero if the electric field is uniform.

3. Charges of +2q, +q, and -q are distributed in an area as shown in figure. Consider a Gaussian surface located around the +2q charge, with a point P located on the surface as shown. Which of the statements below is true?
(a) The electric field is the same everywhere inside the Gaussian surface. (b) The net electric field at point P can be determined using the Gaussian surface shown. (c) The net flux through the Gaussian surface depends only on the +2q charge. (d) The electric field at P depends only on the +2q charge. (e) The electric field is the same everywhere on the Gaussian surface.

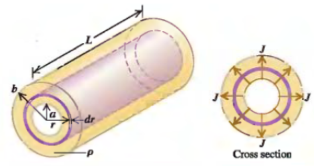


4. Two charges, of magnitude -Q and +4Q, are located as indicated in the diagram above. At which position will the electric field due to these two charges be zero?
(a) C (b) B (c) E (d) A (e) D



5. If the electron drift velocity is tripled in a wire, what effect does it do on the current density in this wire?
(a) it decreases by a factor of two (b) it increases by a factor three (c) it decreases by a factor of three (d) it increases by a factor of two (e) it stays the same

6. Figure shows the current flows radially from inside of the conductor toward outside (not along the length of the conductor) in a hollow cylinder with length L and inner and outer radii a and b. What is the resistance to this radial current flow if its resistivity is ρ.



(a) $R = (\rho\pi)\ln(b^2 - a^2)$ (b) $R = \frac{\rho}{2\pi L}\ln(b/a)$ (c) $R = \frac{\pi\rho}{L(b^2-a^2)}$ (d) $R = (\rho\pi)\frac{Lb^2}{(b^2-a^2)}$
(e) $R = (\rho\pi)(b^2 - a^2)$

7. The current in a wire varies with time according to the relationship $I = 55A - 2(A/s^2)t^2$. How many coulombs of charge pass a cross-section of the wire in the time interval between $t = 0$ and $t = 3s$?
(a) 52 A (b) 124 A (c) 147 A (d) 152 A (e) 48 A

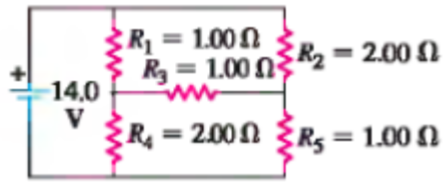
8. The electrostatic potential between the plates of a parallel plate capacitor ....
(a) increases with the position squared from the positive to the negative plate. (b) is constant. (c) increases linearly with position from the positive to the negative plate. (d) is equal to zero. (e) decreases linearly with position from the positive to the negative plate.

9. A spherical capacitor consists of a spherical conducting shell of radius b and charge -Q concentric with a smaller conducting sphere of radius a and charge +Q. Enter an expression for the capacitance of this device in terms of Coulomb's Constant k and the two radii a and b.
(a) $\frac{ab}{k(b-a)}$ (b) $\frac{4ab}{k(b+a)}$ (c) $\frac{4kab}{(b-a)}$ (d) $\frac{4kab}{(b+a)}$ (e) $\frac{4ab}{k(b-a)}$

10. Keeping the total charge on a capacitor fixed, what will happen to the electric energy density in a capacitor if one slides a dielectric material between two plates of the capacitor at hand?
(a) Decrease (b) Will not change (c) Density will become polarized (d) Information given above is not enough (e) Increase

Questions 11-15

In the circuit given below each resistor represent a light bulb. Let $R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$, $R_3 = 1\ \Omega$, $R_4 = 2\ \Omega$ and $R_5 = 1\ \Omega$.



11. What is the current flowing through the battery?
(a) 16 A (b) 18 A (c) 22 A (d) 8 A (e) 10 A

12. What is the current flowing through R_1?
(a) 4 A (b) 8 A (c) 6 A (d) 10 A (e) 2 A

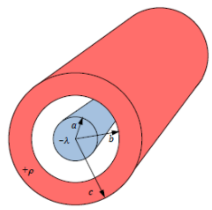
13. What is the current flowing through R_2?
(a) 10 A (b) 8 A (c) 4 A (d) 6 A (e) 2 A

14. What is the current flowing through R_3?
(a) 4 A (b) 10 A (c) 8 A (d) 6 A (e) 2 A

15. What is the equivalent resistor?
(a) $10\ \Omega$ (b) $1.4\ \Omega$ (c) $4.2\ \Omega$ (d) $6\ \Omega$ (e) $3.8\ \Omega$

Questions 16-20

An infinitely long cylindrical conductor has a radius a and a linear charge density of -λ as shown above. The conductor is surrounded by a cylindrical shell made of a nonconducting material of inner radius b, outer radius c, and with a constant volume charge density of $+\rho$. The conductor and nonconductor are located concentrically about a common axis.



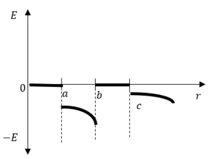
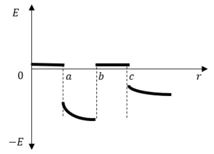
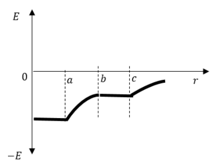
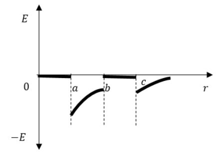
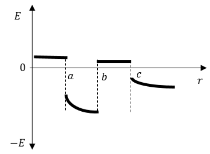
16. Determine the net electric flux per unit length passing through a cylindrically symmetric Gaussian surface located just outside the surface of the conductor.
(a) $\lambda\rho/\epsilon_0$ (b) λ/ϵ_0 (c) $-\rho/\epsilon_0$ (d) $-\lambda/\epsilon_0$ (e) ρ/ϵ_0

17. Use Gauss's Law to determine the magnitude of the electric field E as a function of radius r, where: $r < a$.
(a) $\frac{k\rho}{r}$ (b) $-\frac{k\rho}{r}$ (c) $-\frac{k\lambda}{\epsilon_0 r}$ (d) 0 (e) $-\frac{k\lambda}{r}$

18. Use Gauss's Law to determine the magnitude of the electric field E as a function of radius r, where: $a < r < b$
(a) $-\frac{2k(\rho\pi(r^2-a^2)-\lambda)}{r}$ (b) $\frac{k\rho}{r}$ (c) $\frac{2k\lambda}{r}$ (d) $-\frac{2k(\rho\pi(b^2-a^2)-\lambda)}{r}$ (e) $\frac{k\lambda}{r}$

19. Use Gauss's Law to determine the magnitude of the electric field E as a function of radius r, where: $r > c$.
(a) $\frac{2k(\rho\Pi(c^2-b^2)-\lambda)}{r}$ (b) $\frac{2k\rho(r^2-c^2)}{r}$ (c) $\frac{-2k\lambda(r^2-c^2)}{r}$ (d) $\frac{k\rho}{r}$ (e) $\frac{-2k(\rho\Pi(r^2-c^2)-\lambda)}{r}$

20. Putting an uncharged conducting cylinder around the linear charge density causes the uncharged cylinder to become polarized, with positive charges at the inner surface and negative charges at the outer surface. There is no electric field inside either conductor, and thus no change in electric potential inside the conductors.The following graphs require a general qualitative understanding of how electric field and electric potential changes work, without having to solve for specific functions. Which of the following could be the electric field versus r?

(a) 
(b) 
(c) 
(d) 
(e) 

Questions 21-25

A total charge of Q is placed on a conducting sphere (sphere 1) of radius R_1.

21. What is the electric potential, V_1, at the surface of sphere 1 assuming that the potential infinitely far away from it is zero? (Hint: What is the change in potential if a charge is brought from infinitely far away, where $V(\infty) = 0$, to the surface of the sphere?)
(a) kQ/R_1 (b) 0 (c) kQ^2/R_1^2 (d) kQ/R_1^2 (e) kQ^2/R_1

22. A second conducting sphere (sphere 2) of radius R_2 with an initial net charge of zero ($q = 0$) is connected to sphere 1 using a long thin metal wire. How much charge flows from sphere 1 to sphere 2 to bring them into equilibrium?
(a) $(\frac{R_1}{R_1+R_2})Q$ (b) $(\frac{R_2^2}{(R_1+R_2)^2})Q$ (c) $(\frac{R_2}{R_1+R_2})Q$ (d) $(\frac{R_2}{R_1})Q$ (e) $(\frac{R_1}{R_2})Q$.

23. After the spheres are connected, what is the absolute value of the electric field on the surface of sphere 1?
(a) $\frac{kQ}{R_1^2}$ (b) $\frac{kQ}{R_2^2}$ (c) $\frac{kQ}{R_2(R_1+R_2)}$ (d) $\frac{kQ}{(R_1+R_2)^2}$ (e) $\frac{kQ}{R_1(R_1+R_2)}$

24. After the spheres are connected, what is the absolute value of the electric field on the surface of sphere 2?
(a) $\frac{kQ}{(R_1+R_2)^2}$ (b) $\frac{kQ}{R_2^2}$ (c) $\frac{kQ}{R_1^2}$ (d) $\frac{kQ}{R_1(R_1+R_2)}$ (e) $\frac{kQ}{R_2(R_1+R_2)}$

25. After the spheres are connected, what is the absolute value of the V_2, at the surface of sphere 2 assuming that the potential infinitely far away from it is zero?
(a) $\frac{kQ}{R_2}$ (b) $\frac{kQR_1}{(R_1+R_2)^2}$ (c) $\frac{kQ}{(R_1+R_2)}$ (d) $\frac{kQR_2^2}{(R_1+R_2)^2}$ (e) $\frac{kQ}{R_1}$

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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. Which of the following is ***correct*** for the magnetic force $\vec{F}$ and the torque $\vec{\tau}$ acting on a closed loop of current in a *uniform* magnetic field making an angle of 30° with the normal of the loop.

(a) $\vec{F} = 0$ & $\vec{\tau} = 0$. (b) $\vec{F} = 0$ & $\vec{\tau} \neq 0$. (c) $\vec{F} > 0$ & $\vec{\tau} < 0$. (d) $\vec{F} \neq 0$ & $\vec{\tau} \neq 0$. (e) $\vec{F} \neq 0$ & $\vec{\tau} = 0$.

2. Which of the following is ***wrong***? The Gauss's law for magnetism states that...

(a) The magnetic flux through a through a closed loop is proportional to the enclosed currents.
(b) Magnetic field lines are continuous.
(c) There is no magnetic charge.
(d) The flux of magnetic field over a closed surface is zero.
(e) Every magnetic field line entering a closed surface also exits from it.

3. Which of the following is ***not*** a unit for magnetic flux?

(a) $kg.m^2.\mathrm{s}^{-1}.\mathrm{C}^{-1}$ (b) T/m^2 (c) $T.m^2$ (d) Wb (e) $N.m/A$

4. Which of the following statements are ***correct*** for the motion of charged particles in magnetic field?
I) Magnetic force can never do work on a charged particle.
II) Magnetic force can not change the magnitude of the velocity, only its direction.
III) The magnetic force can have a component parallel to the particle's motion.

(a) I and III (b) Only II (c) Only I (d) I, II and III (e) I and II

5. The speed of light in vacuum is given by;
(a) $\frac{1}{\epsilon_0\mu_0}$ (b) $\sqrt{\epsilon_0\mu_0}$ (c) $\epsilon_0\mu_0$ (d) $\frac{1}{\sqrt{\epsilon_0\mu_0}}$ (e) $(\epsilon_0\mu_0)^2$

6. In the Ampere-Maxwell equation for vacuum $\oint \vec{B}.\vec{dl} = \mu_0(I + I_D)$. The displacement current I_D is given by;

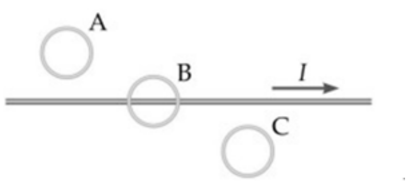
(a) $\mu_0 \frac{d}{dt} \oint \vec{B}.\vec{dl}$ (b) 0 (c) $\mu_0 \frac{d}{dt} \iint \vec{B}.\vec{ds}$ (d) $\epsilon_0 \frac{d}{dt} \iint \vec{E}.\vec{ds}$ (e) $\frac{\iint \vec{E}.\vec{ds}}{\epsilon_0}$

7. Which of the following(s) the mutual inductance can depend on?
I. The shape of the coils
II. Relative position of the coils
III. The number of turns
(a) I, III (b) I, II and III (c) none (d) I, II (e) II, III

8. If the current increases in a solenoid, the induced emf acts to
(a) decrease the flux. (b) first decrease then increase the flux. (c) have no effect on the flux. (d) first increase then decrease the flux. (e) increase the flux.

9. A circular loop of wire is the plane of the paper. The north pole of a bar is been moved toward the center of the loop from a position in front of the paper. The direction of the induced current in the loop,
(a) is clockwise. (b) cannot be determined. (c) is north. (d) is counterclockwise. (e) is south.

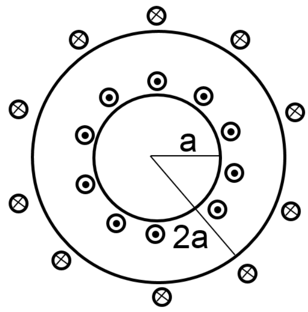
10. The long straight wire in the figure carries a current I that is decreasing with time at a constant rate. The circular loops A, B, and C all lie in a plane containing the wire. The induced emf in each of the loops A, B, and C is such that

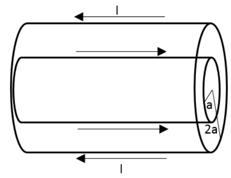


(a) all loops experience counterclockwise emf.
(b) no emf is induced in any of the loops.
(c) loop A has a counter-clockwise emf, loop B has no induced emf, and loop C has a clockwise emf.
(d) loop A has a clockwise emf, loop B has no induced emf, and loop C has a counterclockwise emf.
(e) a counterclockwise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

Questions 11-16

There is a cable which consists of two coaxial thin walled metal cylinders of radii a and $2a$. The inner cylinder carries a current I out of the page and the outer one carries out of the same current I into the page.





11. The magnetic field B in the inner region ($r < a$) is
(a) $2\mu_0 I$ (b) 0 (c) $\mu_0 I/2\pi r$ (d) $\mu_0 I$ (e) $2\pi r \mu_0 I$

12. The magnetic field B in the middle region ($2a > r > a$) is
(a) 0 (b) $\mu_0 I/2\pi r$ (c) $2\pi r \mu_0 I$ (d) $\mu_0 I$ (e) $2\mu_0 I$

13. The magnetic field B in the outer region ($r > a$) is
(a) $\mu_0 I$ (b) $2\pi r \mu_0 I$ (c) $\mu_0 I/2\pi r$ (d) $2\mu_0 I$ (e) 0

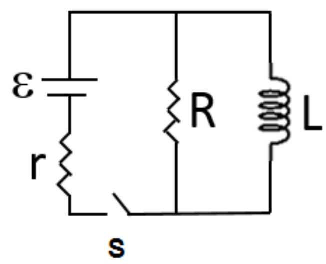
14. The magnetic flux in the inner region ($r < a$) of a section of length b is
(a) 0 (b) $\mu_0 I b$ (c) $\mu_0 I b/2\pi r$ (d) $2\pi r \mu_0 I b \ln(a)$ (e) $2\mu_0 I b \ln(a)$

15. The magnetic flux in the intermediate region ($a < r < 2a$) of a section of length b is
(a) $\mu_0 I b \ln 2/2\pi$ (b) $2\mu_0 I b \ln(a)$ (c) $2\pi r \mu_0 I b \ln(a)$ (d) 0 (e) $\mu_0 I b/2\pi r$

16. The self induction coefficient of this section of length b is
(a) $\mu_0 b/2\pi r$ (b) $2\mu_0 I b \ln(a)$ (c) $2\pi r \mu_0 I b \ln(a)$ (d) 0 (e) $\mu_0 b \ln 2/2\pi$

Questions 17-20

The circuit consists of a battery of emf ε and inner resistance r a switch S and a resistor R and and inductor L in parallel. At $t = 0$ S is closed.



17. What is the current in the resistor R at $t = 0$ immediately after the switch is closed?
(a) ε/r (b) ε/R (c) $\varepsilon/(R - r)$ (d) $\varepsilon/(R + r)$ (e) 0

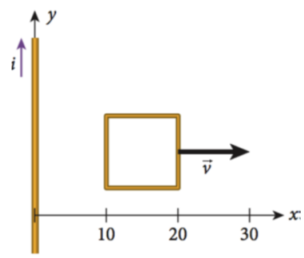
18. What is the current in the inductor L at $t = 0$ immediately after the switch is closed?
(a) $\varepsilon/(R + r)$ (b) ε/R (c) $\varepsilon/(R - r)$ (d) 0 (e) ε/r

19. What is the current in the resistor R as $t \to \infty$ long after the switch is closed?
(a) ε/r (b) $\varepsilon/(R - r)$ (c) $\varepsilon/(R + r)$ (d) ε/R (e) 0

20. What is the current in the inductor L as $t \to \infty$ long after the switch is closed?
(a) $\varepsilon/(R + r)$ (b) 0 (c) $\varepsilon/(R - r)$ (d) ε/r (e) ε/R

Questions 21-25

The long, straight wire in the figure has a current I flowing in it. A square loop with a width of L and a resistance of R is positioned at L away from the wire. The loop is then moved in the positive $x-$direction with speed v.



21. Find the direction of the induced current in the loop?
(a) in to the page (b) clockwise (c) out of the page (d) counter-clockwise (e) none of them

22. Identify the directions of the magnetic forces acting on all sides of the square loop. (You can enter x, -x, y, -y, z, -z, for each of the 4 sides. The first answer is for the top part of the loop, the next for the right side, then the bottom, and finally the left side. Separate the answers for each side by commas.)
(a) y, x, -y, -x (b) x, -y, z, -z (c) z, x, -z, -x (d) x, -z, x, -z (e) y, z, -y, -z

23. Assuming that the magnetic fields value is B_0 at the left side and the induced current is I_{ind}, express the magnitude of the net force acting on the loop at the instant it starts to move.
(a) $I_{ind} B_0 L$ (b) $2 I_{ind} B_0 L$ (c) $3 I_{ind} B_0 L/2$ (d) $I_{ind} B_0 L/2$ (e) $3 I_{ind} B_0 L$

For the next two problems let us assume that the width of the loop is very small and is positioned at x meters away from the wire, and the area of the loop wire is A.

24. Express the flux inside the loop due to the straight wire in terms of μ_0, I, A, v and x.
(a) $\mu_0 I A v/\pi x$ (b) $\mu_0 I A v/2\pi x^2$ (c) $\mu_0 I A/2\pi x$ (d) $\mu_0 I A/2\pi x^2$ (e) $\mu_0 I A x/2\pi v$

25. Express the emf induced by the straight wire inside the loop in terms of μ_0, I, A, v and x.
(a) $\mu_0 I A v/\pi x$ (b) $\mu_0 I A/2\pi x^2$ (c) $\mu_0 I A v/2\pi x^2$ (d) $\mu_0 I A/2\pi x$ (e) $\mu_0 I A x/2\pi v$

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

1. Two large, flat, horizontally oriented isolated plates carrying $+Q$ and $-Q$ charges, are parallel to each other, a distance d apart where d is small compared to the area of the plates. Half way between the two plates the electric field has magnitude E. If the separation of the plates is reduced to $d/2$ what is the magnitude of the electric field half way between the plates now?

(a) $4E$ (b) $E/2$ (c) $2E$ (d) E (e) 0

2. If 12.8×10^{-6}J of work is necessery to move 0.8 nC of charge from a positive plate to a negative plate, what is the potential difference (voltage) between the plates?

(a) 16 V (b) 0.16 V (c) 6.25 V (d) 16 kV (e) 6.25 kV

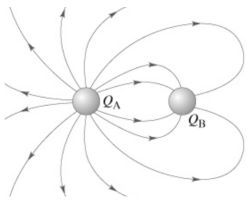
3. In electrostatics (assuming $V(x \to \infty) = 0$) which of the following statements is not correct?

(a) Potential inside a spherical shell carrying a net charge on it is zero. (b) Potential difference between any points in a conductor is zero. (c) Potential of a charge becomes zero only at infinite distance to the charge. (d) Potential is a scaler quantity. (e) Potential due to discrete charges can be calculated from the superposition of the potentials of the individual charges.

4. A positive charge q with mass m moves in the direction of electric field from point A to point B. What you can not say about it?

(a) Its kinetic energy increases. (b) Its potential energy increases. (c) The work necessary to move this charge is negative. (d) The work done on the charge is independent of the path. (e) The charge accelerates in the direction of the electric field.

5. In the figure, the electric field lines are shown for a system of two point charges Q_A, and Q_B. Which of the following could represent the magnitudes and signs of Q_A, and Q_B? (take q to be a positive quantity)



(a) $Q_A = -3q$, $Q_B = +7q$ (b) $Q_A = +7q$, $Q_B = -3q$ (c) $Q_A = +3q$, $Q_B = -7q$ (d) $Q_A = +q$, $Q_B = -q$ (e) $Q_A = -7q$, $Q_B = +3q$

6. Which of the following identifies the electromotive force (emf)?

I) Emf is the voltage developed by any source of electrical energy such as battery or dynamo.
II) Emf sources convert chemical, mechanical, and other forms of energy into electrical energy.
III) EMF is defined as the difference in electric potential between two points of a conducting wire when an electric current of one ampere dissipates one watt of power between those points.
IV) Emf is the electric potential energy per unit charge.

(a) I (b) All is true (c) III and IV (d) I, II (e) I, II and III

7. Which of the following experiments should be performed if you want to measure the exact or very approximate value of the electromotive force of a battery?

I) Measure the potential difference between the leads of the battery when the current of the circuit is zero.
II) Measure the potential difference between the leads of the battery when the net resistance which is series to the battery is large enough.
III) Measure the potential difference between the leads of the battery when the net resistance which is series to the battery is small enough.

(a) I and II (b) II and III (c) I (d) II (e) III

8. When the dielectric constant κ of the medium between the plates of a capacitor is increased, while the charges on the plates kept constant, which of the following is/are true?

I) Potential difference between the plates increases. II) Electric field between the plates decreases. III) Potential energy of the capacitor decreases.

(a) All is true (b) I and III (c) Only I (d) I and II (e) II and III

9. For which surfaces is Gauss's law valid?

(a) Only spherical closed surfaces. (b) All surfaces open or closed. (c) Only cylinderical open surfaces. (d) All open surfaces. (e) All closed surfaces.

Questions 10-13

A piece of metal has a cavity inside. A negative charge $-Q$ is placed inside the cavity. The metal is grounded.

10. What is the excess charge q induced on the inner surface of the cavity, if any?

(a) q =0 due being metal (b) q=+Q due to Gauss's law (c) $q = -Q$ due to being metal (d) $q = -Q$ due to charge conservation (e) $q = -Q$ due to the Gauss's law

11. Is there any charge on the surface of the metal ?

(a) $q = +Q$ due to charge conservation (b) $q = -Q$ due to charge conservation (c) $q = 0$ due to being grounded (d) $q = -Q$ due to the Gauss's law (e) $q = 0$ due to being metal

12. Is there an electric field inside the cavity?

(a) $E = 0$ due to no Electric flux (b) $E \neq 0$ due to net Electric flux (c) $E = 0$ because of the metal being grounded (d) $E = 0$ due to induced charge on the inner surface of the metal (e) $E = 0$ due to charge in the cavity and the charge on the inner surface of the metal

13. Would someone measure an electric field outside the metal?

(a) They can not because the $-Q$ charge is in the cavity not on the surface of the solid (b) They can because induced $-Q$ charge on the outer surface of the solid due to charge conservation (c) They can because induced $-Q$ charge on the outer surface of the solid (d) They can not because metals can shield charge in the cavity whether it is grounded or not (e) Can not due to being grounding

Questions 14-16

In a rectangular coordinate system a positive point charge $q = 6 \times 10^{-9}$C is placed at the point $x = +0.1$ m, $y = 0$ m, and an identical point charge is placed at $x = -0.1$ m, $y = 0$.

14. What is the magnitude of the electric field at the origin?

(a) 5400 V/m (b) 2800 V/m (c) 0 V/m (d) 1350 V/m (e) 10800 V/m

15. What is the magnitude of the electric potential at the origin?

(a) 270 V (b) 1080 V (c) 0 V (d) 10800 V (e) 540 V

16. What is the magnitude of the electric force that applies to a charge $q = 1$ nC located at $x = 0$ m, $y = 0.1$m?

(a) $5400\sqrt{2}$ nN (b) $3600/\sqrt{2}$ nN (c) $2700\sqrt{2}$ nN (d) $1350\sqrt{2}$ nN (e) $1350/\sqrt{2}$ nN

17. A non-uniform charged rod with a charge density $\lambda = x^2 a$ that lies on the positive x-axis between $x = d$ and $x = d + l$. If the total charge is Q, what is the constant a?

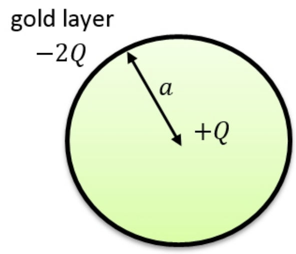
(a) $\frac{Q}{d^2l+dl^2-d^3/3}$ (b) $\frac{Q}{d^2l+dl^2+d^3/3}$ (c) $\frac{3Q}{l^3}$ (d) $\frac{3Q}{d^3}$ (e) $\frac{Q}{d^2l+dl^2+l^3/3}$

18. What is the magnitude and direction of the electric field at the origin due to a non-uniform charged rod with a charge density $\lambda = x^2 a$ that lies on the positive x-axis between $x = d$ and $x = d + l$?

(a) $-\frac{1}{4\pi\epsilon_0} al\ \hat{i}$ (b) $-\frac{1}{4\pi\epsilon_0}\frac{a}{\sqrt{l+d}}\ \hat{i}$ (c) $-\frac{1}{4\pi\epsilon_0}\frac{a}{dl^2+d^2l+l^3/3}\ \hat{i}$ (d) $\frac{1}{4\pi\epsilon_0}\frac{a}{dl^2+d^2l+l^3/3}\ \hat{i}$ (e) $\frac{1}{4\pi\epsilon_0}\frac{a}{\sqrt{1+d}}\ \hat{i}$

Questions 19-22

A solid non-conducting sphere of radius a has a total charge Q uniformly distributed throughout its volume. The surface of the sphere is coated with a thin conducting layer of gold. A total charge of $-2Q$ is placed on this conducting layer. Take $Q = 10$ nC and $a = 1.0$ m. r is the distance measured from the center. (Take π=3)



19. What is the electric field E inside the sphere and at $r = 1/3$ m?

(a) 3 V/m (b) 0 V/m (c) 10 V/m (d) 30 V/m (e) 300 V/m

20. What is the electric field E at $r = 1$ m <u>inside</u> the gold layer?

(a) 30 V/m (b) 0 V/m (c) 10 V/m (d) 9 V/m (e) 300 V/m

21. What is the electric field E outside and at $r = 3$ m?

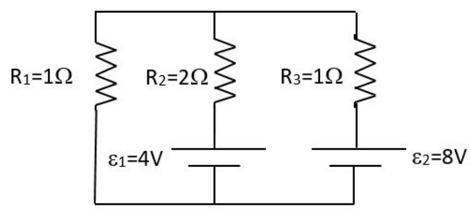
(a) -20 V/m (b) 1 V/m (c) 20 V/m (d) -10 V/m (e) 10 V/m

22. What is the charge density at the inner surface of the gold layer?

(a) $-5/3$ nC/m^2 (b) $5/3$ nC/m^2 (c) 0 nC/m^2 (d) $-5/6$ nC/m^2 (e) $5/6$ nC/m^2

Questions 23-25

In the circuit shown in the Figure:



23. What is the magnitude of the electric current that flows through the R_1?

(a) 4 A (b) 12 A (c) 6 A (d) 3 A (e) 1 A

24. What is the potential difference between the terminals of R_2?

(a) 2 V (b) 0 V (c) 3 V (d) 8 V (e) 7 V

25. What is the dissipated energy on R_3 during 10 seconds?

(a) 120 J (b) 107 J (c) 214 J (d) 160 J (e) 80 J

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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.

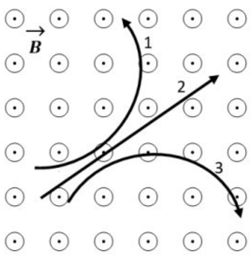
1. The unit of magnetic field Tesla and unit of magnetic flux Weber are related as

(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.

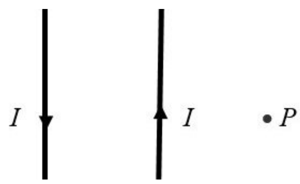


(a) 1 is positive, 2 is negative, and 3 is neutral. (b) 1 is negative, 2 is neutral, and 3 is positive. (c) 1 is positive, 2 is neutral, and 3 is negative. (d) 1 is neutral, 2 is negative, and 3 is positive. (e) 1 is neutral, 2 is positive, and 3 is negative.

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.

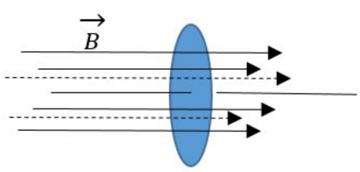
8. If there are electric and magnetic fields, the energy density u is given by;

(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) $\frac{1}{\mu_0\epsilon_0}\frac{d\Phi_E}{dt}$

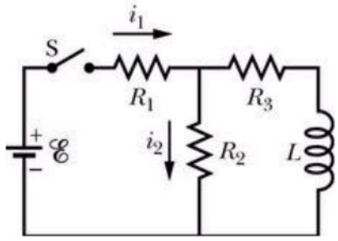
10. When an increasing magnetic field is applied through the surface of a coin as in the figure, which of the following will be true?



(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.

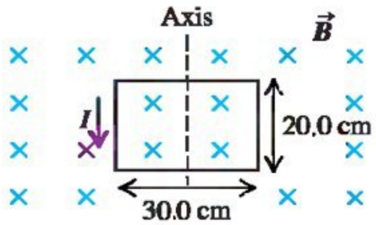
(a) 0 A , 0 A (b) 0 A , 3 A (c) 9 A , 6 A (d) 7.5 A , 0 A (e) 0 A , 6 A

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

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

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

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Student ID		Signature		

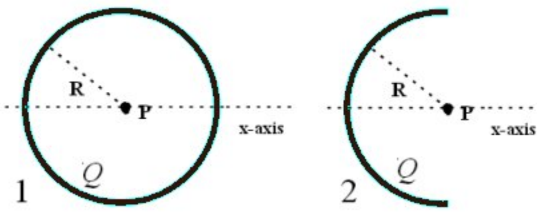
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. What is the unit of the electromotive force?

(a) J/Q (b) V m (c) N (d) V s (e) J/s

2. A charge Q is uniformly distributed on insulating circular and semicircular objects in both cases shown in figure. What is the ratio of the potentials at point P, $V_1(P)/V_2(P)$?

(a) $\sqrt{2}$ (b) 1 (c) 2 (d) $\pi/2$ (e) $2/\pi$



3. For the same setup in problem (3) what is the ratio of the Electric Field at point P, $E_1(P)/E_2(P)$?

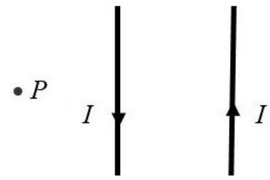
(a) 0 (b) $\pi/2$ (c) 1 (d) ∞ (e) $\pi/\sqrt{2}$

4. Ions having equal charges but masses of M and $2M$ are accelerated through the the potential difference V and $2V$ respectively 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) R (b) $2R$ (c) $R/\sqrt{2}$ (d) $\sqrt{2}R$ (e) $R/2$

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 left of the two wire, the magnetic field

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



6. When varying current i flows through an inductor what is the form of the induced electromotive force between the the terminals of the inductor

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

7. A circuit is setup by connecting the terminals of a charged capacitor C to the terminals of an ideal inductor L with zero electrical resistance. How can the behavior of the circuit be explained?

I) The circuit will undergo electrical oscillations with angular frequency $\omega = \sqrt{LC}$.
II) Total energy stored in the capacitor will be transferred to the inductor and remains there.
III) After a sufficient time, the total energy is dissipated.
IV) The total energy $\frac{1}{2}Q^2/C$ at any time after, is the sum of the energy stored in the capacitor and in the inductor.

(a) III, IV (b) I, II, IV (c) IV (d) I, III, IV (e) I, IV

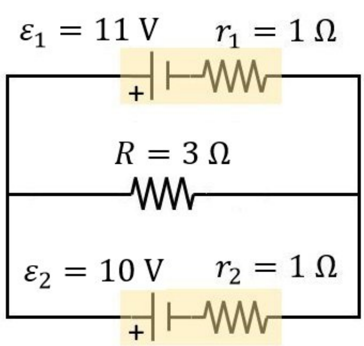
8. Which of the statements below are true for the poynting vector $\vec{S}$ defined for an electromagnetic wave?

I) $\vec{S}$ points in the direction of wave propagation
II) $|\vec{S}|$ is proportional to $|\vec{E}||\vec{B}|$
III) $\vec{S}$ is proportional to $\vec{E}\times\vec{B}$
IV) The intensity I of the wave is proportional to S_{ave} , the magnitude of the average value of $\vec{S}$

(a) III, IV (b) I, II, III, IV (c) I, III, IV (d) I, II, IV (e) I, II

Questions 9-13

For the circuit shown in figure answer the following questions:



9. What is the current through the 3 Ω resistor?

(a) 1 A (b) 2/5 A (c) 3 A (d) 21/5 (e) 2 A

10. What is the total rate of dissipation of electrical energy in the 3 Ω resistor?

(a) 9 W (b) 27 W (c) 18 W (d) 12 W (e) 25 W

11. What is the potential difference across resistor r_1 ?

(a) 10 V (b) 3 V (c) 2 V (d) 1 V (e) 8 V

12. What is the power delivered from the battery labeled as 1 to the 3 Ω resistor?

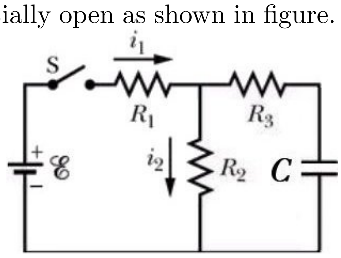
(a) 9 W (b) 12 W (c) 18 W (d) 27 W (e) 25 W

13. What the total rate of dissipation of electrical energy in the 3 Ω resistor and in the internal resistance of the batteries.

(a) 31 W (b) 11 W (c) 5 W (d) 32 W (e) 22 W

Questions 14-18

In the figure, $\mathcal{E} = 30$ V, $R_1 = 2k\Omega$, $R_2 = 2k\Omega$, $R_3 = 4k\Omega$, and $C = 4 \times 10^{-6}$ F. The switch is initially open as shown in figure. Find the values of i_1 and i_2 respectively,



14. immediately after the closing of switch S

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

15. a long time later after the closing.

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

16. immediately after the reopening of switch S

(a) 0 A , 2.5 A (b) 9 A , 6 A (c) 7.5 A , 0 A (d) 0 A , 5 A (e) 0 A , 7.5 A

17. What is the current i_2 when the charge of the capacitor is halved to its full charge?

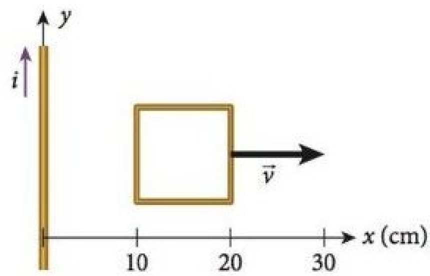
(a) i_2 reduces to its $1/e$ (b) i_2 is a steady current and does not change until there are no charges left on the capacitor. (c) i_2 reduces to its half. (d) i_2 reduces to its quarter. (e) i_2 reduces to its RC where $R = R_2 + R3$

18. What is the energy stored in the electric field between the plates of the capacitor before the switch is reopened?

(a) 1.8 $\times 10^{-4}$ J (b) 6 $\times 10^{-5}$ J (c) 1.8 $\times 10^{-3}$ J (d) 4.5 $\times 10^{-4}$ J (e) 3 $\times 10^{-5}$ J

Questions 19-22

The long, straight wire in the figure has a current i flowing in it. The center of square loop with sides l and resistance R is positioned a distance b away from the wire as shown. The loop is then moved in the positive x-direction with speed v



19. What is the magnitude and direction of the magnetic field at the center of the rectangular loop. due to the current carrying long wire?

(a) $-\mu_0 i/(2\pi l^2)\hat{k}$ (b) $\mu_0 i^2/(2\pi b)\hat{k}$ (c) $\mu_0 i/(2\pi b)\hat{k}$ (d) $-\mu_0 i/(2\pi b)\hat{k}$ (e) $\mu_0 i/(2\pi l^2)\hat{k}$

20. What is the direction of the induced current in the loop and how does it change as the loop moves to the right?

(a) It flows in the Clockwise direction and increases as the loop moves to the right.
(b) It flows in the Counter Clockwise direction and decreases as the loop moves to the right.
(c) It flows in the Clockwise direction and decreases as the loop moves to the right.
(d) It flows in the Counter Clockwise direction and increases as the loop moves to the right.
(e) Its direction cannot be specified and it does not change as the loop moves

21. Identify the directions of the magnetic forces acting on all sides of the square loop. Forces are labeled as F_1; force acting on the left side, F_2; force acting on the right side, F_3; force acting on the top side, F_4; force acting on the bottom side respectively. $(\leftarrow -\hat{i}, \uparrow \hat{j}, \downarrow -\hat{j}, \rightarrow \hat{i})$

(a) F_1, F_3, F_4, F_2 , all pointing in the positive z-direction
(b) $F_1(\rightarrow), F_3(\downarrow), F_4(\uparrow), F_2(\leftarrow)$
(c) $F_1(\leftarrow), F_3(\uparrow), F_4(\downarrow), F_2(\rightarrow)$
(d) $F_1(\leftarrow), F_2(\rightarrow), F_3(\uparrow), F_4(\downarrow)$
(e) $F_1(\rightarrow), F_2(\leftarrow), F_3(\downarrow), F_4(\uparrow)$

22. Identify the magnitudes of the magnetic forces acting on all sides of the square loop. Forces are labeled as F_1; force acting on the left side, F_2; force acting on the right side, F_3; force acting on the top side, F_4; force acting on the bottom side respectively.

(a) $F_1 > F_3 > F_4 > F_2$ (b) $F_1 < F_3 = F_4 < F_2$ (c) $F_1 < F_2 < F_3 < F_4$ (d) $F_1 > F_3 = F_4 > F_2$ (e) $F_1 = F_2 = F_3 = F_4$

Questions 23-25

A plane sinusoidal electromagnetic wave in air has a wavelength of 6 cm and an electric field amplitude of 6 V/m. Take $\mu_0 = 1.2 \times 10^{-6}$ Tm/A.

23. What is the frequency?

(a) 5×10^9 Hz (b) 6×10^9 Hz (c) 4×10^9 Hz (d) 2×10^9 Hz (e) 3×10^9 Hz

24. What is the amplitude of the magnetic field?

(a) 1×10^{-8} T (b) 5×10^{-8} T (c) 4×10^{-8} T (d) 3×10^{-8} T (e) 2×10^{-8} T

25. What is the intensity?

(a) 0.0125 W/m^2 (b) 0.025 W/m^2 (c) 0.125 W/m^2 (d) 0.1 W/m^2 (e) 0.05 W/m^2

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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. What is the unit of the electrical resistivity?

(a) Ω^{-1} (b) Ω m^2 (c) Ω (d) Ω m (e) Ω/m^2

2. Poynting vector $\vec{S}$ is equal to the

(a) Is not related to electromagnetic energy or momentum.
(b) Electromagnetic energy per unit area per unit time
(c) Electromagnetic momentum per unit volume
(d) Electromagnetic energy per unit volume
(e) Electromagnetic energy per unit time

3. The relation between the $\vec{E}$ field and the electrical flux Φ_E is :
(Here $\int d\vec{l}$ denotes integration along a path and $\int d\vec{A}$ denotes integration over a surface)

(a) $\int \vec{E} \cdot d\vec{A}$ (b) $\frac{1}{4\pi\epsilon_0} \int \vec{E} \times d\vec{A}$ (c) $\frac{1}{4\pi\varepsilon_0} \int \vec{E} \cdot d\vec{A}$ (d) $-\int_a^b \vec{E} \cdot d\vec{l}$ (e) $\int_a^b \vec{E} \cdot d\vec{l}$

4. The equation $\vec{E} = \rho\,\vec{J}$ relating electric field resistivity and current density is valid ...

(a) Wherever a current flows. (b) Only in insulators since $\vec{E} = 0$ in conductors. (c) Only in case of cylindrical symmetry. (d) Only in electrostatics. (e) Only in case of spherical symmetry.

5. The torque $\vec{\tau}$, a uniform magnetic field $\vec{B}$ exerts on a closed planar loop C carrying a current I is:
(Here A is the surface area of the loop and $\hat{n}$ is its normal vector. l is the total length of the loop.)

(a) $\vec{\tau} = I\,A\,(\hat{n} \times \vec{B})$ (b) $\vec{\tau} = I\,A\,(\vec{B} \cdot \hat{n})$ (c) $\vec{\tau} = I\,l\,(\vec{B} \cdot \hat{n})$ (d) $\vec{\tau} = I\,l\,(\vec{B} \times \hat{n})$ (e) Uniform magnetic field cannot exert a torque on a closed loop.

6. The net force, magnetic field $\vec{B}$ exerts on a loop C carrying a current I is:

(a) always zero if $\vec{B}$ is uniform (b) always zero if $\vec{B}$ is normal to the plane of loop C. (c) never zero. (d) always zero if $\vec{B}$ is in the plane of loop C. (e) always zero.

7. A 4.0 mH coil carries a current of 5.0 A. How much energy is stored in the coil's magnetic field?

(a) 10 mJ (b) 50 mJ (c) 4 mJ (d) 20 mJ (e) 40 mJ

8. What is the resonant frequency of a 1 μF capacitor and a 10 mH coil in series?

(a) 1 mHz (b) 10 MHz (c) $\frac{1}{2\pi}$ 10 kHz (d) $\frac{1}{2\pi}$ 100 MHz (e) 1 kHz

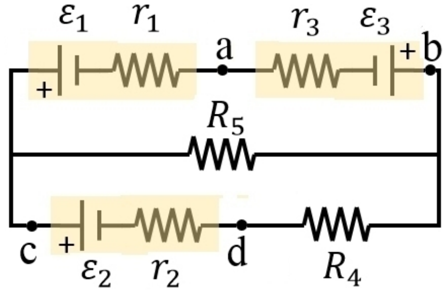
9. A charged particle is moving in a constant magnetic field. Assume that the magnetic field is neither parallel nor anti parallel to the velocity. Which of the followings is/are false for the magnetic field?

I) It does no work on the particle.
II) It may increase the speed of the particle.
III) It may change the velocity of the particle.
IV) It can act only on the particle while the particle is in motion.
V) It does not change the kinetic energy of the particle.

(a) II, V (b) I (c) II, III (d) II (e) II, III, IV

Questions 10-14

The values of the component for the given figure is as follows:
$\varepsilon_1 = 4$V , $r_1 = 1\Omega$, $\varepsilon_2 = 4$V , $r_2 = 1\Omega$, $\varepsilon_3 = 2$V , $r_3 = 1\Omega$, $R_4 = 4\Omega$ and $R_5 = 2\Omega$.
Answer the following questions:



10. What is the magnitude of current through the resistor R_4?

(a) 0.3 A (b) 0.5 A (c) 1.2 A (d) 2.1 A (e) 1.5 A

11. What is the absolute value of potential drop between the terminals of the resistor R_5?

(a) 3.75 V (b) 0.5 V (c) 2.25 V (d) 2 V (e) 1.5 V

12. What is the absolute value of potential difference between point a and point b?

(a) 1.75 V (b) 2.25 V (c) 0.25 V (d) 0.5 V (e) 1.5 V

13. What is the absolute value of potential difference between point c and point d?

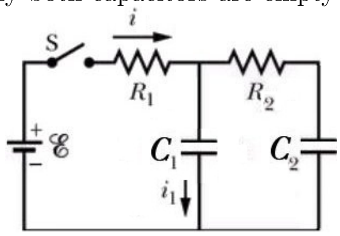
(a) 2.25 V (b) 3.75 V (c) 3.5 V (d) 1.25 V (e) 1.5 V

14. What the total rate of dissipation of electrical energy in the complete circuit?

(a) 2.5 W (b) 4 W (c) 3 W (d) 5 W (e) 3.5 W

Questions 15-19

In the figure, $\mathcal{E} = 10$ V, $R_1 = 5k\Omega$, $R_2 = 5k\Omega$, $C_1 = 6 \times 10^{-6}$ F , and $C_2 = 4 \times 10^{-6}$ F. Initially both capacitors are empty and the switch is open.



15. What is the magnitude of i immediately after the closing of switch S?

(a) 3 mA (b) 1 mA (c) 2 mA (d) 15 mA (e) 4 mA

16. What is the magnitude of i_1 immediately after the closing of switch S?

(a) 3 mA (b) 1 mA (c) 4 mA (d) 2 mA (e) 15 mA

17. What is the ratio of the charges Q_1/Q_2, the charges accumulated on C_1 and C_2, a long time later after the closing, respectively. (ie $t \to \infty$)

(a) 5/3 (b) 1 (c) 10/3 (d) 3/2 (e) 1/2

18. What is the magnitude of i_1 immediately after the reopening of switch S?

(a) 1 mA (b) 2 mA (c) 0 mA (d) 2/5 mA (e) 5/3 mA

19. What is the total energy dissipated on R_2 after the reopening of switch S?

(a) (4/3) $\times 10^{-4}$ J (b) 4 $\times 10^{-4}$ J (c) 6 $\times 10^{-4}$ J (d) 0 J (e) (5/6) $\times 10^{-4}$ J

Questions 20-22

The force on a charged particle moving in a magnetic field can be computed as the vector sum of the forces due to each separate component of the magnetic field. As an example. a particle with charge q is moving with speed v in the $-y$-direction. It is moving in a uniform magnetic field $\vec{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k}$.

20. What are the components of the force $\vec{F}$ exerted on the particle by the magnetic field?

(a) $\vec{F} = q\vec{v}(-B_x\hat{k} + B_z\hat{i})$
(b) $\vec{F} = q\vec{v}(B_x\hat{k} - B_z\hat{i})$
(c) $\vec{F} = q\vec{v}(B_z\hat{k} + B_x\hat{i})$
(d) $\vec{F} = q\vec{v}(B_z\hat{k} - B_x\hat{i})$
(e) $\vec{F} = q\vec{v}(B_y\hat{k} - B_x\hat{i})$

21. If $q > 0$, what must the signs of the components of $\vec{B}$ be if all of the components of $\vec{F}$ are positive?

(a) $B_x = 0$, $B_y < 0$, $B_z > 0$
(b) $B_y > 0$, $B_z > 0$
(c) $B_x > 0$, $B_y = 0$, $B_z < 0$
(d) $B_x > 0$, $B_z < 0$
(e) $B_x > 0$, $B_y < 0$, $B_z < 0$

22. If $q < 0$ and $B_x = B_y = B_z = B_0 > 0$, find the magnitude of $\vec{F}$ in terms of $\mid q \mid$, v and B_0

(a) $(1/\sqrt{2}) \mid q \mid vB_0$ (b) $\mid q \mid vB_0$ (c) $2 \mid q \mid vB_0$ (d) $\sqrt{2} \mid q \mid vB_0$ (e) $(1/2) \mid q \mid vB_0$

Questions 23-25

A sinusoidal electromagnetic wave emitted by an electronic device has a wavelength of 24 cm and a magnetic field amplitude of 1.8 $\times 10^{-10}$ T at a distance of 250 m from the antenna. Take $\mu_0 = 1.2 \times 10^{-6}$ Tm/A and c = 3 $\times 10^8$ m/s.

23. Calculate the frequency of the wave.

(a) 8×10^{-8} Hz (b) 1.25×10^9 Hz (c) 2.5×10^9 Hz (d) 2.5×10^{-9} Hz (e) 8×10^8 Hz

24. Calculate the amplitude of electric field.

(a) $(5/3) \times 10^{18}$ V/m (b) $(3/2) \times 10^{-4}$ V/m (c) 6×10^{-19} V/m (d) $(2/3) \times 10^4$ V/m (e) 5.4×10^{-2} V/m

25. Calculate the intensity of the wave.

(a) 4.86×10^{-12} W/m^2 (b) 8.1×10^{-6} W/m^2 (c) 4.05×10^{-6} W/m^2 (d) 1.5×10^{-4} W/m^2 (e) 2.25×10^4 W/m^2

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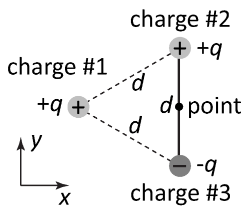
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.
Please take $e = 1.6 \times 10^{-19}$**C,** $k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{N.m^2}{C^2}$

1. When you rub a plastic rod with fur, the plastic rod becomes negatively charged and the fur becomes positively charged. As a consequence of rubbing the rod with the fur:
(a) The rod gains mass and the fur loses mass. (b) The rod loses mass and the fur gains mass. (c) None of the other options is correct. (d) The rod and fur both gain mass. (e) The rod and fur both lose mass.

Questions 2-3

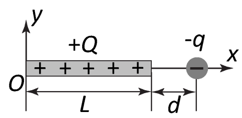
Three point charges located in vacuum lie at the vertices of an equilateral triangle with side length d as shown in the figure.



2. The net electric force exerted on the charge #1 is:
(a) $\frac{1}{4\pi\epsilon_0} q^2/(2d^2)\hat{j}$ (b) 0 (c) $\frac{1}{4\pi\epsilon_0} 2q^2/d^2\hat{j}$ (d) $\frac{1}{4\pi\epsilon_0} (\sqrt{3}q^2)/(2d^2)\hat{j}$ (e) -$\frac{1}{4\pi\epsilon_0} q^2/d^2\hat{j}$

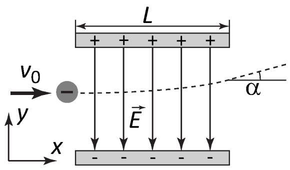
3. The net electric field created by all three charges at (point P) is:
(a) $\frac{1}{4\pi\epsilon_0}(4q/3d^2)\hat{i}$ (b) $\frac{1}{4\pi\epsilon_0}(q/d^2)\left(\frac{1}{3}\hat{i}+2\hat{j}\right)$ (c) $\frac{1}{4\pi\epsilon_0}(q/d^2)\left(\frac{1}{3}\hat{i}-2\hat{j}\right)$ (d) $\frac{1}{4\pi\epsilon_0}(4q/d^2)\left(\frac{1}{3}\hat{i}+2\hat{j}\right)$
(e) $\frac{1}{4\pi\epsilon_0}(4q/d^2)\left(\frac{1}{3}\hat{i}-2\hat{j}\right)$

4. Positive charge $+Q$ is distributed uniformly along the x-axis from $x = 0$ to $x = L$. A negative point charge $-q$ is located on the positive x-axis at a distance d to the right of the end of charge distribution $+Q$ (see picture). What is the electric force acting on the negative charge $-q$?



(a) $-\frac{1}{4\pi\epsilon_0}\frac{Qq}{(L+d)^2}\hat{i}$ (b) $-\frac{1}{4\pi\epsilon_0}\frac{Qq}{(L+d)}\hat{i}$ (c) $-\frac{1}{4\pi\epsilon_0}\frac{Qq}{d(L+d)}\hat{i}$ (d) $-\frac{1}{4\pi\epsilon_0}\frac{Qq}{(\frac{L}{2}+d)^2}\hat{i}$ (e) $-\frac{1}{4\pi\epsilon_0}\frac{Qq}{d^2}\hat{i}$

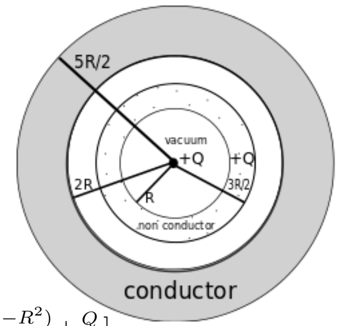
5. An electron with velocity $v_0 = 8000$ m/s directed along the positive x-axis enters the gap between two metal plates with a uniform, vertically oriented electric field $\vec{E}$ between them (see the picture). The length of the plates is $L = 32$ mm. What is the electric field strength between the plates if the electron is deflected vertically by angle $\alpha = 1.6 \times 10^{-3}$ rad? Take electron mass $m_e = 10^{-30}$ kg, electron charge $q_e = 1.6 \times 10^{-19}$ C, $\tan\alpha \approx \alpha$, and ignore the effect of gravity on the electron.



(a) 8×10^{-4} N/C (b) 4×10^{-3} N/C (c) 2×10^{-5} N/C (d) 8×10^{-5} N/C (e) 2×10^{-4} N/C

Questions 6-9

Charges are distributed in spherical geometries as shown in the picture. Q charge is placed at the center of a sphere. Between R and 3R/2 there is a nonconducting material and Q charge is uniformly distributed in it. Between 2R and 5R/2 there is conducting shell with no charge.



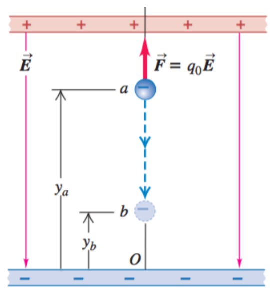
6. What is the E field between 0 and R ?
(a) -$\frac{Q}{4\pi\varepsilon_0 r}$ (b) $\frac{Q}{4\pi\varepsilon_0 r^2}$ (c) 0 (d) $\frac{Qr}{4\pi\varepsilon_0}$ (e) $\frac{Q}{4\pi\varepsilon_0 r^3}$

7. What is the electric field between R and 3R/2 ?
(a) 0 (b) $\frac{1}{4\pi r^3}[\frac{4Q(r^3-R^3)}{5R^3\varepsilon_0} - \frac{Q}{\varepsilon_0}]$ (c) $\frac{1}{4\pi r^2}[\frac{4Q(r^3-R^3)}{5R^2\varepsilon_0}]$ (d) $\frac{1}{4\pi r^2}[\frac{8Q(r^3-R^3)}{19R^3\varepsilon_0} + \frac{Q}{\varepsilon_0}]$ (e) $\frac{1}{2\pi r^2}[\frac{4Q(r^2-R^2)}{5R^3\varepsilon_0} + \frac{Q}{\varepsilon_0}]$

8. What is the electric field between 2R and 5R/2 ?
(a) 0 (b) $\frac{Q}{4\pi\varepsilon_0 r^2}$ (c) $\frac{-Q}{2\pi\varepsilon_0 r^2}$ (d) $\frac{2Q}{4\pi\varepsilon_0 r^3}$ (e) $\frac{3Q}{2\pi\varepsilon_0 r^2}$

9. What is the electric field at r>5R/2 ?
(a) $\frac{2Q}{4\pi\varepsilon_0 r^2}$ (b) $\frac{Q}{4\pi\varepsilon_0 r^3}$ (c) 0 (d) $\frac{2Q}{4\pi\varepsilon_0 r^3}$ (e) $\frac{Q}{4\pi\varepsilon_0 r^2}$

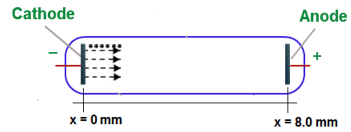
10. According to the figure, which is the following true for a negative test charge moving in the direction of the electric field E?



(a) Field does negative work on charge, potential energy is not changed (b) Field does positive work on charge, potential energy increases (c) Field does positive work on charge, potential energy decreases (d) Field does negative work on charge, potential energy increases (e) Field does negative work on charge, potential energy decreases

Questions 11-14

A vacuum tube diode consists of concentric cylindrical electrodes, the negative cathode and the positive anode. Because of the accumulation of charge near the cathode the electric potential between the electrodes can be given by V(x)=C $x^{4/3}$, where x is the distance from the cathode and C is a constant, characteristic of a particular diode and operating conditions. Assume that the distance between the cathode and anode is 8.0 mm and the potential difference between electrodes is 240 V:



11. Determine the value of C.

(a) 3.0×10^4 V/m$^{4/3}$ (b) 30.0×10^4 V/m$^{4/3}$ (c) 8.0×10^4 V/m$^{4/3}$ (d) 1.5×10^4 V/m$^{4/3}$ (e) 15.0×10^4 V/m$^{4/3}$

12. Obtain the electric field between the electrodes as a function of x.

(a) $(-8.0\times10^5)x^{1/3}$ (b) $(-2.0\times10^5)x^{1/3}$ (c) $(1.0\times10^5)x^{1/3}$ (d) $(8.0\times10^5)x^{1/3}$ (e) $(2.0\times10^5)x^{1/3}$

13. E points:

(a) out of the page (b) from the negative cathode to the positive anode (c) from the positive anode to the negative cathode (d) parallel to the plates from left to right (e) into the page

14. Determine the force on an electron on the anode plate(x = 8 mm).(e = 1.6×10^{-19} C)

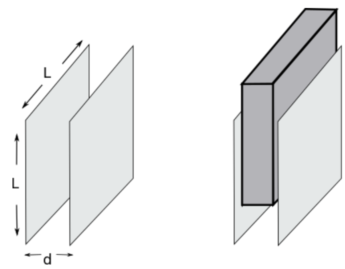
(a) 6.4×10^{-15} N (b) 1.6×10^{-15} N (c) -6.4×10^{-15} N (d) 3.2×10^{-15} N (e) -3.2×10^{-15} N

Questions 15-20

A parallel plate capacitor has square plates of side L=10 cm separated by a distance d=3 mm as shown in the figure. the capacitor is changed by a battery with potential difference $V_0 = 100$ V; the battery is then connected.

15. Determine the capacitance of C_0.

(a) 100 pF (b) 0.3 pF (c) 10 pF (d) 30 pF (e) 300 pF



16. Determine the charge of the capacitor.

(a) 1 nC (b) 3nC (c) 100 nC (d) 30 nC (e) 300 nC

17. Determine the electric potential energy stored in the capacitor at this point.

(a) 100 nJ (b) 150 nJ (c) 15 nJ (d) 5 nJ (e) 50 nJ

18. Now a slab of plexiglass ($\kappa = 3$) is then inserted so that it fills 2/3 of its volume between the plates as shown in the figure. What is the new capacitance?

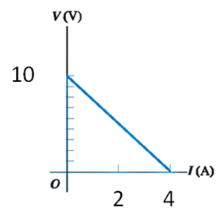
(a) 25 pF (b) 10 pF (c) 5 pF (d) 50 pF (e) 100 pF

19. What is the new potential difference between the plates in case c?

(a) 600 V (b) 6 V (c) 60 V (d) 30 V (e) 10 V

20. What is the charge in the new capacitor?

(a) 10 nC (b) 30 nC (c) 3 nC (d) 6 nC (e) 60 nC



21. An idealized voltmeter is connected across the terminals of a battery while the current is varied. Figure shows a graph of the voltmeter reading V as a function of the current I through the battery. Find the emf ϵ and the internal resistance of the battery.

(a) 12 V, 3 Ω (b) 8 V, 2 Ω (c) 10 V, 0.25 Ω (d) 10 V, 0.5 Ω (e) 10 V, 2.5 Ω

Questions 22-24

An electrical conductor designed to carry large currents has a circular cross section 4 mm in diameter and is 12.0 m long. The resistance between its ends is 0.100 Ω. (e = 1.6×10^{-19} C, π=3)

22. What is the resistivity of the material?

(a) $3\cdot10^{-7}$ Ωm (b) $2.5\cdot10^{-8}$ Ωm (c) $5\cdot10^{-8}$ Ωm (d) $2\cdot10^{-7}$ Ωm (e) 10^{-7} Ωm

23. If the electric-field magnitude in the conductor is 1.6 V/m. What is the total current?

(a) 75 A (b) 388 A (c) 192 A (d) 19.2 A (e) 38.8 A

24. If the material has 10^{29} free electrons per cubic meter, find the average drift of the charge carriers.

(a) $3\cdot10^{-3}$ m/s (b) $2\cdot10^{-3}$ m/s (c) 10^{-3} m/s (d) $4\cdot10^{-3}$ m/s (e) $1.6\cdot10^{-3}$ m/s

25. A toaster using a Nichrome heating element operates at 220 V. When it is switched on at 20°C the heating element carries an initial current of 2.20 A. A few seconds later current reaches the steady value of 2.00 A. What is the final temperature of the element? The average value of the temperature coefficient of resistivity for Nichrome over the temperature range is $4\cdot10^{-4}$ (C°)$^{-1}$.

(a) 270°C (b) 250°C (c) 400°C (d) 500°C (e) 200°C

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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.

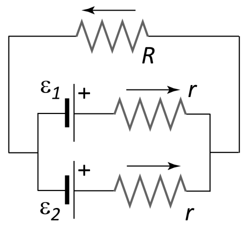
Please take $e = 1.6 \times 10^{-19}$**C,** $k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{N.m^2}{C^2}$

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)?

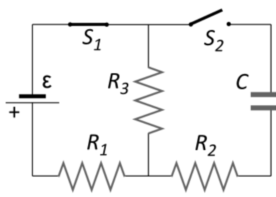
(a) 1.00 A (b) 2.10 A (c) 1.25 A (d) -1.00 A (e) -2.10 A

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

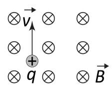
6. After switch S_2 has been closed for a long time, switch S_1 is opened and the capacitor starts discharging. How long will it take until the current in the resistor R_2 drops to 3 mA? In the calculation, take $\log 0.05 = -3$.

(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?

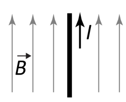
(a) 27 mJ (b) 9 mJ (c) 22.5 mJ (d) 18 mJ (e) 13.5 mJ

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?



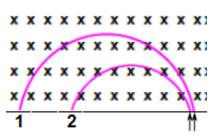
(a) into the page (b) downward (c) to the right (d) to the left (e) out of the page

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?

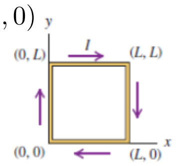


(a) Impossible to tell from the picture. (b) They have no mass. (c) Particle 2. (d) Particle 1. (e) Both charges are equal.

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) $\mu_0 n I_0 \omega \cos \omega t$

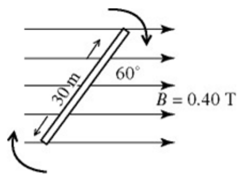
16. Find emf induced in one loop.

(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.

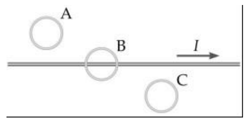
(a) $-a\mu_0 n I_0 \omega \cos \omega t/2$ (b) $-a^2 n I_0 \omega \cos \omega t/2$ (c) 0 (d) insufficient information (e) $-\pi a^2 \mu_0 n I_0 \omega \cos \omega t L$

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 $\pi = 3$.



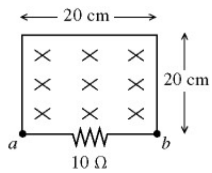
(a) 2.52 V (b) 6.3 V (c) 25.2 V (d) 1.26 V (e) 12.6 V

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.

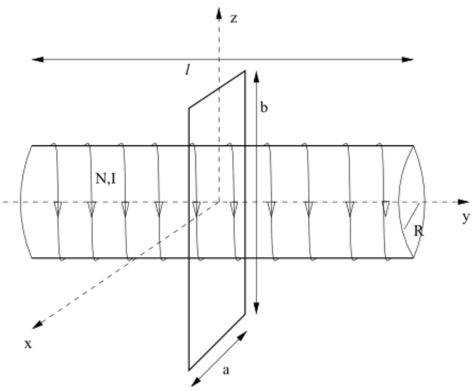
20. As shown in the figure, a wire and a 10 Ω resistor are used to form a circuit in the shape of a square, 20 cm by 20 cm. A uniform but non steady magnetic field is directed into the plane of the circuit. The magnitude of the magnetic field is decreased from 1.50 T to 0.50 T in a time interval of 100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

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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 $e = 1.6 \times 10^{-19}$**C,** $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \frac{N.m^2}{C^2}$

1. Positive charge Q is distributed uniformly throughout an insulating sphere of radius R, centered at the origin. A particle with a positive charge Q is placed at $x = 2$R on the x axis. The magnitude of the electric field at $x =$ R/2 on the x axis is:

(a) $Q/(8\pi\varepsilon_0 R^2)$ (b) none of these (c) $Q/(4\pi\varepsilon_0 R^2)$ (d) $11Q/(18\pi\varepsilon_0 R^2)$ (e) $Q/(72\pi\varepsilon_0 R^2)$

2. Positive charge Q is placed on a conducting spherical shell with inner radius R_1 and outer radius R_2. A point charge q is placed at the center of the cavity. The magnitude of the electric field at a point outside the shell, a distance r from the center, is:

(a) $Q/4\pi\varepsilon_0(R_1^2 - r^2)$ (b) $q/4\pi\varepsilon_0 r^2$ (c) $Q/4\pi\varepsilon_0 R_1^2$ (d) $(q+Q)/4\pi\varepsilon_0(R_1^2 - r^2)$ (e) $(q+Q)/4\pi\varepsilon_0 r^2$

3. If the electric field is in positive x direction and has a magnitude given by $E = Cx^2$ where C is a constant, then electric potential V is given by

(a) Cx^3 (b) $2Cx$ (c) $-Cx^3/3$ (d) $-2Cx$ (e) $-3Cx^3$

4. A total charge of $Q_1 = 1.2 \times 10^{-6}$ C is placed on a conducting sphere (spere 1) of radius R_1=30 cm. A second conducting sphere (sphere 2) of radius R_2=60 cm with an initial net charge of zero (Q_2=0) is connected to sphere 1 using a long thin metal wire. How much charge flows from sphere 1 to sphere 2 to bring the two spheres into equilibrium.

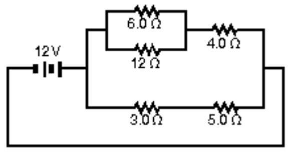
(a) 1.2×10^{-6} C (b) 0.8×10^{-6} C (c) 0.4×10^{-6} C (d) 0.6×10^{-6} C (e) 1.0×10^{-6} C

5. Two conducting spheres have radii of R_1 and R_2 with R_1 greater than R_2. The sphere with R_1 radius has positive charge and the one with R_2 radius has negative charge. If they are far apart, the capacitance is proportional to:

(a) none of these (b) $R_1R_2/(R_1\text{-}R_2)$ (c) $(R_1+R_2)/R_1R_2$ (d) $R_1R_2/(R_1+R_2)$ (e) $(R_1\text{-}R_2)/R_1R_2$

6. Two parallel plate capacitors are identical in terms of their dimensions except one is filled with air and the other one is filled with oil. Both capacitors carry the same charge. The ratio of the electric fields E_{air}/E_{oil} is:

(a) 1 (b) greater than 1 (c) between 0 and 1 (d) infinite (e) 0

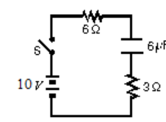


7. The current in the 5.0-Ω resistor in the circuit shown is:

(a) 1.5 A (b) 0.42 A (c) 0.67 A (d) 3.0 A (e) 2.4 A

8. What is the current in 3 Ω resistor at the moment of the switch is closed (t=0)?

(a) 0 A (b) 10/6 A (c) 1.5 A (d) 10/3 A (e) 10/9 A

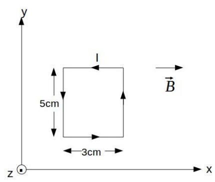


9. An electron enters a region of uniform perpendicular **E** and **B** fields. It is observed that the velocity **v** of the electron is unaffected. A possible explanation is:

(a) **v** is perpendicular to both **E** and **B** and has magnitude E/B. (b) the given situation is impossible. (c) **v** is parallel to **B**, so the magnetic force is zero. (d) **v** is perpendicular to both **E** and **B** and has magnitude B/E. (e) **v** is parallel to **E** and has magnitude E/B

10. A rectangular coil with 20 windings carries a current of 2.0 mA flowing in the counterclockwise direction. This coil has two sides that are parallel to the y-axis and have length 5.0 cm and two sides that are parallel to the x-axis and have length 3.0 cm. A uniform magnetic field of 50 μT acts in the positive x-direction. What torque (in $N.m$) must be applied to the loop to hold it steady?

(a) $(3.0\times10^{-9})\hat{\jmath}$ (b) $(4.7\times10^{-5})\hat{\jmath}$ (c) $(2.5\times10^{-8})\hat{k}$ (d) $(6.0\times10^{-5})\hat{k}$ (e) $(1.5\times10^{-5})\hat{\imath}$

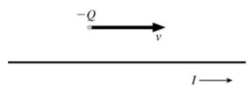


11. Two long parallel conductors are seperated by 5.0×10^{-3} m and each wire carries 3 A current in opposite directions. What is the type and magnitude of mutual force between 0.5 m long segments of each wire? Magnetic permeability in empty space is $\mu_0 = 4\pi \times 10^{-7} T \cdot m/A$ and take π=3.

(a) attractive, 0.06×10^{-4} N (b) repulsive, 0.6×10^{-4} N (c) repulsive, 1.8×10^{-4} N (d) repulsive, 3.6×10^{-4} N (e) attractive, 1.8×10^{-4} N

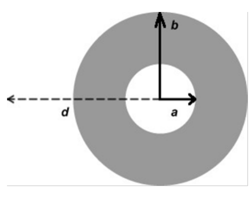
12. A negatively charged particle is moving to the right, directly above a wire having a current flowing to the right, as shown in the figure. In which direction is the magnetic force exerted on the particle?

(a) The magnetic force is zero since the velocity is parallel to the (b) upward (c) out of the page
(d) into the page (e) downward current.

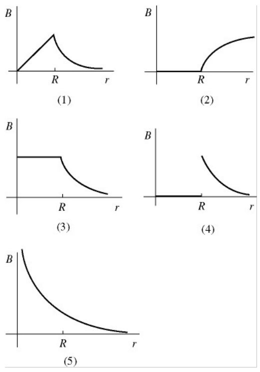


13. The figure shows the cross-section of a hollow cylinder of inner radius a = 5.0 cm and outer radius b = 7.0 cm. A uniform current density of 1.0 A/ cm^2 flows through the cylinder parallel to its axis. Calculate the magnitude of the magnetic field at a distance of d = 10 cm from the axis of the cylinder. ($\mu_0 = 4\pi \times 10^{-7}$ T $\cdot$ m/A). Take π=3.

(a) 2.5×10^{-4}T (b) 1.44×10^{-4}T (c) 0.50×10^{-4}T (d) 4.5×10^{-4}T (e) 0.00 T



14. A very long, hollow, thin-walled conducting cylindrical shell (like a pipe) of radius R carries a current along its length uniformly distributed throughout the thin shell. Which one of the graphs shown in the figure most accurately describes the magnitude B of the magnetic field produced by this current as a function of the distance r from the central axis?



(a) 1

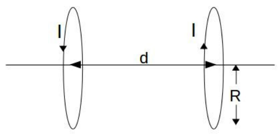
(b) 2

(c) 4

(d) 3

(e) 5

15. Two coaxial circular coils of radius R = 15 cm, each carrying 4.0 A in the same direction, are positioned a distance $d = 20$ cm apart, as shown in the figure. Calculate the magnitude of the magnetic field halfway between the coils along the line connecting their centers. ($\mu_0 = 4\pi \times 10^{-7}$ T · m/A). Take π=3.



(a) 0.9×10^{-5}T (b) 9.2×10^{-5}T (c) 1.9×10^{-5}T (d) $0.0T$ (e) 3.9×10^{-5}T

Questions 16-17

An inductor coil of N turns is cylindrical with length l and radius a. The current through the inductor is $I(t) = I_0 t/t_0$

16. What is the electromotive force induced around a single turn of the inductor coil? $r(r < a)$

(a) $\pi a \mu_0 N^2 I_0/(lt_0)$ (b) $\pi a^2 \mu_0 N I_0/(l^2 t_0)$ (c) $\pi a^2 \mu_0 N I_0/(lt_0)$ (d) $\pi a \mu_0 N I_0/(l^2 t_0)$ (e) $\pi a^2 \mu_0 N^2 I_0/(lt_0)$

17. What is the magnitude of the electric field E around one of the coils of the inductor?

(a) $a^2 \mu_0 N I_0/(2lt_0)$ (b) $a\mu_0 N I_0/(2lt_0)$ (c) $a\mu_0 N I_0/(2l^2 t_0)$ (d) $a\mu_0 N^2 I_0/(2l^2 t_0)$ (e) $a\mu_0 N^2 I_0/(2lt_0)$

Questions 18-20

An LR circuit consists of two resistors of value R, an inductor L, a battery of emf ε and a switch S all arranged in series. At time $t = 0$ the switch is closed.

18. What is the current right after the switch is closed at t=0 in the circuit?

(a) $\varepsilon/4R$ (b) ε/R (c) 0 (d) $\varepsilon/2R$ (e) ∞

19. What is the current long after the switch is closed in the circuit?

(a) ε/R (b) ∞ (c) 0 (d) $\varepsilon/4R$ (e) $\varepsilon/2R$

20. What is the magnetic energy stored in the inductor between t=0 and the state of equilibrium?

(a) $L^2\varepsilon/4R^2$ (b) $L\varepsilon^2/8R^2$ (c) $L\varepsilon^2/4R^2$ (d) $L\varepsilon^2/8R$ (e) $L\varepsilon^2/4R$

Questions 21-25

Electric field component of an electromagnetic wave propagating in vacuum in the direction of +z is given by $\vec{E} = -18(V/m)\ sin(kz - \omega t)\ \hat{i}$, where $k = 1m^{-1}$. Take $\pi = 3$.

21. What is the direction of magnetic field component?

(a) +z (b) −y (c) +x (d) −x (e) +y

22. What is the amplitude of magnetic field component of this electromagnetic wave?

(a) 2.10^{-8} T (b) 3.10^{-8} T (c) 4.10^{-8} T (d) 5.10^{-8} T (e) 6.10^{-8} T

23. What is the amplitude of Poynting vector of this wave?

(a) 0.45 (W/m^2) (b) 9 (W/m^2) (c) 0.9 (W/m^2) (d) 0.3 (W/m^2) (e) 0.09 (W/m^2)

24. What is the wavelength of this wave?

(a) 0.12 m (b) 0.6 m (c) 6 m (d) 12 m (e) 6 cm

25. If this wave was travelling in a medium with dielectric constant of K=2, what would be the speed of propagation of this wave in this medium? c is the speed of light in vacuum.

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

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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 point charge Q is located a short distance from a point charge $3Q$, and no other charges are present. If the electrical force acting on Q is $\vec{F}$, what is the electrical force on acting $3Q$?

(a) $3\vec{F}$ (b) $\vec{F}/\sqrt{3}$ (c) $-\vec{F}$ (d) $\sqrt{3}\vec{F}$ (e) $\vec{F}/3$

2. The electric potential V in a region of space is given by $V(x,y,z) = A(-3x^2 + 2y^2 - 3z^2)$ where A is a constant. Derive an expression for the electric field $\vec{E}$ at any point in this region.

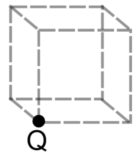
(a) $A(-6x\,\hat{\imath} + 4y\,\hat{\jmath} - 3z\,\hat{k})$ (b) $A(-3x\,\hat{\imath} + 2y\,\hat{\jmath} - 3z\,\hat{k})$ (c) $A(6x\,\hat{\imath} - 4y\,\hat{\jmath} + 6z\,\hat{k})$ (d) $A(3x\,\hat{\imath} - 2y\,\hat{\jmath} + 3z\,\hat{k})$
(e) $A(-6x\,\hat{\imath} + 4y\,\hat{\jmath} - 6z\,\hat{k})$

3. A cylindrical capacitor consists of an inner conductor of radius r_1 surrounded by an outer conductor of radius r_2. The length of the cylinder is L ($L \gg r_2$). What is its capacitance?

(a) $C = \pi^2\epsilon_0 r_2/(r_1 L)$ (b) $C = 2\pi\epsilon_0 L/\ln(r_2/r_1)$ (c) $C = \epsilon_0 r_2 r_1/L$ (d) $C = 4\pi^2\epsilon_0 r_2 r_1/L$ (e) $C = 2\pi\epsilon_0 L\ln(r_2/r_1)$

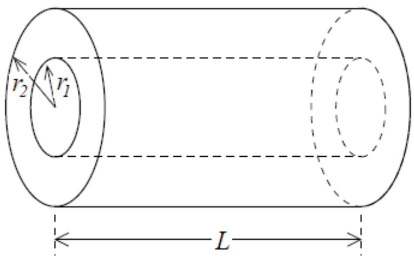
4. A single positive point charge, Q, is at one corner of a cube with sides of length L, as shown in the figure. The net electric flux through the three adjacent sides is zero. The net electric flux through each of the other three sides is

(a) $Q/(8\varepsilon_0)$ (b) $Q/(9\varepsilon_0)$ (c) $Q/(6\varepsilon_0)$ (d) $Q/(3\varepsilon_0)$ (e) $Q/(24\varepsilon_0)$



Questions 5-7

A hollow cylindrical resistor with inner radius r_1 and outer radius r_2, and length L, is made of a material whose resistivity is ρ. Suppose current, I, flows radially outward from the inner radius to the outer.



5. What is the current density $\vec{J}$ at a distance r from the center?

(a) $\frac{-Ir}{2\pi L}\hat{r}$ (b) $\frac{-I}{\pi r^2}\hat{r}$ (c) $\frac{I}{\pi L^2}\hat{r}$ (d) $\frac{I}{2\pi r L}\hat{r}$ (e) $\frac{I}{\pi r^2}\hat{r}$

6. What is the electric field vector $\vec{E}$ at a distance r from the center?

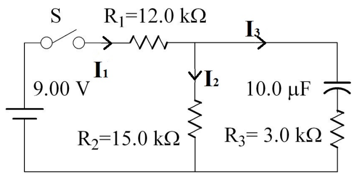
(a) $\frac{-\rho}{2\pi r L}\hat{r}$ (b) $\frac{2\rho I}{\pi r^2}\hat{r}$ (c) $\frac{\rho I}{2\pi r L}\hat{r}$ (d) $\frac{\rho}{\pi L^2}\hat{r}$ (e) $\frac{\rho I}{\pi r^2}\hat{r}$

7. What is the potential difference, ΔV between the inner and outer cylinders?

(a) $\frac{\rho I}{\pi r^2}\ln\frac{r_2}{r_1}$ (b) $\frac{\rho I}{2L}\ln\frac{r_1}{r_2}$ (c) $\frac{\rho I}{2\pi L}\ln\frac{r_2}{r_1}$ (d) $\frac{\rho I}{\pi L}\ln\frac{r_1}{r_2}$ (e) $\frac{\rho I}{L}\ln\frac{r_2}{r_1}$

Questions 8-10

Considering the figure on the right for the questions from 8 to 10,



8. Find the steady-state current in each resistor a long time after the switch is closed

(a) $I_1 = I_2 = 0$ mA, $I_3 = 3$ mA (b) $I_1 = I_2 = 3$ mA, $I_3 = 3$ mA (c) $I_1 = I_2 = 1/3$ mA, $I_3 = 0$ mA (d) $I_1 = I_2 = 3$ mA, $I_3 = 0$ mA (e) $I_1 = I_2 = 1/3$ mA, $I_3 = 3$ mA

9. Find charge Q on the capacitor in the steady state

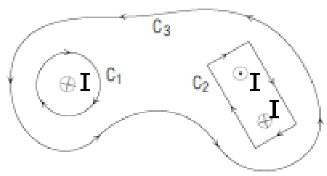
(a) 500 μC (b) 50 μC (c) 100 μC (d) 5 μC (e) 200 μC

10. What is the current I_2 in the resistor R_2 long time after the switch is opened?

(a) 3 mA (b) 1/3 mA (c) 1 mA (d) 0 mA (e) infinity

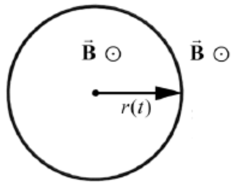
11. Three infinitely long parallel wires each carries a current I in the direction shown in the figure. What is the value of $\oint \vec{B}d\vec{l}$ for path C_3?

(a) $-\mu_0 I$ (b) 0 (c) $3\mu_0 I$ (d) $-2\mu_0 I$ (e) $\mu_0 I$



Questions 12-13

A stretchable and flexible conducting circular ring with radius $r(t)$ has constant resistance R. It is placed in a uniform magnetic field $\vec{B}$ that is directed out of the page as shown in figure. External agents exert radial outward forces that cause the ring to expand at a constant speed, v from radius a to a larger radius b over a time interval $0 \leq t \leq T$, where T is a constant with units of seconds.



12. What is the magnitude and direction of the induced current, I in the ring? (CW: clockwise, CCW: counterclockwise)

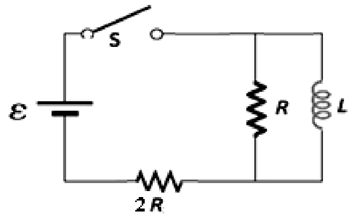
(a) $I = \pi r^2 Bv/2R$, CCW (b) $I = 2rBv^2/R$, CW (c) $I = 2\pi^2 r^2 Bv/R^2$, CW (d) $I = 2\pi rBv/R$, CW (e) $I = \pi RBv/r$, CCW

13. What is the power dissipated as Joule heating during the time interval $0 \leq t \leq T$?

(a) $P = 4\pi^2 r^2 B^2 v^2/R$ (b) $P = \pi^2 r^2 B^2 v^2/R^2$ (c) $P = 4r^2 B^2 v/R$ (d) $P = r^2 B^2 v^2/R$ (e) $P = 2\pi^2 r^2 Bv/R^2$

Questions 14-17

In the circuit in the figure, the emf of the battery is ε, the resistances are R and $2R$, and the inductance is L. For questions 14-15 consider the time $t = 0$ immediately after the switch S is closed.



14. What is the current in the inductor L?

(a) $\varepsilon/3R$ (b) 0 (c) ε/R (d) ∞ (e) $\varepsilon/2R$

15. What is the current in resistor $2R$?

(a) $\varepsilon/3R$ (b) $\varepsilon/2R$ (c) ε/R (d) ∞ (e) 0

For questions 16-17 consider the time $t \to \infty$, long after the switch is closed.

16. What is the current in the resistor $2R$?

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

17. What is the energy stored in the inductor L?

(a) $\frac{1}{8}L(\varepsilon/R)^2$ (b) 0 (c) $\frac{1}{2}L(\varepsilon/2R)^2$ (d) $L(\varepsilon/R)^2$ (e) $\frac{1}{8}L(2\varepsilon/3R)^2$

Questions 18-21

An electromagnetic wave with 1 GHz frequency propagates in the $+z$ direction.

18. If the electric field is $\vec{E} = 300\cos(kz - wt)\hat{\imath}$, what is the time-dependent magnetic field? (Take $\pi = 3$ and $c = 3 \times 10^8 m/s$).

(a) $\vec{B} = 10^{-6}\cos(20z - 6 \cdot 10^9 t)\hat{k}$
(b) $\vec{B} = 300\cos(20z - 6 \cdot 10^9 t)\hat{\jmath}$ (c) $\vec{B} = 10^{-6}\cos(20z - 6 \cdot 10^9 t)\hat{\jmath}$ (d) $\vec{B} = -10^{-6}\cos(20z - 6 \cdot 10^9 t)\hat{k}$ (e) $\vec{B} = 10^{-6}\cos(20z + 6 \cdot 10^9 t)\hat{\imath}$

19. What is the Poynting vector of this electromagnetic wave?

(a) $\vec{S} = 10^{-4}\mu_0^{-1}\cos^2(20z - 10^9 t)\hat{k}$ (b) $\vec{S} = 3 \times 10^{-4}\mu_0^{-1}\cos(20z - 10^9 t)\hat{k}$ (c) $\vec{S} = 10^{-4}\mu_0^{-1}\cos(20z - 6 \cdot 10^9 t)\hat{k}$
(d) $\vec{S} = 10^{-4}\mu_0^{-1}\cos^2(10z - 10^9 t)\hat{k}$ (e) $\vec{S} = 3 \times 10^{-4}\mu_0^{-1}\cos^2(20z - 6 \cdot 10^9 t)\hat{k}$

20. What is the energy density of the electric field at $z = 3$ m and $t = 10^{-8}$ s in this electromagnetic wave?

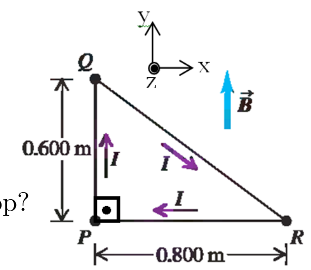
(a) $(9/2) \times 10^4 \epsilon_0$ (b) $(1/2) \times 10^4 \epsilon_0$ (c) $9 \times 10^4 \epsilon_0$ (d) $2 \times 10^4 \epsilon_0$ (e) $(9/2) \times 10^2 \epsilon_0$

21. If this electromagnetic wave was ditributed isotropically (distributed to every direction equally) from an antenna, what would be the ratio of power per unit area at 1 km distance and at 4 km distance?

(a) 1/6 (b) 16 (c) 4 (d) 2 (e) 1/4

Questions 22-24

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 magnetic field is in the same direction as the current inside PQ segment of the loop.



22. What is the net force on the loop?

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

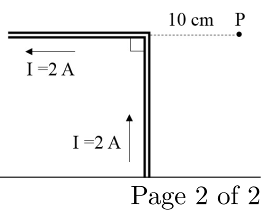
23. Calculate the magnetic moment of the loop.

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

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

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

25. An infinitely long wire carrying a current of $2A$ is bent at a right angle as shown in the Figure. What is the magnetic field magnitude in Tesla a point P, 10 cm from the corner?



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

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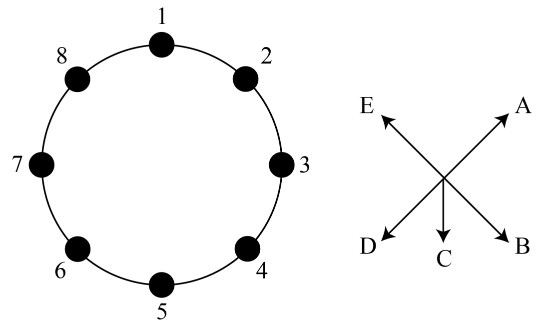
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

For calculations take: Speed of light $c = 3 \times 10^8$ m/s, $\pi = 3$, $k_e = 9 \times 10^9$ N.m^2/C^2

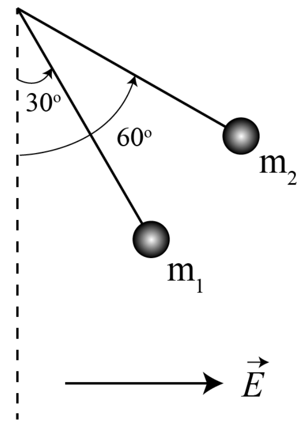


1. Eight particles of equal charge are located around a circle as shown in the figure. Which vector shown best represents the force experienced by charge 4?

(a) E (b) B (c) A (d) C (e) D

2. Two small identical spheres are separated by a distance d. The spheres originally have equal charges and the magnitude of the repulsive force that each experiences is F. If half of the charge on one sphere is moved to the other sphere, the magnitude of the force becomes

(a) F (b) 3F/4 (c) 3F (d) 3F/2 (e) F/2



3. A ball of mass m_1 and charge q is suspended from a light string in the presence of a horizontal electric field, $\vec{E}$, near the surface of the earth. At equilibrium it makes an angle of 30° with the vertical. When it is replaced by a mass of m_2 and charge q, it makes and angle of 60° with the vertical in equilibrium as shown below.What is the ratio of the masses m_1/m_2?

(a) $2/\sqrt{3}$
(b) $\sqrt{3}$
(c) 3
(d) $1/\sqrt{3}$
(e) 1/3

4. The electrostatic potential between the plates of a parallel plate capacitor ...

(a) ... increases quadratically with the position from the positive to the negative plate. (b) ... is constant. (c) ... is equal to zero. (d) ... increases linearly with position from the positive to the negative plate. (e) ... decreases linearly with position from the positive to the negative plate.

5. The magnitude of the electric field between the plates of a parallel plate capacitor ...

(a) ... is equal to zero. (b) ... is constant. (c) ... decreases linearly with position from the positive to the negative plate. (d) ... increases quadratically with the position from the positive to the negative plate. (e) ... increases linearly with position from the positive to the negative plate.

6. Two charged conducting spheres with charges $+Q$ and $-Q$ are separated by center to center distance d. The attractive force between them

(a) is greater than $k\,Q^2/d^2$ (b) is equal to $k\,Q^2/d^2$ (c) is zero. (d) is less than $k\,Q^2/d^2$ (e) is not well defined.

7. First charge a capacitor with a battery and then remove the capacitor from the battery so that the plates remain charged. You then insert a dielectric material with $K > 1$ centered between the plates (but it is not touching the plates). Which of the following increases in magnitude?

(a) The potential difference between the plates. (b) The electric energy stored between the plates. (c) The capacitance. (d) The magnitude of the electric field between the plates. (e) The charge on each plate.

8. The units of electric constant k is equivalent to

(a) $\text{Watt} \cdot \text{m} \cdot \text{s}^2/\text{C}^2$. (b) $\text{Watt} \cdot \text{s}^2/\text{C}^2 \cdot \text{m}^2$. (c) $\text{Watt} \cdot \text{m} \cdot \text{s}/\text{C}^2$. (d) $\text{Watt} \cdot \text{m}^2 \cdot \text{s}/\text{C}^2$. (e) $\text{Watt} \cdot \text{s}/\text{C}^2 \cdot \text{m}$.

9. A wire has a uniform cross sectional area of 1 cm^2 and a length of 1 m. When the potential difference across the wire is increased by $16\,V$, the current increases by 2 A. What is the resistivity of the wire?

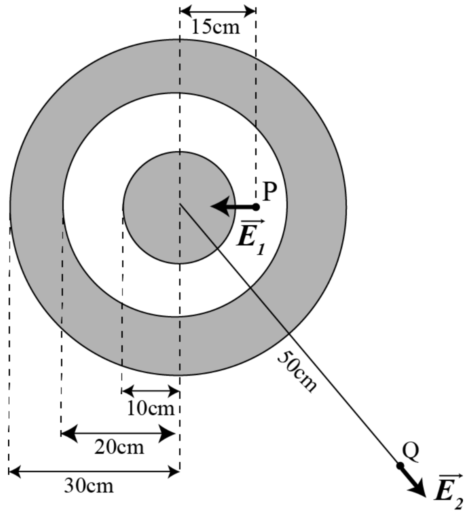
(a) $2 \cdot 10^{-4}\,\Omega \cdot m$ (b) $16 \cdot 10^{-4}\,\Omega \cdot m$ (c) $4 \cdot 10^{-4}\,\Omega \cdot m$ (d) $1 \cdot 10^{-4}\,\Omega \cdot m$ (e) $8 \cdot 10^{-4}\,\Omega \cdot m$

10. A potential difference of 16 V is maintained across an electrical device with a resistance of $4\,\Omega$. What total charge passes through a cross section of wire attached to this device over a period of 2 s?

(a) $8\,C$ (b) $0.5\,C$ (c) $4\,C$ (d) $2\,C$ (e) $32\,C$

Questions 11-15

A solid metal sphere of radius 10 cm is concentric with a hollow metal sphere with inner and outer radii of 20 cm and 30 cm, respectively (see the figure). The electric field at point P, at a distance of 15 cm from the center, is found to be $E_1 = 9 \cdot 10^5$ N/C, directed radially inward. The electric field at point Q, at a distance of 50 cm from the center, is found to be $E_2 = 18 \cdot 10^4$ N/C, directed radially outward.



11. What is the total charge on the surface of the solid sphere? (Use the constants given at the front page)

(a) $-1.5 \cdot 10^{-6}$ C (b) $-5 \cdot 10^{-6}$ C (c) $-4.5 \cdot 10^{-6}$ C (d) $-9 \cdot 10^{-6}$ C (e) $-2.25 \cdot 10^{-6}$ C

12. What is the total charge on the surface of the inner surface of the hollow sphere?

(a) $1.5 \cdot 10^{-6} C$ (b) $9 \cdot 10^{-6} C$ (c) $5 \cdot 10^{-6} C$ (d) $4.5 \cdot 10^{-6} C$ (e) $2.25 \cdot 10^{-6} C$

13. What is the total charge on the surface of the outer surface of the hollow sphere?

(a) $5 \cdot 10^{-6} C$ (b) $1.5 \cdot 10^{-6} C$ (c) $2.25 \cdot 10^{-6} C$ (d) $9 \cdot 10^{-6} C$ (e) $4.5 \cdot 10^{-6} C$

14. What is the magnitude of the electric field at a distance of 25 cm from the center?

(a) $13.5 \cdot 10^4 N/C$ (b) $24 \cdot 10^4 N/C$ (c) $15 \cdot 10^4 N/C$ (d) 0 (e) $5.4 \cdot 10^4 N/C$

15. What is the magnitude of the electric field at a distance of 4 cm from the center?

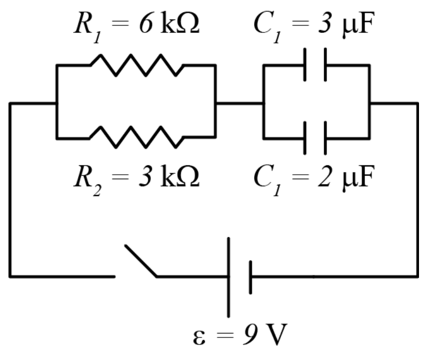
(a) $45 \cdot 10^4$ N/C (b) $24 \cdot 10^4$ N/C (c) $18 \cdot 10^4$ N/C (d) $9 \cdot 10^4$ N/C (e) 0

Questions 16-20

Consider the circuit shown in the figure. For calculations use the approximations: $e \approx 2.7$, $\sqrt{e} \approx 1.6$, $1/\sqrt{e} \approx 0.6$

16. Calculate the current flows from the circuit immediately after the switch is closed.

(a) 18 mA (b) 0.1 mA (c) 4.5 mA (d) 0 (e) 1 mA



17. Calculate the current flows from the circuit long after the switch is closed.

(a) 3 mA (b) 0.1 mA (c) 4.5 mA (d) 0 (e) 1 mA

18. Calculate the charge across the capacitor C_1 long after the switch is closed.

(a) 45 μ C (b) 27 μ C (c) 9 μ C (d) 18 μ C (e) 0

19. Calculate the charge across the capacitor C_2 long after the switch is closed.

(a) 0 (b) 9 μ C (c) 18 μ C (d) 45 μ C (e) 27 μ C

20. Calculate the charge across the capacitor C_2 after the switch is closed for 5 μ s.

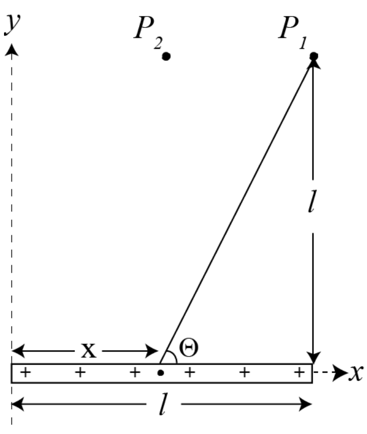
(a) 7.2 μ C (b) 14.4 μ C (c) 3.6 μ C (d) 28.8 μ C (e) 1.8 μ C

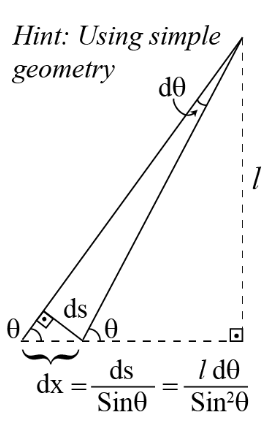
Questions 21-25

For questions 21-23, consider a positively homogeneously charged metal rod which is shown in the figure.

21. From point P_1 to point P_2 the electric potential difference $V_{P_1} - V_{P_2}$ ...

(a) ... can't be determined. (b) ... is positive. (c) ... is zero. (d) ... is negative. (e) ... is infinite.





22. The work done by us, in moving a positive charge with a slow constant velocity from point P_1 to point P_2, ...

(a) ... is zero.
(b) ... is infinite. (c) ... can't be determined. (d) ... is negative.
(e) ... is positive.

23. The work done by the electric field, when a positive charge is moved by us with a slow constant velocity from point P_1 to point P_2, ...

(a) ... is infinite. (b) ... can't be determined. (c) ... is negative.
(d) ... is zero.
(e) ... is positive.

24. Now consider the case when the metal rod's charge density is a function of the angle Θ with horizontal x axis as $\lambda = \lambda_0 \sin^2 \Theta$.

Express the total charge Q in terms of λ_0 and the length of the rod l.

(a) $\lambda_0 l\pi/2$ (b) $\lambda_0 l\pi/4$ (c) $\lambda_0 l\, 3\pi/2$ (d) $\lambda_0 l\pi/8$ (e) $\lambda_0 l\pi$

25. Express the electric potential V_{P_1} at point P_1, in terms of λ_0 and the electric constant k.

(a) $\frac{\sqrt{2}}{2} k\lambda_0$ (b) $(\sqrt{2}-1)k\lambda_0 l$ (c) $(\sqrt{2}-1)k\lambda_0/l$ (d) $k\lambda_0(1-\frac{\sqrt{2}}{2})$ (e) $\frac{\sqrt{2}}{2}k\lambda_0/l$

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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 calculations take: Speed of light $c = 3 \times 10^8$ m/s, $\pi = 3$, $\mu_0 = 4\pi \times 10^{-7}$ T.m/A, $\epsilon_0 = 9 \times 10^{-12}$ C^2/N.m^2

1. Which of the following is equivalent to Tesla, the SI unit of magnetic field?

(a) kg / A · m (b) N / A · s (c) Weber / m^3 (d) kg / C · s (e) N · m/ A

2. Which of the following is not a source of magnetostatic fields?

(a) A charged disk rotating at a uniform speed (b) An accelerated charge (c) An electrical field changing linearly with time (d) A DC current in a wire (e) A permanent magnet

3. Which of the following statements about electromagnetic waves is/are correct?
1-The electric field vector is perpendicular to the magnetic field vector. 2-The electric field vector is perpendicular to the direction of wave propagation. 3-The magnetic field vector is perpendicular to the direction of wave propagation. 4-They are longitudinal waves

(a) 1, 2, 3 and 4 (b) 1 and 4 (c) 1, 2 and 3 (d) Only 1 (e) 2 and 3

4. Which of the following is not equivalent to 1 Henry?

(a) 1 Wb / Ω (b) 1 J/A^2 (c) 1 Wb/A (d) 1 Ω · s (e) 1 V · s/A

5. Which of the following statements are correct for the motion of charged particles in magnetic field?
I) Magnetic force can never do work on a charged particle
II) Magnetic force can not change the magnitude of the velocity, only its direction.
III) The magnetic force can have a component parallel to the particle's motion.

(a) I and III (b) I, II and III (c) Only II (d) I and II (e) Only I

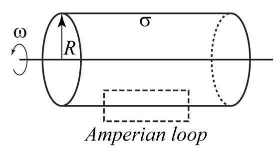
6. Which of the following combinations both have the units of time?

(a) $\sqrt{LC}$, L/R (b) $\sqrt{LC}$, LR (c) $\sqrt{L/C}$, LR (d) $\sqrt{L/C}$, L/R (e) LC, $\sqrt{L/R}$

7. Which of the following statements about magnetic dipoles is not correct?

(a) The net force acting on a dipole in a non-uniform magnetic field need not be zero in general. (b) The torque acting on a dipole in a uniform magnetic field is zero in general. (c) Potential energy is minimum when the dipole is aligned with a magnetic field. (d) It's magnetic field at large distances is inversely proportional to the cube of the distance (e) The net force acting on a dipole in a uniform magnetic field is zero in general.

8. A long and thin cylindrical shell of radius R carries a uniform surface charge density $\sigma > 0$. It is rotating with a constant angular speed ω about its axis. What is the magnitude of the magnetic field inside the cylinder? (Hint: Use Ampere's law for the loop, analogically to a long thin solenoid)



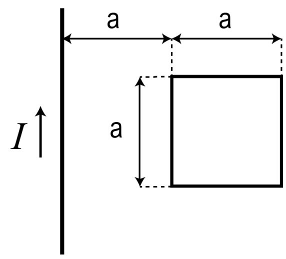
(a) $B = 2\pi\mu_0 R\sigma\omega$ (b) $B = \frac{1}{2}\mu_0 R\sigma\omega$ (c) $B = \frac{1}{2\pi}\mu_0 R\sigma\omega$ (d) $B = 2\mu_0 R\sigma\omega$ (e) $B = \mu_0 R\sigma\omega$

9. An ideal solenoid with cross-sectional area S and length ℓ has N turns. How many times greater is the inductance of another solenoid with cross-sectional area $2S$, length 2ℓ and number of turns $2N$?

(a) 1/2 (b) $\sqrt{2}$ (c) 16 (d) 4 (e) 2

Questions 10-14

The long, straight wire in the figure has a current I flowing in it. A square loop with each side a and a resistance of R is positioned at a distance a away from the wire.



10. Which of the following gives the magnetic flux through the loop due to the current in the straight wire?

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

11. Which of the following is the mutual inductance of the system?

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

12. What is the magnetic force acting on the top segment of the loop due to the magnetic field produced by the straight wire if a current I' is flowing in the loop.

(a) $F = \mu_0 II' \ln 2/4\pi$ (b) $F = \mu_0 II'/\pi$ (c) $F = \mu_0 II'/2\pi$ (d) $F = 2\mu_0 II'/\pi$ (e) $F = \mu_0 II' \ln 2/2\pi$

13. The loop is now moved in the positive $x-$direction with speed v. Which of the following is the magnitude and direction of the induced current in the loop at the instant the loop starts to move?

(a) Counterclockwise, $\mu_0 Iv/4\pi R$ (b) Clockwise, $\mu_0 Iv/4\pi R$ (c) Clockwise, $\mu_0 Iv/4\pi R$ (d) Counterclockwise, $\mu_0 Iv/4\pi R$ (e) Clockwise, $\mu_0 Iv/2\pi R$

14. The loop is now stationary and back at the distance of a. What is the direction and magnitude of the induced current on the loop if the current in the straight wire changes as $I(t) = I_0 \exp(-bt)$ where $b > 0$?

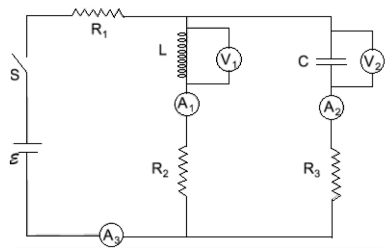
(a) Clockwise, $\frac{\mu_0}{4\pi R} I_0 ab e^{-bt}$ (b) Clockwise, $\frac{\mu_0}{2\pi R} I_0 ab e^{-bt}$ (c) Clockwise, $\frac{\mu_0}{2\pi R} I_0 a \ln 2 b e^{-bt}$ (d) Counterclockwise, $\frac{\mu_0}{4\pi R} I_0 a \ln 2 b e^{-bt}$ (e) Counterclockwise, $\frac{\mu_0}{2\pi R} I_0 a \ln 2 b e^{-bt}$

15. Which of the following actions will not induce a current in a loop of wire in a uniform magnetic field?

(a) Changing the strength of the field (b) Changing the area of the loop (c) Rotating the loop about an axis perpendicular to the field (d) Moving the loop outside the field (e) Moving the loop with a constant velocity within the field

Questions 16-20

In the the circuit shown in Figure, $\mathcal{E} = 12\ V$, $R_1 = 2\ \Omega$, $R_2 = 1\ \Omega$, $R_3 = 4\ \Omega$, $L = 1\ H$ and $C = 2\ \mu F$. The switch is closed at time $t = 0$ with no charge initially on the capacitor.



16. What are the readings of V_1, A_1, and A_3 just after the switch S has been closed?
(a) $V_1 = 0\ V,\ A_1 = 4\ A,\ A_3 = 4\ A$ (b) $V_1 = 18/7\ V,\ A_1 = 24/7\ A,\ A_3 = 30/7\ A$ (c) $V_1 = 0\ V,\ A_1 = 0\ A,\ A_3 = 2\ A$ (d) $V_1 = 32/5\ V,\ A_1 = 8/5\ A,\ A_3 = 2\ A$ (e) $V_1 = 8\ V,\ A_1 = 0\ A,\ A_3 = 2\ A$

17. What are the readings of V_2 and A_2 just after the switch S has been closed?
(a) $V_2 = 32/5\ V,\ A_2 = 2/5\ A$ (b) $V_2 = 0\ V,\ A_2 = 2\ A$ (c) $V_2 = 0\ V,\ A_2 = 0\ A$ (d) $V_2 = 12\ V,\ A_2 = 0\ A$ (e) $V_2 = 0\ V,\ A_2 = 6/7\ A$

18. What would be the readings of V_1, A_1 and A_3 after a long time has elapsed?
(a) $V_1 = 6\ V,\ A_1 = 2\ A,\ A_3 = 4\ A$ (b) $V_1 = 8\ V,\ A_1 = 0\ A,\ A_3 = 2\ A$ (c) $V_1 = 0\ V,\ A_1 = 0\ A,\ A_3 = 2\ A$ (d) $V_1 = 0\ V,\ A_1 = 4\ A,\ A_3 = 4\ A$ (e) $V_1 = 12\ V,\ A_1 = 0\ A,\ A_3 = 0\ A$

19. What would be the readings of V_2 and A_2 after a long time has elapsed?
(a) $V_2 = 4\ V,\ A_2 = 0\ A$ (b) $V_2 = 12\ V,\ A_2 = 0\ A$ (c) $V_2 = 32/5\ V,\ A_2 = 2/5\ A$ (d) $V_2 = 2\ V,\ A_2 = 6/7\ A$ (e) $V_2 = 0\ V,\ A_2 = 2\ A$

20. What would be the maximum charge on the capacitor after a long time has elapsed?
(a) $64/5\ \mu$ Coulomb (b) $4\ \mu$ Coulomb (c) $8\ \mu$ Coulomb (d) $24\ \mu$ Coulomb (e) 0 Coulomb

Questions 21-25

The magnetic field component of a sinusoidal plane electromagnetic wave propagating in vacuum is represented as $\vec{B}(y,t) = (+\hat{\imath})(10^{-8}\ T)\cos\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$. If $\pi = 3, c = 3\cdot 10^8\ (\frac{m}{s})$, $\mu_0 = 4\pi\cdot 10^{-7}\ (\frac{Tm}{A})$,

21. What is the direction of propagation of the wave? (a) $-\hat{\imath}$ (b) $-\hat{\jmath}$ (c) $+\hat{\jmath}$ (d) $+\hat{k}$ (e) $+\hat{\imath}$

22. What is the wave number k of the wave? (a) $2/3\ \text{m}^{-1}$ (b) $1.5\ \text{m}^{-1}$ (c) $6\ \text{m}^{-1}$ (d) $1\ \text{m}^{-1}$ (e) $0.5\ \text{m}^{-1}$

23. Which of the following represents the electric field component of the wave?
(a) $\vec{E}(y,t) = (-\hat{k})\ 3(\frac{N}{C})\cos\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$
(b) $\vec{E}(y,t) = (+\hat{k})\ 3(\frac{N}{C})\cos\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$
(c) $\vec{E}(y,t) = (+\hat{k})\ \frac{1}{3}10^{-16}(\frac{N}{C})\cos\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$
(d) $\vec{E}(y,t) = (+\hat{\jmath})\ \frac{1}{3}10^{-16}(\frac{N}{C})\cos\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$
(e) $\vec{E}(y,t) = (-\hat{k})\ \frac{1}{3}10^{-16}(\frac{N}{C})\cos\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$

24. Which of the following represents the Poynting vector for the wave?
(a) $\vec{S}(y,t) = (+\hat{\jmath})\ \frac{10^{-17}}{36}(\frac{Watt}{m^2})\cos^2\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$
(b) $\vec{S}(y,t) = (-\hat{k})\ \frac{10^{-17}}{36}(\frac{Watt}{m^2})\cos^2\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$
(c) $\vec{S}(y,t) = (+\hat{\jmath})\ 2.5\cdot 10^{-2}(\frac{Watt}{m^2})\cos^2\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$
(d) $\vec{S}(y,t) = (-\hat{\jmath})\ 2.5\cdot 10^{-2}(\frac{Watt}{m^2})\cos^2\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$
(e) $\vec{S}(y,t) = (-\hat{\jmath})\ \frac{10^{-17}}{36}(\frac{Watt}{m^2})\cos^2\left(ky - (2\cdot 10^8\ \frac{rad}{s})t\right)$

25. If the wave is totally reflected from a stationary plane which is located perpendicular to the direction of propagation, what would be the radiation pressure exerted by the wave on the surface?

(a) $\frac{10^{-9}}{6}(\frac{N}{m^2})$ (b) $15\cdot 10^{-9}(\frac{N}{m^2})$ (c) $\frac{10^{-9}}{24}(\frac{N}{m^2})$ (d) $\frac{10^{-9}}{12}(\frac{N}{m^2})$ (e) $7.5\cdot 10^{-9}(\frac{N}{m^2})$

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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.

1. A spherical conducting shell with net charge $+q$ surrounds a point charge of $-q$ positioned at the centre of the shell. What are the charges on the inner and outer surfaces of the shell, respectively, when static equilibrium is reached?

(a) q, $2q$ (b) $2q$, q (c) $2q$, $3q$ (d) q, 0 (e) q, q

2. A solid sphere has a uniform charge density and a net charge of +6 nC. At electrostatic equilibrium the electric field inside the sphere

(a) varies as $1/r$ (b) is zero (c) varies as r (d) is constant. (e) varies as $1/r^2$

3. The electric field in a region of space is given as $E = -30x + 2$, where x is in meters and E is in Volts/meter. What is the electric potential at $x = 2$ meters, relative to the origin?

(a) -60 V (b) $+60$ V (c) 3 V (d) -3 V (e) $+56$ V

4. How does the energy stored in a parallel plate capacitor change when the separation between the plates is doubled while kept at the same potential?

(a) Cubed (b) Doubled (c) Halved (d) Remains the same (e) Cube rooted

5. Two uniformly charged infinitely long parallel wires with linear charge density λ are seperated with a distance r. The electrostatic force between the wires

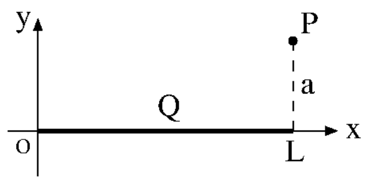
(a) varies as $1/r$ (b) varies as $1/r^2$ (c) is independent of the distance (d) varies as $1/r^3$ (e) varies as r

6. Electric flux through a closed surface is **always**

(a) zero, if there is a charge distribution in it.
(b) related to the shape of the surface.
(c) negative if net charge inside the surface is positive.
(d) positive if net charge inside the surface is negative.
(e) zero, if net charge inside the surface is zero.

Questions 7-9

A uniform line of charge of length L lying between $x = 0$ to $x = L$ is charged with Q.



7. Which of the following gives the x component of the electric field at point P?

(a) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{(L-x)\,dx}{[(L-x)^2+a^2]^{3/2}}$ (b) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{dx}{[(L-x)^2+a^2]}$ (c) $\frac{Q/L}{4\pi\epsilon_0}\int_0^a \frac{(L-x)\,dx}{[(L-x)^2+a^2]^{3/2}}$ (d) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{x\,dx}{[(L-x)^2+a^2]^{3/2}}$ (e) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{a\,dx}{[(L-x)^2+a^2]^{3/2}}$

8. Which of the following is the y component of electric field vector at point P?

(a) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{dx}{[(L-x)^2+a^2]}$ (b) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{(L-x)\,dx}{[(L-x)^2+a^2]^{3/2}}$ (c) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{x\,dx}{[(L-x)^2+a^2]^{3/2}}$ (d) $\frac{Q/L}{4\pi\epsilon_0}\int_0^a \frac{(L-x)\,dx}{[(L-x)^2+a^2]^{3/2}}$ (e) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{a\,dx}{[(L-x)^2+a^2]^{3/2}}$

9. Which of the following gives the electric potential at point P?

(a) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{(L-x)dx}{[(L-x)^2+a^2]^{3/2}}$ (b) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{a dx}{[(L-x)^2+a^2]^{3/2}}$ (c) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{dx}{[(L-x)^2+a^2]^{1/2}}$ (d) $\frac{Q/L}{4\pi\epsilon_0}\int_0^a \frac{dx}{[(L-x)^2+a^2]^{1/2}}$ (e) $\frac{Q/L}{4\pi\epsilon_0}\int_0^L \frac{dx}{[x^2+a^2]^{1/2}}$

Questions 10-14

A spherical object with radius a has total charge $-Q$ distributed uniformly over its volume. r is the radial distance from the origin.

10. What is the magnitude and direction of the electric field in the region $r < a$?

(a) $-3Qr/4\pi\epsilon_0 a^3$ (b) $-Q/4\pi\epsilon_0 r^2$ (c) 0 (d) $-Q/2\pi\epsilon_0 ar$ (e) $-Qr/4\pi\epsilon_0 a^3$

11. What is the electric potential at a distance $r > a$, assuming the potential is zero at infinity?
(a) $-Q/4\pi\epsilon_0 r$ (b) $-Q/4\pi\epsilon_0 a$ (c) $Qa/4\pi\epsilon_0 r^2$ (d) $-Qa^2/8\pi\epsilon_0 r^3$ (e) $-Qr/4\pi\epsilon_0 a^2$

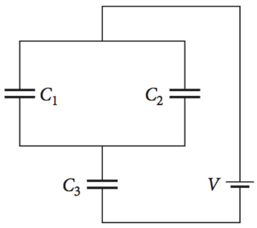
12. What is the electric potential at a distance $r < a$?
(a) $-Q(3 - r^2/a^2)/8\pi\epsilon_0 a$
(b) $-Q(3 - a^2/r^2)/8\pi\epsilon_0 a$
(c) $-Q(2 - a^2/r^2)/4\pi\epsilon_0 a$
(d) $-Q(2 - r^2/a^2)/4\pi\epsilon_0 a$
(e) $-Q(2 - r/a)/4\pi\epsilon_0 a$

13. What is total energy stored in the electric field *outside* the sphere?
(a) $-Q^2/8\pi\epsilon_0 a$ (b) $Q^2/4\pi\epsilon_0 a$ (c) $Q^2/8\pi\epsilon_0 a$ (d) $3Q^2/8\pi\epsilon_0 a$ (e) $3Q^2/5\pi\epsilon_0 a$

14. What is the total energy stored in the electric field *inside* the sphere?
(a) $Q^2/20\pi\epsilon_0 a$ (b) $Q^2/40\pi\epsilon_0 a$ (c) $3Q^2/40\pi\epsilon_0 a$ (d) $-Q^2/40\pi\epsilon_0 a$ (e) $3Q^2/5\pi\epsilon_0 a$

Questions 15-18

Three capacitors with capacitances $C_1 = 2.0\ \mu$F, $C_2 = 4.0\ \mu$F, and $C_3 = 6.0\ \mu$F are connected in a circuit as shown in the figure, with an applied potential of V. After the charges on the capacitors have reached their equilibrium, the charge Q_2 on the second capacitor (C_2) is found to be 30 μC.



15. What is the charge, Q_1, on the capacitor C_1?
(a) 5 μC (b) 25 μC (c) 10 μC (d) 15 μC (e) 20 μC

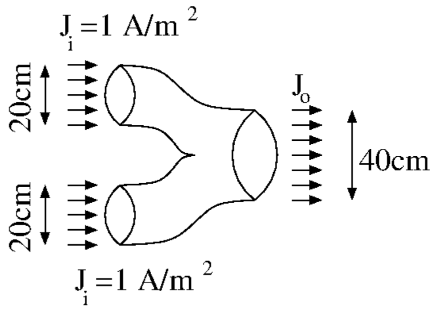
16. What is the charge, Q_3, on capacitor C_3 ?
(a) 45 μC (b) 30 μC (c) 35 μC (d) 15 μC (e) 25 μC

17. What is the magnitude of the applied voltage (V) ?
(a) 25 (b) 15 (c) 10 (d) 5 (e) 20

18. How much energy is stored in C_1 ?
(a) 0 μJ (b) 125/4 μJ (c) 225/4 μJ (d) 12.5/4 μJ (e) 22.5/4 μJ

Questions 19-22

A conductor made from a copper-alloy is given in the figure. Assume all branches have circular cross sections. The diameter of both of the inputs is 20 cm and the diameter of the output is 40 cm. The current densities (J) at both of the inputs are equal and given as 1A/m^2 each. (Charge density of free electrons $n_e = 5.0\ 10^{28}(1/m^3)$)



19. Which one is correct?
(a) Current is conserved here.
(b) Current densities are conserved.
(c) Electrons move faster in the output.
(d) Total resistance at the input is smaller compared to the one at the output.
(e) Drift velocities of electrons in one of the inputs and the output are the same.

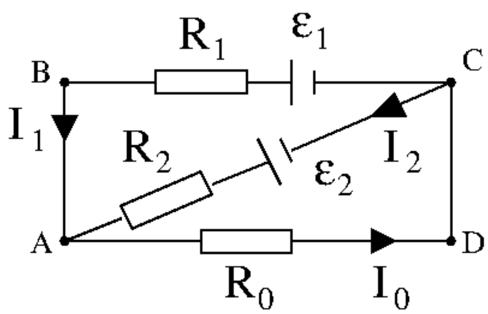
20. What should be current density at the output?
(a) 2.0 A/m^2 (b) 4.0 A/m^2 (c) 0.5 A/m^2 (d) 0.25 A/m^2 (e) 1.0 A/m^2

21. What should be the ratio between the total input and output currents?
(a) 0.25 (b) 2 (c) 0.5 (d) 1 (e) 4

22. What should be the drift velocity (in m/s) of electrons at the output?
(a) 5.0 10^{-6} (b) 5.0 10^{-10} (c) 6.25 10^{-11} (d) 5.0 10^{-8} (e) 6.25 10^{-4}

Questions 23-25

An electric circuit with ϵ_1=12 V, ϵ_2=6V, $R_0 = 8\Omega$, $R_1 = 6\Omega$ and $R_2 = 3\Omega$ are given.



23. What is I_1 current in Amperes?
(a) 1 (b) 1/3 (c) 16/15 (d) 4/15 (e) 14/15

24. What is the magnitude of $(V_A - V_C)$ in Volts?
(a) 28/5 (b) 12 (c) 3 (d) 24/5 (e) 32/5

25. What is power dissipated through R_1 resistor in watts?
(a) 392/75 (b) 1/75 (c) 39/75 (d) 0 (e) 4/75

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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.

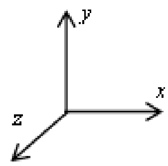
(a) $evBR$ (b) zero (c) $evB2\pi R$ (d) $e\frac{v^2}{R}B$ (e) ev^2BR

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

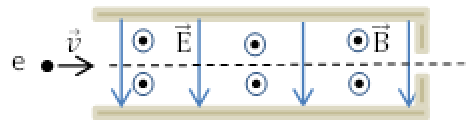
(a) $\frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$ (b) $\frac{4\pi}{\mu_0}\frac{q\vec{v}\times\hat{r}}{r^2}$ (c) $\frac{\mu_0}{4\pi}q\vec{v}\times\hat{r}$ (d) $\frac{\mu_0}{4\pi}\frac{q\vec{v}.\hat{r}}{r^2}$ (e) $\frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^3}$

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.

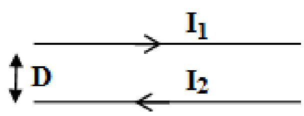


6. Only those electrons from the cathode that have a certain speed are required to pass through the hole at the right side of the instrument shown in figure. Electric field $\vec{E}$ (below direction) and magnetic field $\vec{B}$ (outside direction) are applied as shown in the figure. What is the speed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



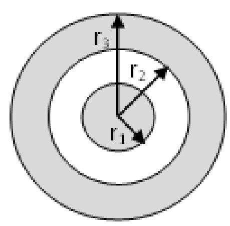
(a) $\frac{\mu_0 L I_1 I_2}{2\pi D}$, up (b) $\frac{\mu_0 L I_1 I_2}{2\pi D}$, to the right (c) $\frac{\mu_0 L I_1 I_2}{2\pi D}$, to the left (d) $\frac{\mu_0 L I_1}{2\pi D}$, up
(e) $\frac{\mu_0 L I_2}{2\pi D}$, down

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

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

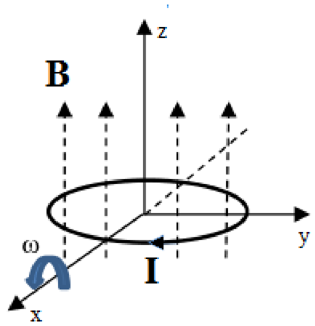
(a) $\frac{\mu_0 I}{2\pi(r_3^2 - r_2^2)}(\frac{r_3^2 - r^2}{r})$ (b) $\frac{\mu_0 I r}{2\pi(r_3^2 - r_2^2)}$ (c) $\frac{\mu_0 I}{2\pi(r_3^2 - r_2^2)}(\frac{r^2 - r_2^2}{r})$ (d) 0 (e) $\frac{\mu_0 I r}{2\pi r_3^2}$

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 $t = T/4$?

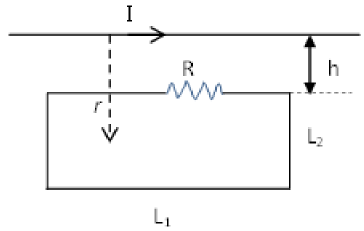
(a) 0 (b) $-I2\pi RB\hat{k}$ (c) $I\pi R^2B\hat{k}$ (d) $I\pi R^2B\hat{\imath}$ (e) $-I\pi R^2B\hat{\imath}$

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

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

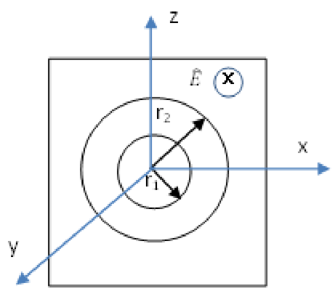
(a) $\frac{\mu_0 b h}{2\pi R}\ln(1+\frac{L_1}{L_2})$, clockwise (b) $\frac{\mu_0 b L_1 L_2}{2\pi h R}$, counter-clockwise (c) $\frac{-\mu_0 a L_2}{2\pi R}\ln(1+\frac{L_1}{h})$, counter-clockwise (d) $\frac{\mu_0 b L_1 L_2}{2\pi R}$, clockwise (e) $\frac{\mu_0 b L_1}{2\pi R}\ln(1+\frac{L_2}{h})$, counter-clockwise

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 please take: Speed of light $c = 3\times10^8$ m/s, $\pi = 3$, $\epsilon_0 = 9\times10^{-12}$ C^2/N.m^2, $\mu_0 = 12\times10^{-7}$ C^2/N.m^2, electron charge $e = 1.6\times10^{-19}$ (C).

1. Which of the following is incorrect (false) for the static electric field (the field created by the static electric charges) and the electric potential?

(a) Both the electric field and the potential are zero inside the solid metal sphere of charge Q .

(b) Electric field lines are perpendicular to the equipotential surfaces.

(c) If the potential is constant at a chosen point, the electric field is zero at the same point.

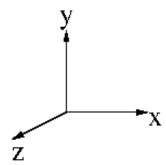
(d) The electric potential between two points can be calculated via the integral of the electric field between these two points.

(e) Derivative of the potential with respect to any coordinate (x, y, z) gives the corresponding electric field component with opposite sign.

2. The charge density of a spherical distribution is given as $\rho(r) = \rho_0(1 - \frac{r}{R})$ where R is the radius and r is the position with respect to the origin of the sphere. What is the magnitude of the electric field of this charge distribution at r=R/2?

(a) $\frac{5\rho_0\pi R^2}{48\epsilon_0}$ (b) $\frac{5\rho_0 R}{8\epsilon_0}$ (c) $\frac{5\rho_0 R^2}{32\epsilon_0}$ (d) $\frac{5\rho_0 R}{48\epsilon_0}$ (e) $\frac{5\rho_0\pi R^2}{32\epsilon_0}$

3. In figure, a constant magnetic field B is applied in y-direction and a constant electric field where $E = vB$ is applied in negative z-direction. A positive point-like charge q is moving with the constant velocity v, in the x direction enters this region at point O (the origin of the reference frame). Which of the following gives the correct answer about the magnitude and the direction of the net force on the q charge?



(a) 0 (b) $qvB(\hat{j} - \hat{k})$ (c) $-2qvB\hat{k}$ (d) $qvB(\hat{j} + \hat{k})$ (e) $2qvB\hat{k}$

4. Consider an inductor made up of a section of a very long (air-core) solenoid of length l , radius R and n turns per unit length. Suppose at some instant, the current, I, changes at a rate $dI/dt = 2$A/s. What is the magnitude of the Poynting vector inside the inductor?

(a) $\mu_0 n^2 RI$ (b) $\frac{\mu_0 n^2 RI}{2}$ (c) $\frac{n^2 RI}{2\mu_0}$ (d) $\mu_0 nR^2 I$ (e) $\frac{\pi R^2 nI}{\mu_0}$

5. Electric field component of an electromagnetic (EM) wave is given as $\vec{E} = 150(V/m)\sin[1.5(rad/m)\ x - 4.5\times10^8(rad/s)\ t]\hat{j}$. What is the approximate value of the average intensity of this EM wave?

(a) 0.31 W/m^2 (b) 31.0 W/m^2 (c) 3.1 W/m^2 (d) 0 W/m^2 (e) 310 W/m^2

6. A square shaped conducting loop with side b falls down in -y direction in a constant magnetic field applied in -z direction as shown in the figure. The resistance of the square loop is R. What is the magnitude and the direction of the induced current in the k-l segment of the loop. Take the gravitational acceleration as g.

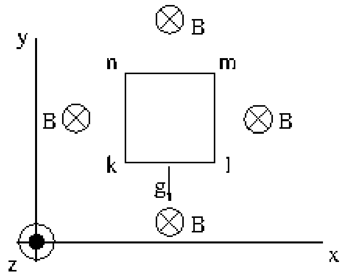
(a) No induced current is generated in this case.

(b) $\frac{Bbgt}{R}$; +x direction

(c) $\frac{Bbgt^2}{2R}$; +x direction

(d) $\frac{Bbgt^2}{2R}$; -x direction

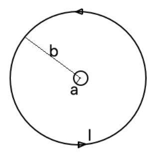
(e) $\frac{Bbgt}{R}$; -x direction



7. An induced emf never occurs in which of the following,

(a) A loop near a wire carrying a DC current switching on and off. (b) A rod moving perpendicular to a magnetic field. (c) A solenoid connected to a DC current. (d) A circular loop which its diameter expands in a magnetic field. (e) A disk rotating in a magnetic field.

8. What is the mutual inductance between two equi-centered circular loops lying on the same plane as shown. The outer loop carries the current I and b ≫ a.



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

9. What is the energy density in the region with uniform magnetic field of 4 T magnitude?

(a) 4 T/m^3 (b) 9.6×10^{-8} J/m^3 (c) 16 T/m^3 (d) 7.2×10^{-11} J/m^3 (e) $(2/3)\times10^7$ J/m^3

10. Which of the following is not correct for a conductor under an applied potential difference?

(a) Magnitude of electric field is proportional to the resistivity of the conductor. (b) Smaller the cross section is larger the drift velocity of the charge carriers is. (c) Electric field gets stronger where the cross section becomes smaller. (d) Electric field at a certain point is inversely proportional to the current at that point. (e) Average electric field inside the conductor is the potential difference across the conductor divided by the length of the conductor.

11. Ampere's Law $\oint \vec{B}.\vec{dl} = \mu_0 I_{enc}$ cannot be used for calculating the magnetic field
(a) from an infinitely long current carrying wire. (b) from the bundle of infinitely long current carrying wires. (c) inside and outside of a toroid. (d) from a short current carrying line. (e) inside a long solenoid.

Questions 12-16

The magnetic field component of a plane electromagnetic (EM) wave in a transparent medium (non-vacuum) is given as $\vec{B} = 10^{-7}$ (T) $\sin\left(1\times 10^6(\frac{\text{rad}}{\text{m}})x + 2\times 10^{14}(\frac{\text{rad}}{\text{s}})t\right)\hat{j}$

12. Which of the following is the speed of the EM wave in the medium?
(a) 0.5×10^{-8} m/s (b) 2×10^8 m/s (c) 3×10^8 m/s (d) 0.5×10^8 m/s (e) 5×10^{-8} m/s

13. Which of the following is the wavelength of the EM wave?
(a) 6×10^{-6} m (b) $(1/3)\times 10^{-6}$ m (c) $(1/6)\times 10^{-6}$ m (d) 1×10^{-6} m (e) 3×10^{-6} m

14. Which of the following pairs give the directions of propagation and electric field correctly?
(a) $-x, y$ (b) z, x (c) $-x, z$ (d) y, x (e) x, z

15. Which of the following is the electric field vector?
(a) $\vec{E} = 20$ (V/m) $\sin\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)\hat{i}$
(b) $\vec{E} = 30$ (V/m) $\sin\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)\hat{j}$
(c) $\vec{E} = 20$ (V/m) $\sin\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)\hat{k}$
(d) $\vec{E} = 40$ (V/m) $\sin\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)(-\hat{k})$
(e) $\vec{E} = \frac{1}{3}\times 10^{-15}$ (V/m) $\sin\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)\hat{k}$

16. Which of the following is the Poynting vector assuming that the magnetic permeability in the medium is equal to that of the vacuum (as is the case for most transparent materials)?
(a) $\vec{S} = 5(\text{J/s.m}^2)\sin^2\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)(-\hat{i})$
(b) $\vec{S} = (5/3)(\text{J/s.m}^2)\sin^2\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)(-\hat{j})$
(c) $\vec{S} = (5/3)(\text{J/s.m}^2)\sin^2\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)(-\hat{i})$
(d) $\vec{S} = (10)(\text{J/s.m}^2)\sin^2\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)\hat{i}$
(e) $\vec{S} = (5/3)(\text{J/s.m}^2)\sin^2\left(1\times 10^6(\frac{rad}{m})x + 2\times 10^{14}(\frac{rad}{s})t\right)\hat{i}$

Questions 17-21

A solenoid coil has 200 turns and self inductance 4 mH. The current in the coil varies with time according to $I = I_0 cos(2\pi t/T)$ where I_0=800 mA and T=0.03 s.

17. What is the maximum emf induced in the coil?
(a) 0.032 (b) 6.4 (c) 0.64 V (d) 0.064 (e) 3.2

18. What is the maximum flux in each turn of the coil?
(a) 0.8×10^{-5} Wb (b) 1.6×10^{-5} Wb (c) 3.2×10^{-5} Wb (d) 4.8×10^{-5} Wb (e) 0.4×10^{-5} Wb

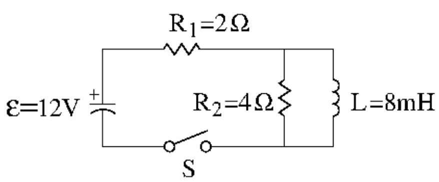
19. If the length of the solenoid is 10 cm, what is the volume of the solenoid
(a) 0.01/2 m^3 (b) 0.01/12 m^3 (c) 0.01/4 m^3 (d) 0.01/6 m^3 (e) 0.01/3 m^3

20. What is the average energy stored in the solenoid over the period T?
(a) 6400 mJ (b) 0.64 mJ (c) 64 mJ (d) 6.4 mJ (e) 640 mJ

21. If a circular coil with 1cm radius is placed inside the solenoid perpendicular to the solenoids axis, what would be the mutual inductance between the inner coil and solenoid?
(a) 0 μH (b) 1.152 μH (c) 1152 μH (d) 11.52 μH (e) 115.2 μH

Questions 22-25

The circuit in figure consists of an emf source, $\epsilon = 12$ V, two resistors, R_1=2Ω, R_2=4Ω and an inductor, L=8 mH. The switch S is kept closed for a long time. (Take ln3=1.)



22. What is the current in the resistor R_2?
(a) 6 A (b) 2 A (c) 1 A (d) 0 A (e) 3 A

23. What is the stored energy in the inductor?
(a) 0 J (b) 0.288 J (c) 0.144 J (d) 0.016 J (e) 0.032 J

24. The switch S is open at t=0. Immediately after opening what is the current in resistor R_2?
(a) 3 A (b) 0 A (c) 2 A (d) 1 A (e) 6 A

25. How long after opening the switch will the current through the inductor decrease one-thirds of its initial value?
(a) 2 ms (b) 32 ms (c) 8 ms (d) 48 ms (e) 16 ms

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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. Electric field inside a hollow metallic charged sphere

(a) increases towards the center. (b) is zero. (c) is none of the other options. (d) depends on the total charge of the sphere. (e) decreases towards the center.

2. When a dielectric material is placed in an electric field, the field strength

(a) becomes infinite. (b) remains unchanged. (c) increases. (d) decreases. (e) reduces to zero.

3. A constant voltage source (a battery) is kept connected to a parallel plate capacitor before and after a dielectric material is inserted in between the plates. The dielectric constant of the material is $\kappa = 5$. What is the new electric field (after inserting the dielectric) when compared to the original field before inserting the dielectric?

(a) (1/5) times of the original one. (b) 5 times larger than the original one. (c) (1/25) times of the original one. (d) 25 times larger than the original one. (e) The same as the original one.

4. The electric field at a point located at a distance d from a straight charged conductor with length l (where $d \gg l$) is approximately

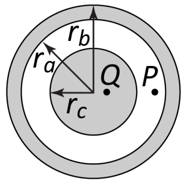
(a) inversely proportional to d. (b) proportional to d/l^2. (c) proportional to d^2. (d) proportional to d. (e) inversely proportional to d^2.

5. Unit of electric flux density is

(a) Weber/m^2 (b) Newton/Coulomb (c) Farad.m^2 (d) Farad (e) Weber

Questions 6-7

A very long, hollow metal cylinder has inner and outer radii of $r_a = 12$ cm and $r_b = 15$ cm, respectively. As shown in the figure, another very long, solid, uniformly charged insulating cylinder of radius $r_c = 5$ cm is located at the center of the hollow metal cylinder. The electric field at point P, a distance of $r_P = 10$ cm from the axis of the cylinders, is found to be $E_P = 3.6 \times 10^4$ N/C, directed radially outward. Take $k = 9 \times 10^9$ N.m^2/C^2.



6. Determine the total charge per unit length on the inner surface of the hollow metal cylinder.

(a) 2×10^{-7} C/m (b) -2×10^{-7} C/m (c) 1×10^{-8} C/m (d) 2×10^{-5} C/m (e) -2×10^{-5} C/m

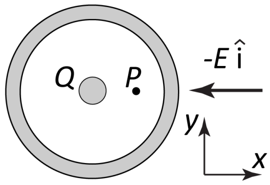
7. Determine the electric field at point Q, a distance of $r_Q = 1.25$ cm from the center of the solid insulating cylinder.

(a) 2.7×10^4 N/C (b) 3.6×10^4 N/C (c) 1.8×10^4 N/C (d) 7.2×10^4 N/C (e) 0.9×10^4 N/C

8. Two identical lightweight metal spheres are suspended near each other from insulating fibers. One sphere has a net charge; the other sphere has no net charge. The spheres will

(a) repel each other (b) attract each other (c) either attract or repel, depending on the sign of the charge on the charged sphere (d) start moving in a circle centered on their common center of mass (e) exert no net force on each other

9. A coaxial cable consist of a long, straight filament surrounded by a long, coaxial, cylindrical conducting shell (see figure). Assume charge Q is on the filament, zero net charge is on the shell, and the electric field is $E_1\hat{\imath}$ at a particular point P midway between the filament and the inner surface of the shell. Next, you place the cable into a uniform external field $-E\hat{\imath}$ where $E_1 > E > 0$. What is the x-component of the total electric field at P then?



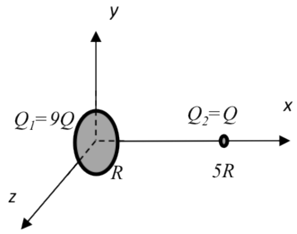
(a) $-E_1$ (b) Between 0 and E_1 (c) Between 0 and $-E_1$ (d) 0 (e) E_1

10. In a certain region of the space, the electric field is zero. From this fact, what can you conclude about the electric potential in this region?

(a) It has to be zero. (b) None of the other answers is necessarily true. (c) It has to be positive. (d) It does not vary with position. (e) It has to be negative.

Questions 11-15

A non-conducting solid sphere of radius R, uniformly charged with charge $Q_1 = 9Q$, is located at the center of the rectangular coordinate system. That is, the origin of the coordinate system coincides with the center of the sphere (shown in the figure on the right). Furthermore, a point-like charge, $Q_2 = Q$, is located at a distance $5R$ from the center of the sphere, as shown in the figure. Q is in c oulomb and R is in meter. The system is in vacuum and the dielectric constant of the non-conducting charged sphere is about 1.0, $\kappa \cong 1.0$ ($\epsilon = \kappa\epsilon_0 \approx \epsilon_0$)



11. What is the electric field vector at $x = R/2$?

(a) $\frac{721}{162}k\frac{Q}{R^2}(-\hat{\imath})$ (b) $\frac{729}{162}k\frac{Q}{R^2}(\hat{\imath})$ (c) $\frac{729}{162}k\frac{Q}{R^2}(-\hat{\imath})$ (d) $\frac{4}{81}k\frac{Q}{R^2}(\hat{\imath})$ (e) $\frac{721}{162}k\frac{Q}{R^2}(\hat{\imath})$

12. At what value of x does the electric field change its direction?

(a) $\frac{5R}{2}$ (b) $\frac{5R}{4}$ (c) $\frac{15R}{4}$ (d) $-R$ (e) 0

13. What is the electric field vector at the point $(0, 0, 5R)$?

(a) $\frac{kQ}{50R^2}(19\hat{k}-2\hat{\imath})$ (b) $\frac{kQ}{50R^2}(19\hat{k}+2\hat{\imath})$ (c) $\frac{kQ}{50R^2}\frac{\sqrt{2}}{2}[(18\sqrt{2}+1)\hat{k}-\hat{\imath}]$ (d) $\frac{2\sqrt{2}kQ}{50R^2}[(18\sqrt{2}-1)\hat{k}+\hat{\imath}]$ (e) $\frac{2\sqrt{2}kQ}{50R^2}[(18\sqrt{2}+1)\hat{k}-\hat{\imath}]$

14. What is the potential difference between the surface of the sphere and the position at $x = 3R$, $V(R, 0, 0) - V(3R, 0, 0)$?

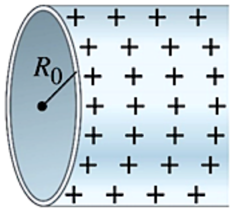
(a) $\frac{67}{2}k\frac{Q^2}{R}$ (b) $\frac{185}{20}k\frac{Q}{R}$ (c) $\frac{9}{5}k\frac{Q}{R}$ (d) $\frac{23}{4}k\frac{Q}{R}$ (e) -$\frac{9}{5}k\frac{Q}{R}$

15. If another point-like particle of charge Q is released from the point $(R, 0, 0)$ with a non-zero initial kinetic energy, what will be the difference in the final and initial kinetic energies of this particle when it reaches the point $(3R, 0, 0)$?

(a) $\frac{23}{4}k\frac{Q^2}{R^2}$ (b) $\frac{37}{4}k\frac{Q}{R}$ (c) $\frac{37}{4}k\frac{Q^2}{R^2}$ (d) $\frac{23}{4}k\frac{Q^2}{R}$ (e) $\frac{67}{2}k\frac{Q}{R}$

Questions 16-19

A long cylindrical shell of radius R_0 and length l ($R_0 \ll l$) has a uniform surface charge density σ (C/m^2).



16. What is the electric field outside the cylindrical shell?

(a) $\frac{\sigma r}{2R_0}$ (b) $\frac{\sigma}{2\pi\epsilon_0}(\frac{r}{R_0})^2$ (c) $\frac{\sigma R_0}{\epsilon_0 r}$ (d) $\frac{\sigma r}{2\pi\epsilon_0 R_0}$ (e) $\frac{\sigma r}{2\pi\epsilon_0 R_0^2}$

17. What is the electric field inside the cylindrical shell?

(a) 0 (b) $\frac{\sigma R_0}{\epsilon_0 r}$ (c) $\frac{\sigma r}{2R_0}$ (d) $\frac{\sigma r}{2\pi\epsilon_0 R_0}$ (e) $\frac{\sigma r}{2\pi\epsilon_0 R_0^2}$

18. The shell is at an electric potential V_0. What is the potential at a distance $r > R_0$ from the center of the shell?

(a) $V_0 - \frac{\sigma R_0}{2\pi\epsilon_0}\ln(\frac{R_0}{r})$ (b) $V_0 + \frac{\sigma R_0}{\epsilon_0}\ln(\frac{r}{R_0})$ (c) V_0 (d) $V_0 - \frac{\sigma R_0}{\epsilon_0}\ln(\frac{r}{R_0})$ (e) $V_0 - \frac{\sigma}{2\pi\epsilon_0}\ln(\frac{r}{R_0})$

19. The shell is at an electric potential V_0. What is the potential at a distance $r < R_0$ from the center of the shell?

(a) $\frac{\sigma R_0}{2\pi\epsilon_0}\ln(\frac{r}{R_0})$ (b) 0 (c) V_0 (d) $\frac{\sigma R_0}{2\pi\epsilon_0}\ln(\frac{R_0}{r})$ (e) $-V_0$

20. The functional form of the electric potential is given as $V(x, y, z) = Axy^2z$ where x, y, z are given in meters and A is a constant. Calculate the magnitude of the electric field in V/m at point (1,1,1) m.

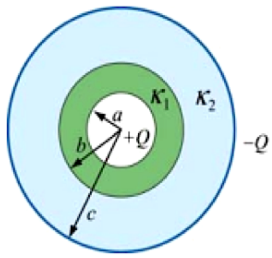
(a) $A\sqrt{5}$ (b) $2A$ (c) $A\sqrt{3}$ (d) $A\sqrt{6}$ (e) $3A$

21. The electric potential is given as $V(x, y, z) = Ay^2 - Bxy + Cx$ where A, B and C are positive constants. At which of the following points in space is the electric field equal to zero?

(a) $x = -B^2/2AC, y = -C/B, z = 0$ (b) $x = -A^2/2BC, y = -C/B, z = 0$ (c) $x = 2BC/A^2, y = -C/A, z = 0$ (d) $x = 2AC/B^2, y = C/B, z = 0$ (e) $x = -2AC/B^2, y = -C/A, z = 0$

Questions 22-25

The spherical capacitor shown in the figure consists of a solid metal core of radius $a = 10$ cm. Outside there is a non-conducting material with dielectric constant $\kappa_1 = 3$ up to the radius $b = 2a$ and another non-conducting material with $\kappa_2 = 2$ up to the radius $c = 3a$. The region from radius $r = 3a$ to $r = 4a$ is metal. The capacitor is connected to a battery of ε equal to 12 V. Assume that the charge on the inner conductor is Q and that the charge on the outer conductor is $-Q$, as shown in the figure.



22. What is the electric field inside the inner sphere and why?

(a) 0 since Ampere's law forbids it. (b) kQ/r because Coulomb's law requires it. (c) kQ/r^2 because Coulomb's law requires it. (d) kQ/r^2 because Gauss's law requires it. (e) 0 since there is no charge inside the solid metal core.

23. What is the electric field between $r = a$ and $r = 2a$ where the dielectric constant is $\kappa_1 = 3$?

(a) $Q/(4\pi\epsilon_0 r^2)$ (b) $Q/(16\pi\epsilon_0 a^2)$ (c) $Q/(12\pi\epsilon_0 a^2)$ (d) 0 (e) $Q/(12\pi\epsilon_0 r^2)$

24. Find the capacitance $C = Q/\varepsilon$ for this device.

(a) $16\pi/(\epsilon_0 a)$ (b) $16\pi\epsilon_0 a^2$ (c) $16\pi\epsilon_0 a$ (d) $16\pi\epsilon_0$ (e) $4\pi\epsilon_0 a$

25. Find the energy stored in the capacitor.

(a) $8\pi\epsilon_0 a\varepsilon^2$ (b) $16\pi\epsilon_0 a\varepsilon^2$ (c) 0 (d) $\varepsilon^2/(8\pi\epsilon_0 a)$ (e) $\varepsilon^2/(4\pi\epsilon_0 a)$

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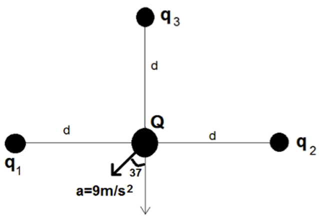
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

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.

Questions 1-3

Three point charges q_1, q_2, and q_3 are located in equal distances d = 1 m to the origin as shown in the figure. Another point charge Q = + 1 μC with mass m = 1 g is located at the origin and has an acceleration a = 9 m/s^2 with 37° angle to the y axis, as shown. (k = 9.109 Nm^2/C^2)



1. What are the sings of the charges?

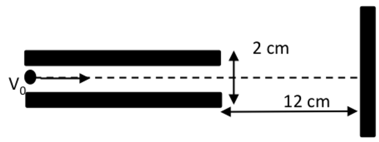
(a) q_2 and q_3 are +, q_1 is − (b) q_2 and q_3 are −, q_1 is + (c) q_1 and q_3 are +, q_2 is − (d) q_1, q_2 and q_3 are − (e) q_1, q_2 and q_3 are +

2. What is the magnitude of the net force acting on Q ?

(a) 9.0×10^{-3} N (b) 7.2 N (c) 7.2×10^{-3} N (d) 6.3×10^{-3} N (e) 9.0 N

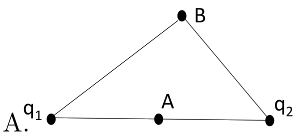
3. What is the magnitude of charge of q_3 ?

(a) 0.6 μC (b) 0.1 μC (c) 0.9 μC (d) 0.8 μC (e) 1.0 μC



4. In a cathode ray tube (CRT) of a computer monitor, an electron with an initial speed $v_0 = 6.6 \times 10^6$ m/s is projected along the axis midway between the deflection plates. The uniform electric field between the plate is 1000 V/m in upward direction. Gravitational force is negligible. How far below the axis has the electron moved when it reaches the end of the plates?

(a) 72 m (b) 8/108 m (c) 1/122 m (d) 8 m (e) 0.67 m

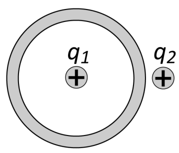


5. Two point charges q_1= 3 nC and q_2= -6 nC are 0.1 m apart. Point A is midway between them; point B is 0.08 m from q_1 and 0.06 m from q_2. Take the electric potential to be zero at infinity. Find the work done by the electric field on a charge of 2nC that travels from point B to A.

(a) 967 nJ (b) -0.29 nJ (c) 0.29 mJ (d) 1125 nJ (e) -145 nJ

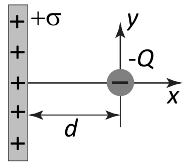
6. A cubic Gaussian surface surrounds a very long, straight, charged filament that passes perpendicularly through two opposite faces of the surface. No other charges are nearby. Through how many of the cubic surface faces is the electric flux zero?

(a) It depends on the location of the filament relative to the Gaussian surface (b) 2 (c) 0 (d) 6 (e) 4



7. A hollow, conducting sphere is initially uncharged. A positive charge, $+q_1$, is placed into the cavity inside the sphere, as shown in the figure. Then, a second positive charge, $+q_2$, is placed near the sphere but outside it. Which of the following statements describes the net electric force on each charge?

(a) There is no net electric force on either charge. (b) There is a net electric force on $+q_2$ but not on $+q_1$. (c) Both charges feel a net electric force of the same magnitude and the same direction. (d) There is a net electric force on $+q_1$ but not on $+q_2$. (e) Both charges feel a net electric force of the same magnitude and opposite directions.

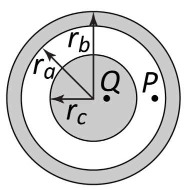


8. A very large nonconducting sheet with a positive uniform surface charge density $\sigma = +2.0\,\mu$C/m^2 is located at a distance $d = 0.2$ m from a negative point charge $Q = -12.0\,\mu$C. At what distance $x > 0$ (measured from the point charge) is the total electric field produced by both charge distributions zero? Take $\pi \approx 3$.

(a) 0.6 m (b) 0.1 m (c) 0.3 m (d) 1.2 m (e) 1 m

Questions 9-10

A hollow metal sphere has inner and outer radii of $r_a = 12$ cm and $r_b = 15$ cm, respectively. As shown in the figure, a solid, uniformly charged insulating sphere of radius $r_c = 5$ cm is located at the center of the hollow metal sphere. The electric field at point P, a distance of $r_P = 10$ cm from the center of the spheres, is found to be $E_P = 3.6 \times 10^4$ N/C, directed radially outward. Take $k = 9 \times 10^9$ N.m^2/C^2.



9. Determine the total charge on the inner surface of the hollow metal sphere.

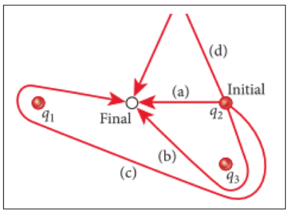
(a) -4×10^{-7} C (b) -4×10^{-8} C (c) 1×10^{-8} C (d) 4×10^{-7} C (e) 4×10^{-8} C

10. Determine the electric field at point Q, a distance of $r_Q = 1.25$ cm from the center of the insulating sphere.

(a) 3.6×10^4 N/C (b) 14.4×10^4 N/C (c) 1.8×10^4 N/C (d) 5.4×10^4 N/C (e) 7.2×10^4 N/C

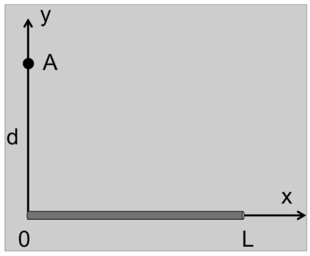
11. Three identical positive point charges are located at fixed points in space. Then charge q_2 is moved from its initial location to a final location as shown in the figure. Which path requires the least work?

(a) d (b) c (c) The work is the same for all the paths (d) b (e) a



Questions 12-15

A thin wire with length L = 4 m and a linear charge density given as a function of x by $\lambda = A$x, is placed along x axis as shown in the figure. $k = 9 \times 10^9$ Vm/C and $A = 2 \times 10^{-9}$ C/m.



12. What is the electric potential (at point A) at a perpendicular distance d = 3 m from one end of the wire?

(a) 12 V (b) 18 V (c) 4 V (d) 36 V (e) 2 V

13. What is the potential energy of a point charge q = 3 nC placed at point A?

(a) 36 nJ (b) 3 nJ (c) 72 nJ (d) 12 nJ (e) 108 nJ

14. What is the y-component of the electric field due to the charged wire at point A?

(a) 7.2 V/m (b) 9 V/m (c) $72/\sqrt{13}$ V/m (d) $36/\sqrt{13}$ V/m (e) 12 V/m

15. The potential in a region of a plane is given as V = 2xy - 3y^2 Volt. What is the y-component of the electric field at a position of (2 m, 3 m)?

(a) 5 V/m (b) $15/\sqrt{13}$ V/m (c) 8 V/m (d) 14 V/m (e) 12 V/m

Questions 16-20

A coaxial cable (TV antenna cable) of length "l" consists of an inner metallic wire of radius "a", a plastic layer around it up to radius"$4a$", outer metal mesh up to radius "$5a$" and an outer plastic layer up to radius "$8a$". The dielectric constant of the plastic is "κ". The inner wire is attached to the positive and the outer mesh wire to the negative terminals of a battery so that a charge of $+Q$ has accumulated on the inner and $-Q$ on the outer wires.

16. What is the electric field at radius $r < a$ inside the inner conductor?

(a) $Q/2\pi\kappa\epsilon_0 l^2$ (b) Q/lr (c) $Q/4\pi\kappa\epsilon_0 r^2$ (d) $Q/2\pi\kappa\epsilon_0 lr$ (e) 0

17. What is the electric field in the plastic layer between the inner and outer conductors?

(a) $Q/2\pi\kappa\epsilon_0 lr$ (b) Q/lr (c) $Q/2\pi\kappa\epsilon_0 r^2$ (d) $Q/2\pi\kappa\epsilon_0 l^2$ (e) 0

18. What is the potential difference between the inner and outer conductors?

(a) $(Q/2\pi\kappa\epsilon_0 l)e^4 a$ (b) $3aQ/lr$ (c) $(Q/2\pi\kappa\epsilon_0 l)\ln 4$ (d) $(Q/2\pi\kappa\epsilon_0 l)(3a)$ (e) 0

19. What is the capacitance of the coaxial cable?

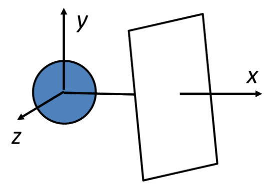
(a) $4\pi\kappa\epsilon_0 l/(\ln 4)$ (b) $l/2\pi\kappa\epsilon_0(\ln 4)$ (c) $2\pi\kappa\epsilon_0 l/(\ln 4)$ (d) 0 (e) $2\pi\kappa\epsilon_0 l/4$

20. What is the energy stored in the capacitor?

(a) $Q^2/4\pi\kappa\epsilon l$ (b) 0 (c) $Q^2 \ln 4/4\pi\kappa\epsilon_0 l$ (d) $Q^2/12\pi\kappa\epsilon_0 la$ (e) $3Q^2 a/4\pi\kappa\epsilon_0 l$

Questions 21-25

A conducting sphere of radius R=20 cm and an infinite non-conducting plane are located at the points (0,0,0) and (1m,0,0), respectively, as shown in figure. The system is in vacuum. The sphere is charged with $+Q = 2 \times 10^{-8}$ C. Positively charged plane has a surface charge density $\sigma = 18$ nC/m^2. Take $k = 9 \times 10^9$ Nm^{2}C^{-2}, charge of a proton $q = 1.6 \times 10^{-19}$ C, and $\epsilon_0 = 18 \times 10^{-12}$ C^2/ Nm^2



21. What is the net electric field (in N/C unit) at a distance x = 0.3 m between the sphere and the plane?

(a) $2000\hat{\imath}$ (b) $400(-\hat{\imath})$ (c) $1000\hat{\imath}$ (d) $400\hat{\imath}$ (e) $1000(-\hat{\imath})$

22. At which value of the x, in between the sphere and the plane, the net electric field change its direction?

(a) 0.36 m (b) 0.6 m (c) $\sqrt{0.72}$ m (d) $\sqrt{0.18}$ m (e) 0.4 m

23. At which value of the x the magnitude of the net electric field has its maximum value?

(a) 0 (b) -1.0 m (c) 1.0 m (d) -0.2 m (e) 0.2 m

24. What is the potential difference between the surface of the sphere and plane?

(a) -180 V (b) -80 V (c) 80 V (d) 1520 V (e) -1520 V

25. If a proton is set free from the surface of the sphere with initial kinetic energy K_1, what will be the change in the final and initial kinetic energies (in unit of Joule) of the proton when it reaches the plane; $K_2 - K_1 =$? (Give your result in terms of nano Joules)

(a) +2432 (b) +1284 (c) -128 (d) -2432 (e) -288

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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?

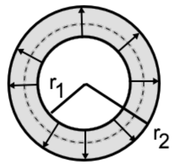
(a) $\rho/(\pi r^2)$ (b) $\pi r^2/(\rho t)$ (c) $\rho/(t\pi r^2)$ (d) $\rho t/(\pi r^2)$ (e) $\rho t/r^2$

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) $d_A = d_B$

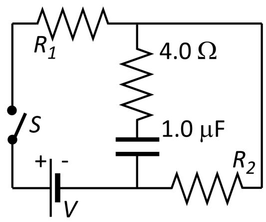
4. Determine the total resistance of a spherical shell made of material with conductivity σ, inner radius r_1, and outer radius r_2. Assume the current flows radially outward.

(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.

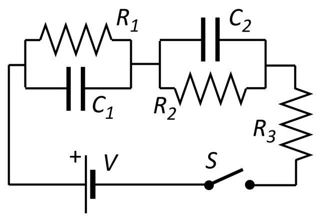
(a) 4.9 V (b) 0 (c) 6.8 V (d) 6.3 V (e) 2.0 V

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)?

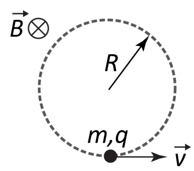
(a) 16 μJ (b) 2 μJ (c) 8 μJ (d) 32 μJ (e) 4 μJ

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 $\vec{B}$.

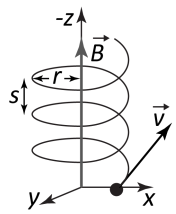
(b) Magnetic force does zero work on a moving charged particle.

(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.

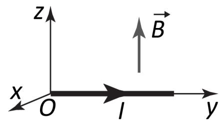
13. A particle with a positive charge q and mass m is traveling through a region with a uniform magnetic field $\vec{B} = B_0(-\hat{k})$ where B_0 is a constant. The velocity of the particle is given as $\vec{v} = v_0\hat{\imath} - 2v_0\hat{k}$ where v_0 is a constant. The path of the particle will be 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.



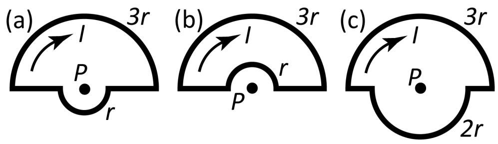
14. What is the magnitude and the direction of the net force on a segment of length L of this wire starting at the origin O?

(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

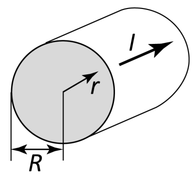
16. The three circuits shown in the figure consist of straight radial segments and concentric circular arcs (half-circles of radii r, $2r$, or $3r$). The circuits carry the same current I in the indicated direction. Rank the circuits according to the magnitude of the magnetic field produced at point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

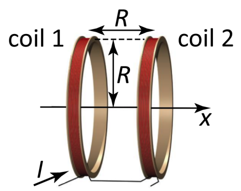
(a) $I/(\pi R^2)$ (b) $3I/(\pi R^2)$ (c) $2I/(\pi R^2)$ (d) $I/(3\pi R^2)$ (e) $3I/(2\pi R^2)$

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?

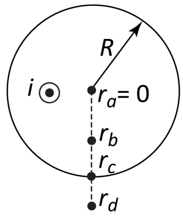
(a) $[16\pi/(5\sqrt{5})] \times 10^{-3}$ T (b) $[32\pi/(5\sqrt{5})] \times 10^{-3}$ T (c) $[4\pi/(5\sqrt{5})] \times 10^{-3}$ T (d) $[8\pi/(5\sqrt{5})] \times 10^{-3}$ T (e) 0

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.

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, $\mu_0 = 4\pi \times 10^{-7}$ Tm/A, electron charge $q_e = 1.6\ 10^{-19}$ C, electron mass $m_e = 9.11 \times 10^{-31}$ kg, $(\ln u)' = u'/u$, $(u/v)' = (u'v - v'u)/v^2$.

1. A metal ring is oriented with the plane of its area perpendicular to a spatially uniform magnetic field that increases at a steady rate. If the radius of the ring is doubled, by what factor does the emf induced in the ring change?

(a) 1/2 (b) 1/4 (c) 4 (d) 8 (e) 2

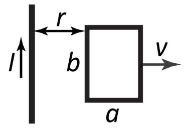
2. A flat rectangular coil consisting of 50 turns measures 20.0 cm by 15.0 cm. It is in a uniform 1.5 T magnetic field, with the plane of the coil parallel to the field. In 0.15 s, the coil is rotated uniformly so that the plane of the coil is now perpendicular to the field. What is the magnitude of the average emf (in volt unit) induced in the coil during this rotation?

(a) 1500 (b) 15 (c) 150 (d) 0.15 (e) 1.5

3. A long thin solenoid has 200 turns per meter and radius 3.0 cm. The current in the solenoid is increasing at a uniform rate of 50.0 A/s. What is the magnitude of the induced electric field (in N/C unit) at a point 1.00 cm from the axis of the solenoid?

(a) 6×10^{-5} (b) 3×10^{-5} (c) 3×10^{-4} (d) 1×10^{-5} (e) 5×10^{-5}

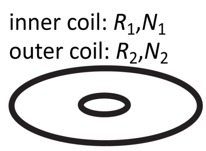
4. A rectangular loop with dimensions a and b is pulled to the right at a constant speed v with respect to a long wire carrying current I, as shown in the figure. What is the magnitude of the net emf ε induced in the loop?



(a) $\frac{\mu_0 I a b v}{2\pi r(r+a)}$ (b) $\frac{\mu_0 I a b}{2\pi r^2}$ (c) 0 (d) $\frac{\mu_0 2 I a b}{\pi r}$ (e) $\frac{\mu_0 I a b v}{2\pi r^2}$

Questions 5-8

A flat circular coil with radius $R_1 = 1$ cm and number of turns $N_1 = 2$ is placed at the center of another flat circular coil with radius R_2 =100 cm and number of turns $N_2 = 10$ as shown in the figure. Both coils are in the same horizontal plane, centered on the same point. The outer coil carries time dependent current $I = I_0 \cos(\omega t)$. Here, I_0= 5 A, ω is angular frequency of the current and t is time. Assume the magnetic field over the inner coil is approximately uniform because of $R_2 \gg R_1$.



5. What is the magnitude of magnetic field due to the outer coil over the inner coil?

(a) $3 \times 10^{-4} \sin(\omega t)$ T (b) $6 \times 10^{-6} \cos(\omega t)$ T (c) $6 \times 10^{-5} \cos(\omega t)$ T (d) $3 \times 10^{-6} \cos(\omega t)$ T (e) $3 \times 10^{-5} \cos(\omega t)$ T

6. What is the mutual inductance between the two coils?

(a) 36 nH (b) 1.8 nH (c) 3.6 nH (d) 0.18 nH (e) 18 nH

7. What is the magnetic energy stored in the inner coil due to the magnetic field generated by the outer coil? Assume the thickness of the inner coil is d and $d \ll R_1$.

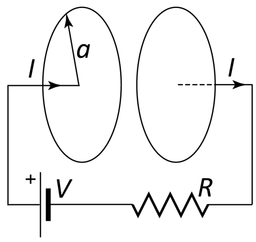
(a) $(9 \times 10^{-7}/8)d \cos(\omega t)\sin(\omega t)$ (b) $(9 \times 10^{-7}/8)d \sin^2(\omega t)$ (c) $(9 \times 10^{-7}/8)d \sin(\omega t)$ (d) $(9 \times 10^{-7}/8)d \cos^2(\omega t)$ (e) $(9 \times 10^{-7}/8)d \cos(\omega t)$

8. What is the induced current in the inner coil if the resistance of this coil is 5 Ω?

(a) $(18 \times 10^{-8}/5)\omega \sin(\omega t)$ (b) $(9 \times 10^{-9}/5)\omega \sin(\omega t)$ (c) $(9 \times 10^{-8}/5)\omega \sin(\omega t)$ (d) $(9 \times 10^{-7}/5)\omega \sin(\omega t)$ (e) $(18 \times 10^{-9}/5)\omega \sin(\omega t)$

Questions 9-11

An air-gap capacitor with 30 pF capacitance shown in the figure consists of two circular metal plates of radius $a = 6$ cm. It is charged by a $V = 72$ V battery through an $R = 2\,\Omega$ resistor. At the instant the battery is connected, the electric field between the plates starts changing rapidly. Assume the electric field is uniform between the plates at any instant and is zero at all points beyond the edges of the plates. Also, the initial charge of the capacitor is zero. At the instant the battery is connected:



9. Calculate the current I flowing into the metal plates.

(a) 124 A (b) 72 A (c) 36 A (d) 18 A (e) 0

10. Calculate the rate of change of electric field dE/dt between the plates.

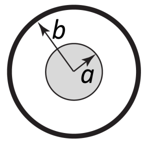
(a) $(4/27) \times 10^{16}$ V/ms (b) $(1/54) \times 10^{16}$ V/ms (c) $(2/27) \times 10^{16}$ V/ms (d) $(1/27) \times 10^{16}$ V/ms (e) None of the above

11. What is the magnitude of the maximum induced magnetic field between the circular plates?

(a) $\frac{\mu_0 \epsilon_0 a}{4}(dE/dt)$ (b) $\mu_0 \epsilon_0 a(dE/dt)$ (c) $\frac{\mu_0 \epsilon_0 a}{2}(dE/dt)$ (d) $\frac{3\mu_0 \epsilon_0 a}{2}(dE/dt)$ (e) None of them

Questions 12-14

The figure shows the end view of a long cylindric rod of radius "a" surrounded by a thin concentric cylindric shell of radius "b". Both are insulators, the inner rod has a volume charge density $+\rho$, and the outer cylindric shell has a surface charge density of -2σ,



12. What is the electric field between the rod and the cylindric shell ($a < r < b$)?

(a) $E = 2\pi a^2\rho/(\epsilon_0 r)$ (b) $E = a^2\rho/(2\epsilon_0 r)$ (c) $E = a^2\rho/(2\pi\epsilon_0 r)$ (d) $E = a^2\rho\pi/(\epsilon_0 r)$ (e) 0

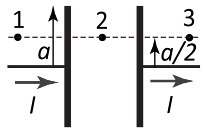
13. What is the electric field outside the cylindric shell ($r > b$)?

(a) $E = (a^2\rho - \sigma)/(2\epsilon_0 r)$ (b) $E = 2\pi a^2\rho/(\epsilon_0 r)$ (c) $E = 4b\sigma/(2\epsilon_0 r)$ (d) $E = \sigma/(2\epsilon_0 r)$ (e) $E = (a^2\rho - 4b\sigma)/(2\epsilon_0 r)$

14. What is the electric field inside the rod ($r < a$)? Assume that the dielectric constant of the rod is approximately equal to 1.

(a) $E = \rho r/(2\epsilon_0)$ (b) $E = \rho r^2/(2\epsilon_0 a)$ (c) $E = 2\rho r/\epsilon_0$ (d) $E = 2\pi a^2\rho/(\epsilon_0 r)$ (e) $E = \rho/(2\pi\epsilon_0 r)$

15. Figure on the right shows the side view of an air-gap capacitor which consists of two circular metal plates of radius a. Three points, labeled 1, 2 and 3, are located a distance $a/2$ from the horizontal center line, with points 1 and 3 outside and point 2 inside the capacitor. Compare the magnitude of the magnetic field at points 1, 2 and 3 during the time interval in which a constant current I is flowing through the capacitor. When computing magnetic fields, you may treat the current-carrying wires as being infinitely long.



(a) $|\vec{B}_1| = 4\sqrt{2}|\vec{B}_2| = |\vec{B}_3|$ (b) $|\vec{B}_1| = 4|\vec{B}_2| = |\vec{B}_3|$ (c) $|\vec{B}_1| = 2\sqrt{2}|\vec{B}_2| = |\vec{B}_3|$ (d) $|\vec{B}_1| = |\vec{B}_2| = |\vec{B}_3|$ (e) $|\vec{B}_1| = 2|\vec{B}_2| = |\vec{B}_3|$

Questions 16-19

A diode laser emits a sinusoidal electromagnetic wave that travels through vacuum. The wavelength of the wave is 900 nm and the maximum value of the electric field is $E_{max} = 120$ V/m. The electric field of the wave is given by $\vec{E} = E_{max}\cos(kx - \omega t)\hat{\jmath}$.

16. Which of the following expressions describes the magnetic field of the wave?

(a) $\vec{B} = [(3/2) \times 10^{-7}\,\text{T}]\cos(kx - \omega t)\hat{\imath}$ (b) $\vec{B} = [1 \times 10^{-7}\,\text{T}]\cos(ky - \omega t)\hat{k}$ (c) $\vec{B} = [4 \times 10^{-7}\,\text{T}]\cos(kx - \omega t)\hat{k}$ (d) $\vec{B} = [(5/3) \times 10^{-7}\,\text{T}]\cos(ky - \omega t)\hat{\jmath}$ (e) $\vec{B} = [9 \times 10^{-7}\,\text{T}]\cos(ky - \omega t)\hat{\imath}$

17. What is the direction of propagation of the wave?

(a) negative x-axis (b) negative y-axis (c) positive y-axis (d) positive x-axis (e) negative z-axis

18. What is the angular frequency of the wave?

(a) 9 $\times 10^{15}$ rad/s (b) 6 $\times 10^{15}$ rad/s (c) 1.5 $\times 10^{15}$ rad/s (d) 2 $\times 10^{15}$ rad/s (e) 3 $\times 10^{15}$ rad/s

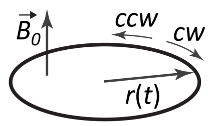
19. What is the average value of the Poynting vector magnitude over a full cycle?

(a) 40 W/m^2 (b) 90 W/m^2 (c) 60 W/m^2 (d) 30 W/m^2 (e) 20 W/m^2

20. A plane electromagnetic wave is traveling in vacuum. The electric and magnetic fields associated with this wave are $\vec{E} = E_{max}\sin(kz - \omega t)\hat{\imath}$ and $\vec{B} = B_{max}\sin(kz - \omega t)\hat{\jmath}$, respectively. Which one of the statements below is incorrect for this electromagnetic wave?

(a) The direction of the Poynting vector depends on the directions of each field. (b) Gauss's Law requires that the electromagnetic wave travels with speed c in vacuum. (c) The relationship between the magnitudes of the electric and magnetic fields is $E_{max} = B_{max}/\sqrt{\epsilon_0\mu_0}$. (d) The direction of the Poynting vector is in the $+z$ direction and its magnitude is $E_{max}B_{max}/\mu_0$. (e) Maxwell's equations require that the electromagnetic wave travels with speed c in vacuum.

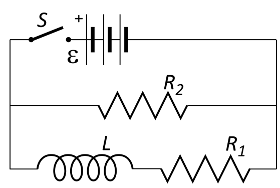
21. An elastic circular conducting loop expands at a constant rate over time such that its radius is given by $r(t) = r_0 + vt$, where r_0 and v are positive constants. The loop has a constant resistance of R and is placed in a uniform magnetic field of magnitude B_0, perpendicular to the plane of the loop, as shown in the figure. Calculate the magnitude and direction of the induced current, i, at time t.



(a) $2\pi B_0 r_0 t r(t)/R$, cw (b) $2\pi B_0 r_0 t r(t)/R$, ccw (c) $\pi B_0 r^2(t)/(vR)$, cw (d) $2\pi B_0 v r(t)/R$, cw (e) $2\pi B_0 v r(t)/R$, ccw

Questions 22-23

In the circuit shown in the figure, the battery supplies emf $\varepsilon = 6.0$ V, the resistances are $R_1 = 3.0\,\Omega$ and $R_2 = 5.0\,\Omega$ and the inductance is $L = 1.5$ H. Calculate:



22. The rate of current change across the resistor R_1 immediately after closing the switch S

(a) 4 A/s (b) 1.2 A/s (c) 0 (d) 2 A/s (e) 3.2 A/s

23. The net current flowing out of the battery long time after closing the switch S

(a) 1.2 A (b) 0 (c) 3.2 A (d) 4 A (e) 2 A

Questions 24-25

At the surface of the Earth, the Sun delivers an estimated 1.5 kW/m^2 of energy per unit time and area. A roof with dimensions of 10 m $\times$ 30 m is exposed to the sunlight incident perpendicularly to it.

24. Estimate the total energy incident on the roof in 1 minute.

(a) 9.0×10^4 J (b) 1.5×10^3 J (c) 7.5×10^3 J (d) 4.5×10^5 J (e) 2.7×10^7 J

25. Find the radiation pressure on the roof. Assume that the roof is a perfect reflector reflecting all of the incident light.

(a) 0.5×10^{-5} Pa (b) 3.0×10^{-3} Pa (c) 1.5×10^{-3} Pa (d) 9.0×10^{-2} Pa (e) 1.0×10^{-5} Pa

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ATTENTION: There is normally only one correct answer for each question and each correct answer is worth the same point. Only the answers on your answer sheet will be graded. Please be sure that you have marked all of your answers on the answer sheet by using a pencil (*not* pen).

If necessary $k = \frac{1}{4\pi\epsilon_0}$, $\epsilon_0 \approx 9 \times 10^{-12}\ C^2/Nm^2$

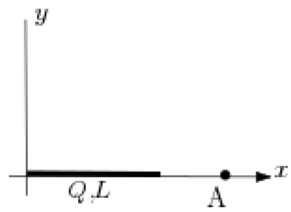
Questions 1-2

1. The magnitude of the electric force between the two charges does not depend on
(a) the distance between the charges (b) the sign of the charges (c) the magnitude of the charges (d) the dielectric constant of the medium (e) the distribution of charges

2. Which of the following has the unit of electric flux in the SI system?
(a) $kg.m^2/A.s^3$ (b) $kg^2.m/A.s^3$ (c) $kg.m^2/A.s^2$ (d) $kg.m^3/A.s^3$ (e) $kg^2.m^3/A.s^2$

Questions 3-6

A rod of length L and charge Q, which is uniformly distributed on the rod, is located on the x-axis, as shown in the figure. The coordinates of A is $(2L, 0)$.



3. What is the electric potential at A?
(a) $\frac{kQ}{L}\ln 3$ (b) $2\frac{kQ}{L}$ (c) $\frac{kQ}{L}\frac{1}{\ln 3}$ (d) $\frac{kQ}{L}\ln 2$ (e) $3\frac{kQ}{L}$

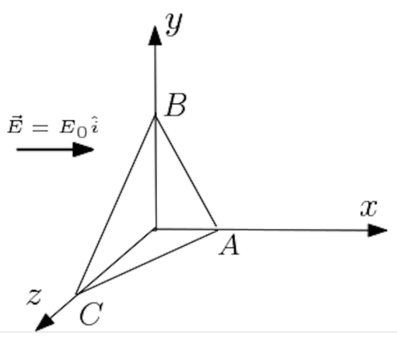
4. What is the magnitude of the electric field at A?
(a) $\frac{1}{2}\frac{kQ}{L^2}$ (b) $3\frac{kQ}{L^2}$ (c) $\frac{1}{3}\frac{kQ}{L^2}$ (d) $2\frac{kQ}{L^2}$ (e) $\frac{3}{2}\frac{kQ}{L^2}$

5. What is the work done **by the electric field** created by this rod to move a test charge of magnitude q from infinity to point A?
(a) $\frac{kQq}{L}\ln 3$ (b) $-\frac{1}{2}\frac{kQq}{L}$ (c) $\frac{kQq}{L}\ln 2$ (d) $-\frac{kQq}{L}\ln 3$ (e) $-\frac{kQq}{L}\ln 2$

6. If the charge density on the rod were $\lambda(x) = \alpha x$ where α is a constant and x is the distance from the origin, what would be the total charge on the rod?
(a) $\frac{3\alpha L^2}{2}$ (b) $\frac{\alpha L}{2}$ (c) $\frac{3\alpha L}{2}$ (d) αL (e) $\frac{\alpha L^2}{2}$

Questions 7-9

Consider a triangular prism located in a three-dimensional cartesian coordinate system, as shown in the figure. There is an external uniform electric field $\vec{E} = E_0\hat{i}$ and there is no charge inside the prism. The coordinates of the vertex points of the prism are: $A:\ (a, 0, 0)$, $B:\ (0, b, 0)$, and $C:\ (0, 0, c)$

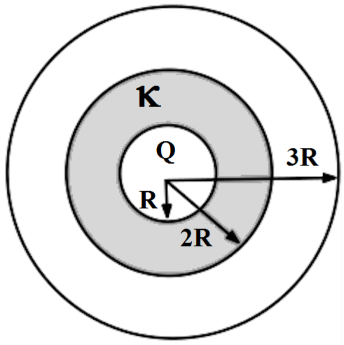


7. What is the total electric flux through the prism? (a) $-\frac{E_0ab}{2}$ (b) 0 (c) $\frac{E_0ab}{2}$ (d) $\frac{E_0bc}{2}$ (e) $-\frac{E_0bc}{2}$

8. What is the electric flux through the surface bounded by the points A, B, and C?
(a) $\frac{E_0ac}{2}$ (b) $-\frac{E_0ab}{2}$ (c) $\frac{E_0bc}{2}$ (d) 0 (e) $-\frac{E_0ac}{2}$

9. If the net electric flux through the prism were 3 Nm^2/C, what would be the amount of charge enclosed by the prism?
(a) $20 \times 10^{-12}\ C$ (b) $27 \times 10^{-12}\ C$ (c) $24 \times 10^{-12}\ C$ (d) $29 \times 10^{-12}\ C$ (e) $18 \times 10^{-12}\ C$

Questions 10-15



Consider the system shown in the figure: A spherical shell of radius R and charge Q is concentric with a neutral spherical **conductor** of inner radius $2R$ and outer radius $3R$, and the region between the spherical shell and the conductor is filled with a dielectric material of constant κ.

10. What is the magnitude of the electric field in the region $R < r < 2R$?
(a) $\frac{2kQ}{3\kappa r^2}$ (b) $\frac{2kQ}{\kappa r^2}$ (c) $\frac{kQ}{\kappa r^2}$ (d) $\frac{kQ}{2\kappa r^2}$ (e) $\frac{kQ}{3\kappa r^2}$

11. What is the magnitude of the electric field in the region $3R < r$?
(a) $\frac{2kQ}{3r^2}$ (b) $\frac{kQ}{2r^2}$ (c) $\frac{2kQ}{r^2}$ (d) $\frac{kQ}{r^2}$ (e) $\frac{kQ}{3r^2}$

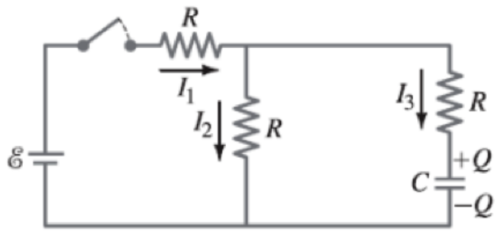
12. What is the charge on the outer surface of the conductor at $r = 3R$?
(a) $3Q$ (b) $2Q$ (c) $-Q$ (d) $-2Q$ (e) Q

13. What is the electric potential in the conductor, assuming that the potential is zero at infinity?
(a) $\frac{kQ}{R}$ (b) $\frac{3kQ}{2R}$ (c) $\frac{2kQ}{3R}$ (d) $\frac{kQ}{2R}$ (e) $\frac{kQ}{3R}$

14. What would be the charge on the inner surface of the conductor if there were no dielectric material in the region $R < r < 2R$?
(a) $3Q$ (b) $2Q$ (c) $-3Q$ (d) $-2Q$ (e) $-Q$

15. What is the electrostatic energy stored in the dielectric region $R < r < 2R$?
(a) $\frac{kQ^2}{4\kappa^2 R}$ (b) $\frac{kQ^2}{3\kappa^2 R}$ (c) $\frac{kQ^2}{\kappa^2 R}$ (d) $\frac{2kQ^2}{3\kappa^2 R}$ (e) $\frac{3kQ^2}{4\kappa^2 R}$

Questions 16-20



Consider the RC-circuit shown in the figure, where all resistors have the same resistance R. The capacitor is initially uncharged and at $t = 0$ the switch is closed.

16. What is the current I_3 immediately after the switch is closed?
(a) $2\varepsilon/(3R)$ (b) $\varepsilon/(2R)$ (c) $\varepsilon/(4R)$ (d) 0 (e) $\varepsilon/(3R)$

17. What is the current I_3 as $t \to \infty$ after the switch is closed?
(a) 0 (b) $\varepsilon/(3R)$ (c) $\varepsilon/(4R)$ (d) $2\varepsilon/(3R)$ (e) $\varepsilon/(2R)$

18. What is the potential difference across the capacitor as $t \to \infty$ after the switch is closed?
(a) $\varepsilon/2$ (b) 0 (c) $2\varepsilon/3$ (d) $\varepsilon/4$ (e) $\varepsilon/3$

19. What is the amount of charge accumulated in the capacitor as a function of time when the switch is closed?
(a) $Q(t) = \frac{\varepsilon C}{3}\left[1 - e^{-2t/(3RC)}\right]$
(b) $Q(t) = \frac{2\varepsilon C}{3}\left[1 - e^{-2t/(3RC)}\right]$
(c) $Q(t) = \frac{\varepsilon C}{2}\left[1 - e^{-2t/(3RC)}\right]$
(d) $Q(t) = \frac{3\varepsilon C}{2}\left[1 - e^{-2t/(3RC)}\right]$
(e) $Q(t) = \frac{3\varepsilon C}{4}\left[1 - e^{-2t/(3RC)}\right]$

20. What is the time constant of the circuit when the switch is closed?
(a) $\frac{RC}{2}$ (b) $\frac{3RC}{4}$ (c) $\frac{2RC}{3}$ (d) $\frac{3RC}{2}$ (e) $\frac{RC}{3}$

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ATTENTION: There is normally only one correct answer for each question and each correct answer is worth the same point. Only the answers on your answer sheet will be graded. Please be sure that you have marked all of your answers on the answer sheet by using a pencil (*not* pen).

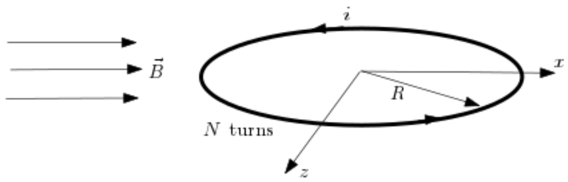
Questions 1-2

1. Which of the following is the displacement current term in the Ampere's Law, expressed in the SI unit system?
(a) $\frac{1}{2}\epsilon_0\vec{E}^2$ (b) $\frac{1}{\mu_0}\vec{E}\times\vec{B}$ (c) $\mu_0\vec{J}$ (d) $-\frac{d\vec{B}}{dt}$ (e) $\epsilon_0\mu_0\frac{\partial\vec{E}}{\partial t}$

2. Which of the following has the unit of magnetic flux in the SI system?
(a) $N.m/A$ (b) $N.m^2/A.s$ (c) $kg^2m/A.s^3$ (d) $kg^2.m^3/As^2$ (e) $kg.m^3/A.s^2$

Questions 3-5

A circular coil of radius $R = 50\ cm$ with $N = 20$ turns of wire lies in the xz-plane, as shown in the figure. The coil carries a current of $i = 8.0\ A$ in a counterclockwise sense when viewed from above. The coil is in a uniform magnetic field of $\vec{B} = 1.50\ T\hat{i}$. (Take $\pi = 3$.)



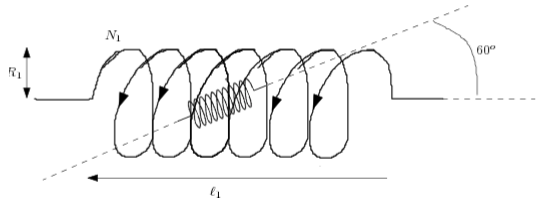
3. What is the magnetic dipole moment vector of the coil?
(a) $120\ Am^2\hat{k}$ (b) $60\ Am^2\hat{k}$ (c) $120\ Am^2\hat{j}$ (d) $30\ Am^2\hat{j}$ (e) $60\ Am^2\hat{j}$

4. What is the torque on the coil for the initial position of the coil shown in the figure?
(a) $-120\ Nm\hat{j}$ (b) $-120\ Nm\hat{k}$ (c) $-180\ Nm\hat{j}$ (d) $-180\ Nm\hat{k}$ (e) $-60\ Nm\hat{j}$

5. If the coil rotates from its initial position to a position where its magnetic moment is parallel to $\vec{B}$, what is the change in the potential energy of the system?
(a) $180\ Nm$ (b) $-180\ Nm$ (c) $0\ Nm$ (d) $-120\ Nm$ (e) $120\ Nm$

Questions 6-10

Consider an ideal solenoid of radius R_1, and length ℓ_1 with N_1 turns carrying a current of i. Another smaller ideal solenoid of radius R_2, and length ℓ_2 with N_2 turns is located inside the bigger one, as shown in the figure. The angle between the symmetry axes of the solenoids is 60^o.



6. What is the magnetic field generated by the bigger solenoid?
(a) $\mu_0N_1(\ell_1+\ell_2)i/(\ell_1\ell_2)$ (b) $\mu_0\sqrt{N_1N_2}i/\ell_1$ (c) $\mu_0(N_1+N_2)i/\ell_1$ (d) μ_0N_1i/ℓ_1 (e) $\mu_0N_2i/\sqrt{\ell_1\ell_2}$

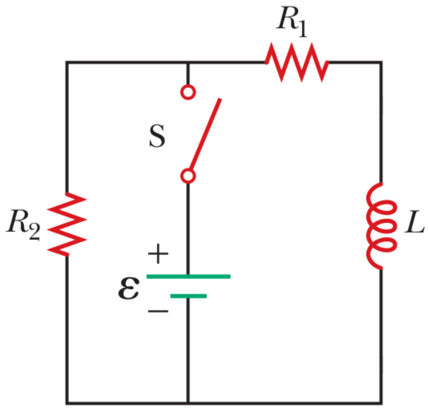
7. What is the magnetic flux generated by the outer solenoid in one loop of the inner (smaller) solenoid?
(a) $\mu_0N_1N_2i\pi R_1R_2/2\ell_1$ (b) $\mu_0N_2^2i\pi R_1R_2/2\ell_1$ (c) $\mu_0N_2^2i\pi R_2^2/2\ell_1$ (d) $\mu_0N_1i\pi R_2^2/2\ell_1$
(e) $\mu_0N_1^2i\pi R_2^2/2\ell_1$

8. What is the self-inductance of the outer (bigger) solenoid?
(a) $\mu_0N_1^2\pi R_1^2/\ell_2$ (b) $\mu_0N_1^2\pi R_1R_2/\ell_2$ (c) $\mu_0N_2^2\pi R_1^2/\ell_1$ (d) $\mu_0N_1N_2\pi R_1^2/\ell_1$ (e) $\mu_0N_1^2\pi R_1^2/\ell_1$

9. What is the mutual-inductance between the outer solenoid and the inner solenoid?
(a) $\mu_0N_1N_2(\ell_1+\ell_2)\pi R_2^2/(\ell_1\ell_2)$ (b) $\mu_0N_1N_2\pi R_2^2/2\ell_1$ (c) $\mu_0N_1^2\pi R_2^2/2\ell_1$ (d) $\mu_0N_1^2(\ell_1+\ell_2)\pi R_2^2/(\ell_1\ell_2)$
(e) $\mu_0N_1N_2\pi R_2^2/\ell_1$

10. What is the magnetic energy stored in the inner solenoid?
(a) $\mu_0N_1^2i^2\pi R_2^2\ell_2/2\ell_1^2$ (b) $\mu_0N_1N_2i^2\pi R_1R_2\ell_2/2\ell_1^2$ (c) $\mu_0N_1^2i^2\pi R_1R_2\ell_2/\ell_1^2$ (d) $\mu_0N_1^2i^2\pi R_2^2\ell_2/\ell_1^2$
(e) $\mu_0N_1^2i^2\pi R_2^2/\ell_1$

Questions 11-14



Consider the RL-circuit shown in the figure. At $t = 0$ the switch S is closed.

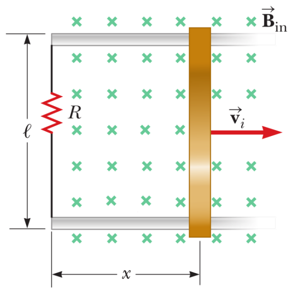
11. What are the currents on R_1 and R_2, respectively, just after the switch S is closed?
(a) $\mathcal{E}/R_1$, 0 (b) $\mathcal{E}/(R_1 + L)$, $\mathcal{E}/R_2$ (c) $\mathcal{E}/R_{eq}$, $\mathcal{E}/R_{eq}$ where $R_{eq} = R_1R_2/(R_1 + R_2)$ (d) $\mathcal{E}/R_1$, $\mathcal{E}/R_2$ (e) 0,$\mathcal{E}/R_2$

12. What is the current on R_2 a long time after the switch S is closed?
(a) $\mathcal{E}/(R_1 + L)$ (b) $\frac{\mathcal{E}(R_1+R_2)}{R_1R_2}$ (c) $\mathcal{E}/(R_1 + R_2)$ (d) $\mathcal{E}/R_2$
(e) $\mathcal{E}/R_1$

13. What are the currents on the resistors at any time t after the switch S is closed?
(a) $\frac{\mathcal{E}}{R_1}\left[1 - e^{-Lt/R_1}\right]$, $i_2 = \mathcal{E}/R_2$ (b) $\frac{\mathcal{E}}{R_1}\left[1 - e^{-R_1t/L}\right]$, $i_2 = \mathcal{E}/(R_1 + R_2)$ (c) $\frac{\mathcal{E}}{R_1}\left[1 - e^{-R_1t/L}\right]$, $i_2 = \mathcal{E}/R_1$ (d) $\frac{\mathcal{E}}{R_2}\left[1 - e^{-R_2t/L}\right]$, $i_2 = \mathcal{E}/R_1$ (e) $\frac{\mathcal{E}}{R_1}\left[1 - e^{-R_1t/L}\right]$, $i_2 = \mathcal{E}/R_2$

14. What is the current on the resistor R_2 immediately after the switch S is opened again?
(a) $\mathcal{E}/(R_1 + L)$ (b) $\mathcal{E}/R_2$ (c) $\mathcal{E}/R_1$ (d) $\mathcal{E}/R_{eq}$ where $R_{eq} = R_1R_2/(R_1 + R_2)$ (e) $\mathcal{E}/(R_1 + R_2)$

Questions 15-16



The conducting bar, shown in the figure, moves on two frictionless, parallel rails in the presence of a uniform magnetic field directed into the page. The bar has mass m, and its length is ℓ. The bar is given an initial velocity v_i to the right at $t = 0$.

15. Which of the following is the magnetic force and its direction acting on the bar when its velocity is v?
(a) $B^2\ell^2v/R$, out of page (b) $B\ell v$, left
(c) $B\ell v$, right (d) $B^2\ell^2v/R$, left (e) $B^2\ell^2v/R$, right

16. Applying Newtons second law to the bar in the horizontal direction, which of the following gives the velocity v at any time t, where τ is the time constant τ?
(a) $v = v_ie^{-t/\tau}$, $\tau = B^2\ell^2/mR$ (b) $v = v_i(1-e^{-t/\tau})$, $\tau = mR/B^2\ell^2$ (c) $v = v_ie^{-t/\tau}$, $\tau = mR/B^2\ell^2$
(d) $v = v_ie^{-t/\tau}$, $\tau = mR/B\ell$
(e) $v = v_i(1 - e^{-t/\tau})$, $\tau = mR/B\ell$

Questions 17-20

The magnetic field component of a plane electromagnetic wave propagating in vacuum is given as $\vec{B} = (3\sqrt{\pi} \times 10^{-8}\ T)sin(\frac{\pi}{3}z + \omega t)\hat{i}$. ($c = 3 \times 10^8\ m/s$ and $\mu_0 = 4\pi \times 10^{-7}\ T.m/A$.)

17. What is thedirection of propagation of this plane electromagnetic wave?
(a) in $+x$-direction (b) in $-x$-direction (c) in $-y$-direction (d) in $+z$-direction (e) in $-z$-direction

18. What is the frequency of this electromagnetic wave?
(a) 125 MHz (b) 75 MHz (c) 50 MHz (d) 25 MHz (e) 100 MHz

19. What is the corresponding electric field component of this plane electromagnetic wave?
(a) $(9\sqrt{\pi}\ N/C)sin(\frac{\pi}{3}z + \omega t)\hat{i}$ (b) $(3\sqrt{\pi}\ N/C)sin(\frac{\pi}{3}z + \omega t)\hat{j}$ (c) $(9\sqrt{\pi}\ N/C)sin(\frac{\pi}{3}z + \omega t)\hat{j}$
(d) $(3\pi\ N/C)sin(\frac{\pi}{3}z + \omega t)\hat{k}$ (e) $(3\sqrt{\pi}\ N/C)sin(\frac{\pi}{3}z + \omega t)\hat{i}$

20. What is the intensity of this electromagnetic wave?
(a) $\frac{27}{40}\ W/m^2$ (b) $\frac{81}{80}\ W/m^2$ (c) $\frac{9}{40}\ W/m^2$ (d) $\frac{27}{80}\ W/m^2$ (e) $\frac{9}{80}\ W/m^2$

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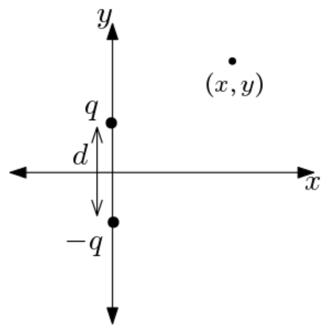
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

For all questions take: $k = 1/(4\pi\epsilon_0) \approx 9 \times 10^9$ N·m^2/C^2

Questions 1-3

Two point charges of magnitude $-q$ and q are located at points $(0, -d/2)$ and $(0, d/2)$, respectively, in a two dimensional xy-coordinate system as shown in the figure. This construction is known as the electric dipole of magnitude $p = qd$.



1. Which of the following is the electric potential created by this dipole at an arbitrary point (x, y)?

(a) $kq\left(\frac{1}{\sqrt{x^2+(y-d/2)^2}} - \frac{1}{\sqrt{x^2+(y-d/2)^2}}\right)$

(b) $kq\left(\frac{1}{\sqrt{x^2+(y-d/2)^2}} - \frac{1}{\sqrt{x^2+(y+d/2)^2}}\right)$

(c) $kq\left(\frac{1}{\sqrt{x^2+(y-d)^2}} + \frac{1}{\sqrt{x^2+(y+d)^2}}\right)$ (d) $kq\left(\frac{1}{\sqrt{x^2+(y-d/2)^2}} + \frac{1}{\sqrt{x^2+(y+d/2)^2}}\right)$

(e) $kq\left(\frac{1}{\sqrt{(x-d/2)^2+(y-d/2)^2}} - \frac{1}{\sqrt{(x-d/2)^2+(y+d/2)^2}}\right)$

2. Which of the following is the electric field vector created at the point $(d, 3d/2)$?

(a) $\frac{kq}{d^2}\left[\left(\frac{1}{2^{3/2}} + \frac{1}{5^{3/2}}\right)\hat{\imath} + \left(\frac{1}{2^{3/2}} + \frac{2}{5^{3/2}}\right)\hat{\jmath}\right]$

(b) $\frac{kq}{d^2}\left[\left(\frac{1}{2^{3/2}} - \frac{1}{5^{3/2}}\right)\hat{\imath} - \left(\frac{1}{2^{3/2}} - \frac{2}{5^{3/2}}\right)\hat{\jmath}\right]$ (c) $\frac{kq}{d^2}\left[\left(\frac{1}{2^{3/2}} - \frac{1}{5^{3/2}}\right)\hat{\imath} + \left(\frac{1}{2^{3/2}} - \frac{2}{5^{3/2}}\right)\hat{\jmath}\right]$ (d) $\frac{kq}{d^2}\left[\left(\frac{1}{2^{3/2}} - \frac{1}{5^{3/2}}\right)\hat{\imath} + \left(\frac{1}{2^{3/2}} + \frac{2}{5^{3/2}}\right)\hat{\jmath}\right]$

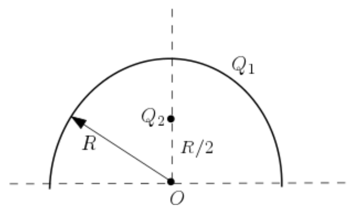
(e) $\frac{kq}{d^2}\left[\left(\frac{1}{2^{3/2}} + \frac{1}{5^{3/2}}\right)\hat{\imath} + \left(\frac{1}{2^{3/2}} - \frac{2}{5^{3/2}}\right)\hat{\jmath}\right]$

3. What is the work done by electric forces on a test charge Q to move it from the point $(4d, 0)$ to $(d, 3d/2)$?

(a) $\frac{kQq}{d}\left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{5}}\right)$ (b) $+\frac{kQq}{d}\left(\frac{1}{\sqrt{3}} - \frac{1}{\sqrt{5}}\right)$ (c) $-\frac{kQq}{d}\left(\frac{1}{\sqrt{2}} - \frac{1}{\sqrt{5}}\right)$ (d) $-\frac{kQq}{d}\left(\frac{1}{\sqrt{2}} - \frac{1}{\sqrt{3}}\right)$ (e) $\frac{kQq}{d}\left(\frac{1}{\sqrt{2}} - \frac{1}{\sqrt{3}}\right)$

Questions 4-5

A wire of charge Q_1 is bended into the shape of a semicircular wire of radius R, and located in a two dimensional xy-coordinate system as shown in the figure. A point charge of Q_2 is located at $(0, R/2)$ in this coordinate system.



4. What is $\frac{Q_2}{Q_1}$ if the electric potential at point O is zero?

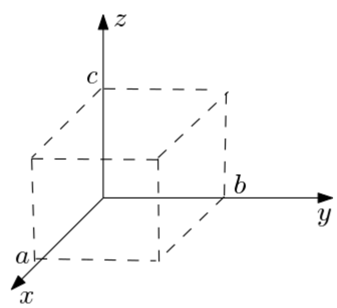
(a) $\frac{1}{3}$ (b) $-\frac{1}{3}$ (c) $\frac{1}{2}$ (d) $-\frac{1}{2}$ (e) -2

5. What is $\frac{Q_2}{Q_1}$ if the electric field at point O is zero?

(a) $\frac{1}{2}$ (b) -2 (c) $\frac{1}{3\pi}$ (d) $-\frac{\pi}{3}$ (e) $-\frac{1}{2\pi}$

Questions 6-8

Consider a region of the shape of a rectangular box in the three dimensional coordinate system shown in the figure.



6. Assuming that if there is no electric charge in the region and there is a uniform electric field of the form $\vec{E} = 3\hat{\imath} - 2\hat{\jmath}$, which of the following is the net electric flux through the region?

(a) $3ac$ (b) $2ab$ (c) $2ac$ (d) 0 (e) $3ab$

7. Assuming that there is an electric field of the form $\vec{E} = 2z\hat{k}$, which of the following is the total electric flux through this region?

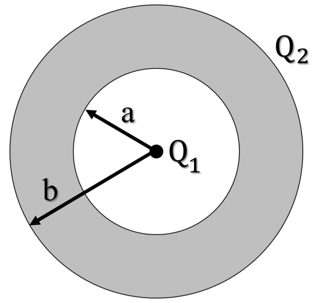
(a) $3abc$ (b) $2abc$ (c) $4abc$ (d) $3bc$ (e) $5abc$

8. For the electric field of the form $\vec{E} = 2z\hat{k}$, what is the amount of electric charge inside the box?

(a) $5\epsilon_0 abc$ (b) $3\epsilon_0 abc$ (c) $2\epsilon_0 abc$ (d) $4\epsilon_0 abc$ (e) $3\epsilon_0 bc$

Questions 9-13

A point charge Q_1 is located at the center of a thick metal shell of inner radius a and outer radius b as shown in the figure. The charge on the outer surface of the metal shell in this configuration is Q_2.



9. What is the total charge on inner surface ($r = a$) of the conducting spherical shell?

(a) Q_1 (b) $-Q_1$ (c) $-2Q_1 + Q_2$ (d) Q_2 (e) $Q_2 - Q_1$

10. What is the electric field at any point in the cavity inside the spherical shell? ($\vec{E}_{r<a} =?$)

(a) $k\frac{2Q_1-Q_2}{r^2}\hat{r}$ (b) $k\frac{Q_1+Q_2}{r^2}\hat{r}$ (c) $k\frac{Q_2}{r^2}\hat{r}$ (d) $k\frac{Q_1-Q_2}{r^2}\hat{r}$ (e) $k\frac{Q_1}{r^2}\hat{r}$

11. What is the potential difference between a point at a distance $a/2$ from the center and a point on the outer surface of the conducting spherical shell? ($V(r = a/2) - V(r = b)$=?)

(a) $k\frac{Q_1+Q_2}{a}$ (b) $k\frac{Q_2}{a}$ (c) $k\frac{Q_1}{b}$ (d) $k\frac{Q_1}{a}$ (e) $k\frac{Q_2-Q_1}{b}$

12. What is the electric field at any point in the region $r > b$? ($\vec{E}_{r>b} =?$)?

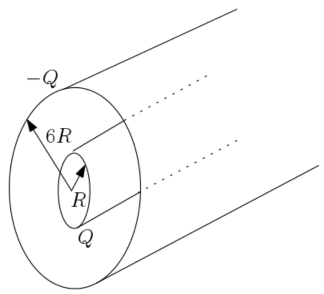
(a) $k\frac{2Q_1-Q_2}{r^2}\hat{r}$ (b) $k\frac{Q_1-Q_2}{r^2}\hat{r}$ (c) $k\frac{Q_1}{r^2}\hat{r}$ (d) $k\frac{Q_1+Q_2}{r^2}\hat{r}$ (e) $k\frac{Q_2}{r^2}\hat{r}$

13. What is the total energy stored in the electric field outside the spherical shell in the region $b < r < \infty$? ($U_{b<r<\infty} =?$)

(a) $\frac{Q_2^2}{8\pi\epsilon_0 b}$ (b) $\frac{2Q_1^2-Q_2^2}{8\pi\epsilon_0 b}$ (c) $\frac{Q_1^2}{8\pi\epsilon_0 b}$ (d) $\frac{Q_2^2+Q_1^2}{8\pi\epsilon_0 a}$ (e) $\frac{Q_2^2-Q_1^2}{8\pi\epsilon_0 a}$

Questions 14-17

A cylindrical capacitor consists of two coaxial cylindrical metal shells as shown in the figure. The inner shell has radius R and charge Q and the outer shell has radius $6R$ and charge $-Q$. Both cylinders have length L which is assumed to be much greater than R.



14. Which of the following is the electric field in the region $6R > r > R$?

(a) $\frac{Q}{2\pi\epsilon_0 L^2}$ (b) $\frac{Q}{2\pi\epsilon_0 r^2}$ (c) $\frac{Q}{4\pi\epsilon_0 r^2}$ (d) $\frac{Q}{4\pi\epsilon_0 Lr}$ (e) $\frac{Q}{2\pi\epsilon_0 Lr}$

15. Which of the following is the potential difference between the shells?

(a) $\frac{Q\ln(3/2)}{4\pi\epsilon_0 L}$ (b) $\frac{Q\ln 5}{2\pi\epsilon_0 L}$ (c) $\frac{Q\ln 6}{2\pi\epsilon_0 L}$ (d) $\frac{Q\ln 6}{4\pi\epsilon_0 L}$ (e) $\frac{Q\ln(5/2)}{2\pi\epsilon_0 L}$

16. Which of the following is the capacitance of the system?

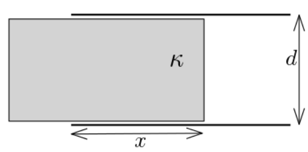
(a) $\frac{2\pi\epsilon_0 L}{\ln 5}$ (b) $\frac{4\pi\epsilon_0 L}{\ln 5}$ (c) $\frac{2\pi\epsilon_0 L}{\ln(3/2)}$ (d) $\frac{2\pi\epsilon_0 L}{\ln 6}$ (e) $\frac{4\pi\epsilon_0 L}{\ln(5/2)}$

17. If the region $3R > r > R$ is filled with a dielectric material of dielectric constant κ, which of the following is the capacitance of the system?

(a) $\frac{2\pi\kappa\epsilon_0 L}{\ln 3+\ln 2}$ (b) $\frac{2\pi\epsilon_0 L}{\kappa\ln 3+\kappa\ln 2}$ (c) $\frac{2\pi\kappa\epsilon_0 L}{\kappa\ln 3+\ln 2}$ (d) $\frac{2\pi\kappa\epsilon_0 L}{\ln 3+\kappa\ln 2}$ (e) $\frac{2\pi\epsilon_0 L}{\kappa\ln 3+\ln 2}$

Questions 18-20

Consider a parallel plate capacitor of capacitance C_0 connected to a battery of voltage V_0. The distance between the plates is d and each plate is a square of side L. A dielectric material of dielectric constant κ is inserted a distance x between the parallel plates of the capacitor as shown in the figure.



18. Which of the following is the capacitance as a function of x?

(a) $C_0\left(1 + (\kappa+1)\frac{x}{L}\right)$ (b) $C_0\left(1 + \kappa\frac{x}{L}\right)$ (c) $C_0\left(1 + (\kappa-1)\frac{x}{L}\right)$ (d) $C_0\left(1 + (2\kappa-1)\frac{x}{L}\right)$
(e) $C_0\left(1 + (\kappa-2)\frac{x}{L}\right)$

19. Assuming that the potential difference between the plates is kept constant (by keeping the voltage source in the system), which of the following is the energy stored in the capacitor after the dielectric is inserted? (U_0 is the stored energy before the dielectric material is inserted.)

(a) $U_0\left(1 + (\kappa-1)\frac{x}{L}\right)$ (b) $U_0\left(1 + (\kappa+1)\frac{x}{L}\right)$ (c) $U_0\left(1 + (\kappa-2)\frac{x}{L}\right)$ (d) $U_0\left(1 + (2\kappa-1)\frac{x}{L}\right)$ (e) $U_0\left(1 + \kappa\frac{x}{L}\right)$

20. Assuming that the charge on the capacitor is kept constant (by removing the battery after charging the plates and before the dielectric is inserted), which of the following is the energy stored in the capacitor after the dielectric is inserted? (U_0 is the stored energy before the dielectric material is inserted.)

(a) $\frac{U_0}{\left(1+(2\kappa-1)\frac{x}{L}\right)}$ (b) $\frac{U_0}{\left(1+(\kappa+1)\frac{x}{L}\right)}$ (c) $\frac{U_0}{\left(1+(\kappa-1)\frac{x}{L}\right)}$ (d) $\frac{U_0}{\left(1+\kappa\frac{x}{L}\right)}$ (e) $\frac{U_0}{\left(1+(\kappa-2)\frac{x}{L}\right)}$

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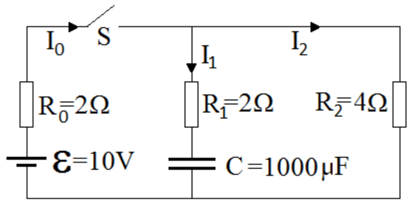
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

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?

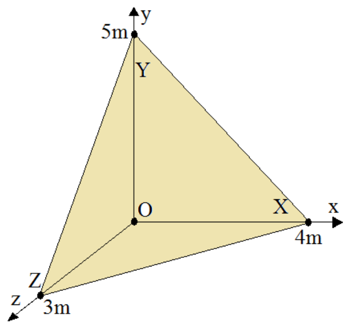
(a) $\frac{5}{4}$ A (b) $\frac{10}{7}$ A (c) $\frac{3}{2}$ A (d) $\frac{5}{7}$ A (e) $\frac{10}{9}$ A

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?

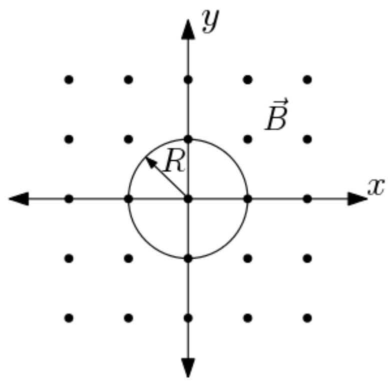
(a) $\frac{5\mu_0 Q\omega}{4\pi R}$ (b) $\frac{\mu_0 Q\omega}{4\pi R}$ (c) $\frac{7\mu_0 Q\omega}{5\pi R}$ (d) $\frac{\mu_0 Q\omega}{2\pi R}$ (e) $\frac{3\mu_0 Q\omega}{4\pi R}$

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) $\dfrac{\text{N}\cdot\text{s}}{\text{A}\cdot\text{m}}$ (b) $\dfrac{\text{N}\cdot\text{m}}{\text{A}\cdot\text{s}}$ (c) $\dfrac{\text{N}}{\text{A}\cdot\text{s}\cdot\text{m}}$ (d) $\dfrac{\text{N}}{\text{A}\cdot\text{m}}$ (e) $\dfrac{\text{N}}{\text{A}\cdot\text{s}}$

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

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

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

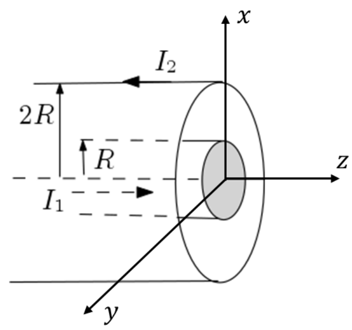
(a) $-3\dfrac{\alpha R}{4}\hat{\imath}$ (b) $-\dfrac{\alpha R}{2}\hat{\imath}$ (c) $\dfrac{\alpha R}{4}\hat{\imath}$ (d) $\dfrac{\alpha R}{3}\hat{\imath}$ (e) $-\dfrac{\alpha R}{4}\hat{\imath}$

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

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

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

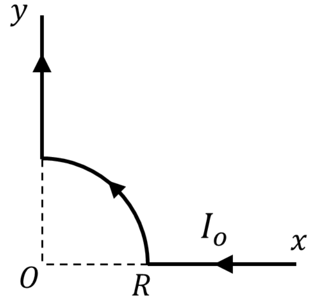
(a) $\dfrac{\mu_0 I_1}{6\pi R}\hat{\imath}$ (b) $\dfrac{\mu_0 I_1}{4\pi R}\hat{\imath}$ (c) $-\dfrac{\mu_0 I_1}{12\pi R}\hat{k}$ (d) $-\dfrac{\mu_0 I_1}{6\pi R}\hat{\jmath}$ (e) $-\dfrac{\mu_0 I_1}{3\pi R}\hat{\imath}$

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

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

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

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

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

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Questions 1-3

The charge distribution within a sphere of radius R and central density ρ_c is given as

$$\rho = \rho_c\left(1 - \frac{r}{R}\right)$$

where r is the radial distance from the center.

1. What is the total charge?

(a) $\frac{\rho_c R^3}{2}$ (b) $\frac{2\pi\rho_c R^3}{3}$ (c) $\frac{\pi\rho_c R^3}{6}$ (d) $\frac{\pi\rho_c R^3}{3}$ (e) $\frac{4\pi\rho_c R^3}{3}$

2. What is the magnitude of the electric field at distance r ($r < R$)?

(a) $\frac{\rho_c r}{3\epsilon_0}\left(1-\frac{r}{R}\right)$ (b) $\frac{\rho_c r}{2\epsilon_0}\left(\frac{1}{3}-\frac{r}{4R}\right)$ (c) $\frac{\rho_c r}{\epsilon_0}\left(\frac{1}{3}-\frac{r}{4R}\right)$ (d) $\frac{3\rho_c r}{\epsilon_0}\left(\frac{1}{3}-\frac{r}{4R}\right)$ (e) $\frac{\rho_c r}{\epsilon_0}\left(1-\frac{r}{R}\right)$

3. What is the potential on the surface of the sphere assuming the potential at infinity ($r \to \infty$) is zero?

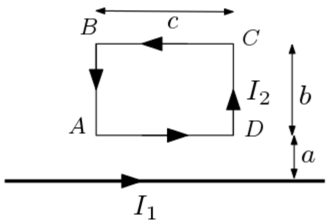
(a) $\frac{\rho_c R^2}{6\epsilon_0}$ (b) $\frac{\pi\rho_c R^2}{12\epsilon_0}$ (c) $\frac{\rho_c R^2}{12\epsilon_0}$ (d) $\frac{\rho_c R^2}{2\epsilon_0}$ (e) $\frac{\pi\rho_c R^2}{6\epsilon_0}$

4. A particle of charge q and mass m moves in a nonuniform magnetic field $\vec{B}$. Which of the following can be the magnetic force when the velocity of the particle is $\vec{v} = 2\hat{\imath} - 3\hat{\jmath}$ m/s?

(a) $\vec{F}_m = -2\hat{\imath}+\hat{\jmath}+\hat{k}$ N (b) $\vec{F}_m = 3\hat{\imath}+\hat{\jmath}+\hat{k}$ N (c) $\vec{F}_m = 2\hat{\imath}+3\hat{\jmath}+\hat{k}$ N (d) $\vec{F}_m = 3\hat{\imath}+2\hat{\jmath}+\hat{k}$ N (e) $\vec{F}_m = -3\hat{\imath}+\hat{\jmath}+\hat{k}$ N

Questions 5-7

A rectangular current loop, of current I_2 and side lengths b and c, is placed at a distance a to a very long current carrying wire of current I_1, as shown in the figure.



5. What is the magnitude of the magnetic force on side AD of the loop due to I_1?

(a) $\frac{\mu_0 I_1 I_2 c}{2\pi a}$ (b) $\frac{3\mu_0 I_1 I_2 c}{2\pi a}$ (c) $\frac{\mu_0 I_1 I_2 c}{3\pi a}$ (d) 0 (e) $\frac{5\mu_0 I_1 I_2 c}{2\pi a}$

6. What is the magnitude of the magnetic force on the side AB of the loop due to I_1?

(a) $\frac{\mu_0 I_1 I_2}{2\pi}\ln\left(1+\frac{b}{a}\right)$ (b) $\frac{\mu_0 I_1 I_2}{3\pi}\ln\left(\frac{b}{a}\right)$ (c) $\frac{\mu_0 I_1 I_2 c}{3\pi a}$ (d) $\frac{\mu_0 I_1 I_2}{2\pi}\ln\left(\frac{a}{b}\right)$ (e) 0

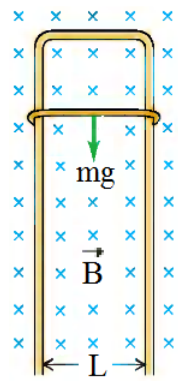
7. What is the magnitude of the net magnetic force on the rectangular loop?

(a) $\frac{\mu_0 I_1 I_2}{2\pi}\frac{ac}{b(a+b)}$ (b) $\frac{\mu_0 I_1 I_2}{2\pi}\frac{bc}{a(a+b)}$ (c) $\frac{\mu_0 I_1 I_2}{3\pi}\frac{b}{(a+b)}$ (d) 0 (e) $\frac{\mu_0 I_1 I_2}{3\pi}\frac{bc}{a(a+b)}$

8. Which of the following is <u>not</u> a unit of inductance in SI?

(a) $Ohm \cdot s$ (b) $\frac{T \cdot s}{J \cdot m}$ (c) $\frac{V \cdot s}{A}$ (d) $\frac{T \cdot m^2}{A}$ (e) $\frac{J}{A^2}$

Questions 9-12



A rectangular loop with width L and a slide wire with mass m are as shown in the figure. A uniform magnetic field B is directed perpendicular to the plane of the loop into the plane of the figure. The slide wire is released from rest. There is no friction between the slide wire and the loop, and the resistance of the loop is negligible in comparison to the resistance R of the slide wire.

9. If the speed of the slide wire is v, what is the induced emf in the loop?

(a) BL^2v (b) BL^2v/R (c) BLv/R (d) BLv (e) BRv

10. What is the magnitude of the magnetic force on the slide wire, when the speed of the slide wire is v?

(a) BLv/R (b) BRv (c) BL^2v/R^2 (d) BL^2v (e) B^2L^2v/R

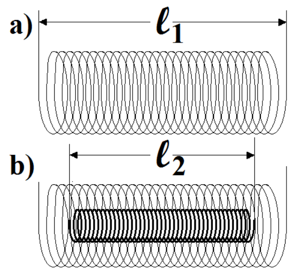
11. What is the terminal speed of the slide wire?

(a) mg/BRL^2 (b) $mgR/4B^2L^2$ (c) $2mg/BRL^2$ (d) mgR/B^2L^2 (e) $2mgR/B^2L^2$

12. After the slide wire reaches its terminal speed, what is the magnitude and the direction of the induced current? (cw: clockwise, ccw: counter clockwise)

(a) BL^2mg/R, ccw (b) BLR/mg, ccw (c) mg/BL, ccw (d) BLR/mg, cw (e) mgR/BL, cw

Questions 13-16



A long, straight solenoid (Figure a) has N_1 turns, uniform cross-sectional area A_1. and length l_1. The current i_1 in this solenoid is changing at a rate of di_1/dt. Assume that the magnetic field is uniform inside the solenoid and zero outside. In the folowing i_1 and i_2 are currents, ϕ_{B1} and ϕ_{B2} are magnetic fluxes in the 1^{st} and the 2^{nd} solenoids respectively.

13. What is the self inductance L_1 of the solenoid in Figure a?

(a) $\mu_o\, A_1{N_1}^2/{l_1}^2$ (b) ${\mu_o}^2\, A_1{N_1}^2/l_1$ (c) $\mu_o\, A_1{N_1}^2/l_1$ (d) $\mu_o\, {A_1}^2{N_1}^2/l_1$ (e) ${\mu_o}^2\, {A_1}^2{N_1}^2/l_1$

14. Now another smaller solenoid is coaxially placed inside the first one (Figure b). The inner solenoid has N_2 turns, uniform cross-sectional area A_2, and length l_2. What is the mutual inductance M of these solenoids?

(a) $\mu_o\, A_2N_1N_2/l_1$ (b) $\mu_o\, A_2N_1N_2/l_1l_2$ (c) $\mu_o\, A_1N_1N_2/l_1$ (d) $\mu_o\, A_1N_1N_2/l_2$ (e) $\mu_o\, A_1N_1N_2/l_1l_2$

15. What is the induced emf in the inner solenoid?

(a) $-L_2di_1/dt$ (b) $-Md\phi_{B2}/dt$ (c) $-L_1di_1/dt$ (d) $-Md\phi_{B1}/dt$ (e) $-Mdi_1/dt$

16. Now assume that the current i_1 in the outer solenoid is set to zero, and a current i_2 which is changing at a rate of di_2/dt is set in the inner solenoid. What is the induced emf in the outer solenoid?

(a) $-Md\phi_{B2}/dt$ (b) $-L_2di_2/dt$ (c) $-L_1di_2/dt$ (d) $-Md\phi_{B1}/dt$ (e) $-Mdi_2/dt$

Questions 17-20

An electromagnetic wave propagating in vacuum has a magnetic field component given by

$$\vec{B}(z,t) = (6\times10^{-8}\;T)\cos\left[(2\times10^{3}\;rad/m)z-\omega t\right]\hat{\jmath}.$$

(Take $\pi\sim3$, $c=3\times10^8\;m/s$, $\mu_0=4\pi\times10^{-7}\;T\cdot m/A$)

17. What is the direction of propagation and wavelength of this electromagnetic wave?

(a) $-y$-direction, $\lambda = 4\times10^{-3}\;m$ (b) $+z$-direction, $\lambda = 4\times10^{-3}\;m$ (c) $+y$-direction, $\lambda = 5\times10^{-3}\;m$
(d) $+y$-direction, $\lambda = 3\times10^{-3}\;m$ (e) $+z$-direction, $\lambda = 3\times10^{-3}\;m$

18. What is the electric field component of this wave?

(a) $\vec{E}(y,t) = (18\;V/m)\cos\left[(2\times10^{3}\;rad/m)y-\omega t\right]\hat{\imath}$
(b) $\vec{E}(z,t) = (18\;V/m)\cos\left[(2\times10^{3}\;rad/m)z-\omega t\right]\hat{\imath}$
(c) $\vec{E}(x,t) = (18\;V/m)\cos\left[(2\times10^{3}\;rad/m)x-\omega t\right]\hat{\imath}$
(d) $\vec{E}(x,t) = (18\;V/m)\cos\left[(2\times10^{3}\;rad/m)x-\omega t\right]\hat{k}$
(e) $\vec{E}(z,t) = (18\;V/m)\cos\left[(2\times10^{3}\;rad/m)z+\omega t\right]\hat{k}$

19. If the speed of this wave in a medium is $v = 6\times10^7\;m/s$, what is the index of refraction of the medium?

(a) 2 (b) 3 (c) 5 (d) 0.5 (e) 0.4

20. What is the average force applied by this electromagnetic wave on a perfecetly absorbing surface of area 0.3 m^2 if the wave is coming the surface perpendicularly?

(a) $1.3\times10^{-9}\;N$ (b) $1.2\times10^{-9}\;N$ (c) $1.5\times10^{-9}\;N$ (d) $4.5\times10^{-10}\;N$ (e) $1.4\times10^{-9}\;N$

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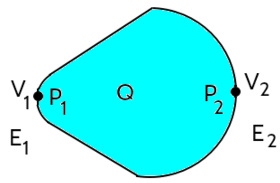
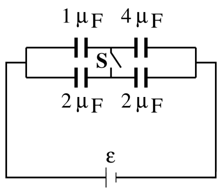
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. A charged metallic body is suspended in air, as shown in the figure. The electric potential and the magnitude of the electric field vector at a point P_1 of the body in air are V_1 and E_1, respectively. At a point P_2 in the figure, these quantities are V_2 and E_2. If the total charge of the body is positive, which one of the following is correct?



(a) $V_1 < V_2$ and $E_1 < E_2$ (b) $V_1 = V_2$ and $E_1 > E_2$ (c) $V_1 > V_2$ and $E_1 > E_2$ (d) $V_1 = V_2$ and $E_1 < E_2$ (e) $V_1 = V_2$ and $E_1 = E_2$

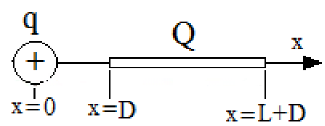
2. What is the ratio of equivalent capacitances for the cases where the switch is open and closed?



(a) $\frac{9}{10}$ (b) $\frac{5}{3}$ (c) $\frac{9}{40}$ (d) 1 (e) $\frac{3}{5}$

Questions 3-7

Positive charge Q is distributed non-uniformly on an insulating rod which lies along the x-axis from $x = D$ to $x = D + L$. Linear charge density of the rod is given as



$$\lambda = \begin{cases} 0 & 0 \le x \le D \\ \alpha x^2 & D \le x \le L + D \end{cases}$$

where α is a constant. A positive point charge q is placed at $x = 0$. (Here $\hat{\imath}$ is the unit vector parallel to positive x-axis)

3. Find α in terms of Q.

(a) $3Q/[(L+D)^3 - D^3]$ (b) $Q/[3(L+D)^3 - 3D^3]$ (c) Q/L^3 (d) $Q/[(L+D)^3 - 2D^3]$ (e) $3Q/(L+D)^3$

4. Which one of the following expressions give the electric field at $x = 0$ which is generated by the rod?

(a) $\frac{-\hat{\imath}\,\alpha}{4\pi\epsilon_o}\int_L^{L+D}\frac{dx}{x^2}$ (b) $\frac{-\hat{\imath}\,\alpha}{4\pi\epsilon_o}\int_L^{L+D}\frac{dx}{x}$ (c) $\frac{-\hat{\imath}\,\alpha}{4\pi\epsilon_o}\int_L^{L+D}dx$ (d) $\frac{-\hat{\imath}\,\alpha}{4\pi\epsilon_o}\int_0^{L}\frac{dx}{x^2}$ (e) $\frac{-\hat{\imath}\,\alpha}{4\pi\epsilon_o}\int_0^{L+D}\frac{dx}{x^2}$

5. Find the electric field generated by the rod at $x = 0$.

(a) $-\frac{(L+D)\alpha}{8\pi\epsilon_o L^2}\hat{\imath}$ (b) $-\frac{\alpha}{4\pi\epsilon_o(L+D)}\hat{\imath}$ (c) $-\frac{L^3\alpha}{4\pi\epsilon_o}\hat{\imath}$ (d) $-\frac{\alpha}{4\pi\epsilon_o L^2}\hat{\imath}$ (e) $-\frac{L\alpha}{4\pi\epsilon_o}\hat{\imath}$

6. Which one of the following is the force that the charge q exerts on the rod?

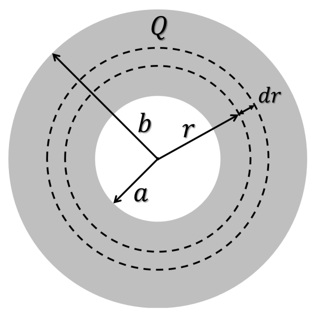
(a) $\frac{-L^3\alpha q}{4\pi\epsilon_o}\hat{\imath}$ (b) $\frac{\alpha q}{4\pi\epsilon_o(L+D)}\hat{\imath}$ (c) $\frac{\alpha q}{4\pi\epsilon_o L^2}\hat{\imath}$ (d) $\frac{(L+D)\alpha q}{8\pi\epsilon_o L^2}\hat{\imath}$ (e) $\frac{L\alpha q}{4\pi\epsilon_o}\hat{\imath}$

7. Assume that another positive point charge Q is placed R apart to the left of charge q. If the net force on q is zero, find the distance R?

(a) $\frac{2Q}{3\alpha L^2}$ (b) $\sqrt{\frac{3Q}{\alpha^2 L}}$ (c) $\sqrt{\frac{3Q}{2\alpha L^3}}$ (d) $\frac{Q}{\alpha L^2}$ (e) $\sqrt{\frac{Q}{\alpha L}}$

Questions 8-9

A solid spherical shell of inner radius a and outer radius $b = 2a$ has a uniform charge density and total charge Q. Assume, the sphere is constructed by adding successive layers of concentric shells of charge dq and of thickness dr. Take $V(\infty) = 0$.



8. When the outer radius is r $(a < r < b)$, how much energy (dU) is needed to add a spherical shell of thickness dr having a charge dq?

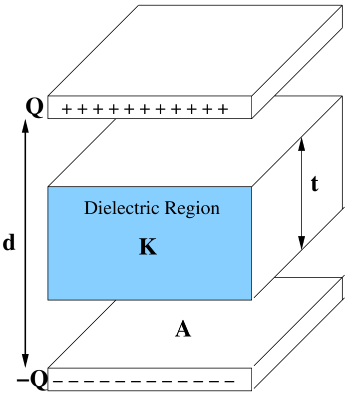
(a) $\frac{3Q^2 r(r^3 - a^3)\,dr}{74\pi\epsilon_o a^6}$ (b) $\frac{3Q^2 r(r^3 - a^3)\,dr}{188\pi\epsilon_o a^6}$ (c) $\frac{3Q^2 r(r^3 - a^3)\,dr}{86\pi\epsilon_o a^6}$ (d) $\frac{3Q^2 r(r^3 - a^3)\,dr}{196\pi\epsilon_o a^6}$ (e) $\frac{3Q^2 r(r^3 - a^3)\,dr}{176\pi\epsilon_o a^6}$

9. Find the energy (U) needed to assemble the total charge Q.

(a) $\frac{141Q^2}{740\pi\epsilon_o a}$ (b) $\frac{141Q^2}{1760\pi\epsilon_o a}$ (c) $\frac{141Q^2}{860\pi\epsilon_o a}$ (d) $\frac{141Q^2}{1960\pi\epsilon_o a}$ (e) $\frac{3Q^2}{40\pi\epsilon_o a}$

Questions 10-14

A non-conducting slab of thickness t, surface area A and dielectric constant K is inserted into space between the plates of a parallel plate capacitor with spacing d, charge Q and area A as shown in the figure. The slab is not necessarily halfway between the capacitor plates. ($\sqrt{A} \gg d$)



10. What is the magnitude of the electric field outside of the dielectric material and between the plates?

(a) $\frac{Q}{K\epsilon_o A}$ (b) $\frac{Qd}{t\epsilon_o A}$ (c) $\frac{Q}{\epsilon_o A}$ (d) $\frac{Q}{(K-1)\epsilon_o A}$ (e) $\frac{Qt}{d\epsilon_o A}$

11. What is the magnitude of the electric field in the dielectric region?

(a) $\frac{Qt^2}{K\epsilon_o A d^2}$ (b) $\frac{Q}{K\epsilon_o A}$ (c) $\frac{Qt}{dK\epsilon_o A}$ (d) $\frac{Qd}{tK\epsilon_o A}$ (e) $\frac{Q}{(K-1)\epsilon_o A}$

12. What is the absolute value of the potential difference between the plates?

(a) $\frac{Q}{K\epsilon_o A}\left[-d-t\left(1-\frac{1}{K}\right)\right]$ (b) $\frac{Q}{K\epsilon_o A}\left[d+t\left(1-\frac{1}{K}\right)\right]$ (c) $\frac{Q}{\epsilon_o A}\left[-d+t\left(-1-\frac{1}{K}\right)\right]$
(d) $\frac{Q}{K\epsilon_o A}\left[-d+t\left(1+\frac{1}{K}\right)\right]$ (e) $\frac{Q}{\epsilon_o A}\left[d-t\left(1-\frac{1}{K}\right)\right]$

13. What is the capacitance of this system?

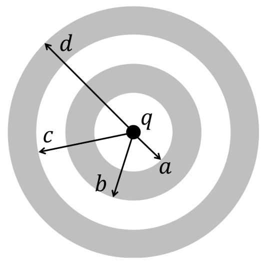
(a) $\frac{\epsilon_o A}{d-Kt}$ (b) $\frac{\epsilon_o A}{d-t[1+(1/K)]}$ (c) $\frac{\epsilon_o A}{d+t[1-(1/K)]}$ (d) $\frac{\epsilon_o A}{d-t[1-(1/K)]}$ (e) $\frac{\epsilon_o A}{d+Kt}$

14. What is the ratio of stored energy between the vacuum region and the dielectric region?

(a) K (b) $\frac{Kt}{d}$ (c) $\frac{K}{d-t}$ (d) $\frac{K(d-t)}{t}$ (e) $\frac{Kd}{t}$

Questions 15-18

A small conducting spherical shell with an inner radius a and outer radius b is concentric with a large conducting spherical shell with an inner c and outer radius d. The inner shell has total charge $3q$ and outer shell has charge $-4q$. A point-like particle of charge q is located at the common center of the two shells. Here $k = 1/(4\pi\epsilon_o)$.



15. Find the electric field (magnitude and direction) in terms of q and the distance of r from the center for $a < r < b$.

(a) zero (b) $k\frac{q}{r^2}$ outward (c) $k\frac{q}{r^2}$ inward (d) $k\frac{4q}{r^2}$ outward (e) $k\frac{2q}{r^2}$ outward

16. Find the electric field (magnitude and direction) in terms of q and the distance of r from the center for $b < r < c$.

(a) $k\frac{2q}{r^2}$ outward (b) $k\frac{3q}{r^2}$ inward (c) $k\frac{4q}{r^2}$ outward (d) $k\frac{q}{r^2}$ outward (e) zero

17. Find the electric field (magnitude and direction) in terms of q and the distance of r from the center for $r > d$.

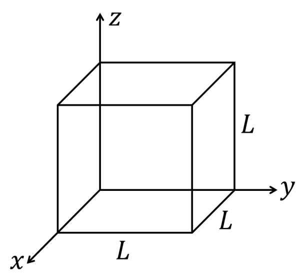
(a) $k\frac{q}{r^2}$ outward (b) $k\frac{3q}{r^2}$ outward (c) zero (d) $k\frac{4q}{r^2}$ outward (e) $k\frac{4q}{r^2}$ inward

18. What is the total charge on the inner surface of the outer shell at $r = c$?

(a) $-q$ (b) $+4q$ (c) $+3q$ (d) $-4q$ (e) $-3q$

Questions 19-20

A cube has sides of length $L = 0.5\,m$. It is placed with one corner at the origin as shown in the figure. The electric field is not uniform but is given by $\vec{E} = [4.0\ N/(C\cdot m)]y\hat{\jmath} - [2.0\ \mathrm{N/(C\cdot m)}]z\hat{k}$.
Take $\epsilon_o = 9\times10^{-12}\ C^2/N\cdot m^2$ **.**



19. Find the total flux for the cube in $N\cdot m^2/C$'s.

(a) 0.5 (b) 0.125 (c) 0 (d) 0.25 (e) 1

20. Find the total electric charge (in coulombs) inside the cube?

(a) $1/9\times10^{-12}$ (b) 2.25×10^{-12} (c) 4.5×10^{-12} (d) 1.125×10^{-12} (e) $1/18\times10^{-12}$

Group Number		Name		Type
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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.

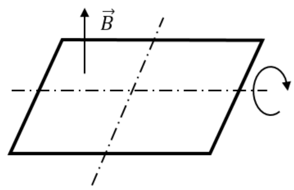
1. A metal wire has resistance R. What will be the resistance of this wire in terms of R if it is stretched to 4 times of its original length, assuming that the volume and resistivity of the material do not change when the wire is stretched?

(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 A/m^2?

(a) $\frac{\pi\times10^7}{2}$ (b) $\pi \times 10^7$ (c) $2\pi \times 10^7$ (d) $\frac{2\times10^7}{\pi}$ (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).

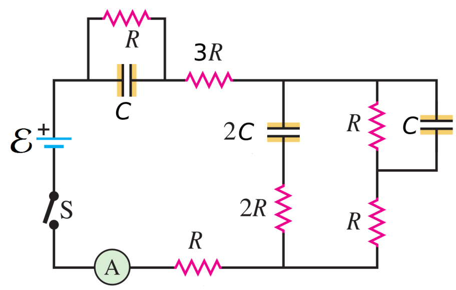
(a) $\frac{\pi}{16}$ (b) $\frac{1}{16\pi}$ (c) $\frac{1}{8\pi}$ (d) $\frac{\pi}{8}$ (e) $\frac{1}{32\pi}$

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?

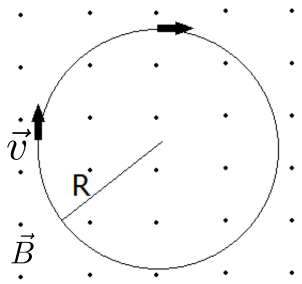
(a) 11/7 (b) 7/4 (c) 4/7 (d) 6/11 (e) 11/6

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?

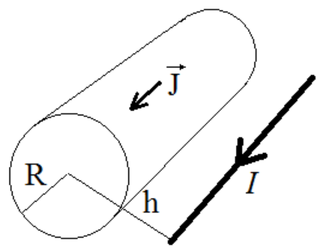
(a) 3×10^7 (b) 8×10^7 (c) 4×10^7 (d) 2×10^7 (e) 10^7

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?

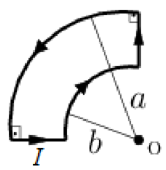
(a) $\frac{\mu_o\pi\alpha R^3}{3h}$ (b) $\frac{\alpha\pi R^3}{h}$ (c) $\frac{\mu_o\alpha h}{3R^3}$ (d) $3\mu_o\alpha\pi R^3$ (e) $\frac{\mu_o\alpha R^3}{3h}$

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?

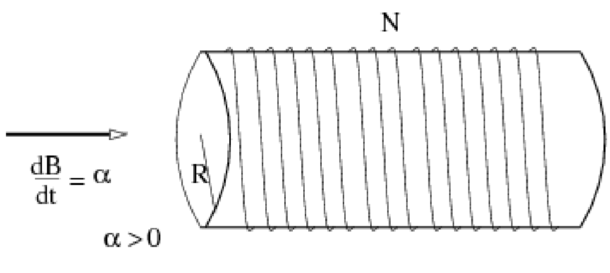
(a) $\frac{I\pi(a^2+b^2)}{2}$ (b) $\frac{I\pi(a^2-b^2)(a^2+b^2)}{4ab}$ (c) $\frac{I\pi(a^2-b^2)}{4}$ (d) $\frac{I\pi(a^2-b^2)}{2}$ (e) $\frac{I\pi(a^2+b^2)}{4}$

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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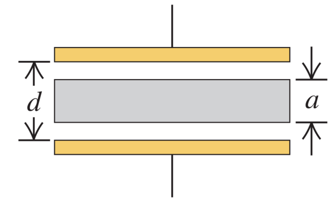
For all questions please take: Speed of light in vacuum c = 3×10^8 **m/s,** $\frac{1}{4\pi\epsilon_o} = 9\times10^9$ **m/F,** $\mu_o = 4\pi\times10^{-7}$ **H/m.**

1. A charge Q is at a perpendicular distance of a to the center of a square surface with sides $2a$. Which of the following gives the flux of electric field through this surface?

(a) $Q/2\epsilon_o$ (b) $2Q/\epsilon_o$ (c) Q/ϵ_o (d) $Q/4\epsilon_o$ (e) $Q/6\epsilon_o$

Questions 2-3



A capacitor is made by two flat plates, each with area A, separated by a distance d and thus has capacitance $C_o = \epsilon_o A/d$ Then a slab having thickness $a = 3d/4$ and the same shape and size as the plates is inserted between them, parallel to the plates and not touching either plate as shown in the Figure.

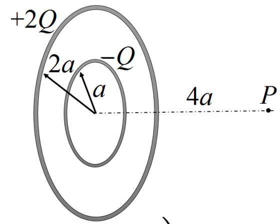
2. What is the capacitance of this arrangement, in units of C_o, if the slab is made of **conducting** material?

(a) 3/4 (b) 2 (c) 4 (d) 4/3 (e) 1/4

3. What is the capacitance of this arrangement, in units of C_o, if the slab is made of **dielectric** material of dielectric constant $\kappa = 3$?

(a) 2 (b) 3 (c) 1/2 (d) 4 (e) 1/4

Questions 4-5



A ring of charge of radius a has total charge $-Q$. Another ring of charge, concentric with the first one and on the same plane, has radius $2a$ and charge $2Q$.

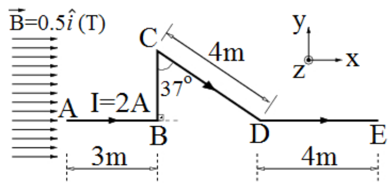
4. Which of the following gives the electric potential at point P which is a distance of $4a$ along the axis of the rings?

(a) $\frac{Q}{4\pi\epsilon_o a}\left(\frac{-1}{17^{3/2}} + \frac{2}{20^{3/2}}\right)$ (b) $\frac{Q}{4\pi\epsilon_o a}\left(\frac{-1}{17} + \frac{2}{20}\right)$ (c) $\frac{Q}{4\pi\epsilon_o a}\left(\frac{-1}{\sqrt{5}} + \frac{2}{\sqrt{6}}\right)$ (d) $\frac{Q}{4\pi\epsilon_o a}\left(\frac{1}{\sqrt{17}} - \frac{2}{\sqrt{20}}\right)$
(e) $\frac{Q}{4\pi\epsilon_o a}\left(\frac{-1}{\sqrt{17}} + \frac{2}{\sqrt{20}}\right)$

5. Which one of the following gives the magnitude of the electric field at point P?

(a) $\frac{Q}{\pi\epsilon_o a^2}\left(\frac{-1}{\sqrt{17}} + \frac{2}{\sqrt{20}}\right)$ (b) $\frac{Q}{\pi\epsilon_o a^2}\left(\frac{-1}{5^{3/2}} + \frac{2}{6^{3/2}}\right)$ (c) $\frac{Q}{\pi\epsilon_o a^2}\left(\frac{-1}{17^{3/2}} + \frac{2}{20^{3/2}}\right)$ (d) $\frac{Q}{4\pi\epsilon_o a^2}\left(\frac{-1}{17^{3/2}} + \frac{2}{20^{3/2}}\right)$
(e) $\frac{Q}{\pi\epsilon_o a^2}\left(\frac{-1}{12^{3/2}} + \frac{2}{18^{3/2}}\right)$

Questions 6-8



A current carrying wire (I=2 A) is placed in uniform magnetic field with 0.5 T magnitude as shown in figure. Magnetic field is in x-direction and the wire is on x-y plane. (cos37=0.8 and sin37=0.6)

6. What is the magnitude of the magnetic force in newtons on the AB segment of the wire?

(a) 4.5 (b) 6.0 (c) 1.5 (d) 0 (e) 3.0

7. What is the magnitude of the magnetic force in newtons on the BC segment of wire?

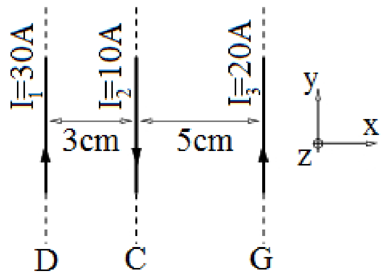
(a) 0 (b) $\sqrt{3.2^2 - 2.4^2}$ (c) 3.2 (d) 2.4 (e) $\sqrt{3.2^2 + 2.4^2}$

8. What is the direction and magnitude of the magnetic force on the CD segment of the wire?

(a) 3.20 (N) and +z (b) 1.92 (N) and +z (c) 2.56 (N) and +z (d) 3.20 (N) and −z (e) 2.56 (N) and −z

Questions 9-10

Consider the three long straight, parallel wires shown in figure.



9. What is the magnetic field vector on the wire C in mT?

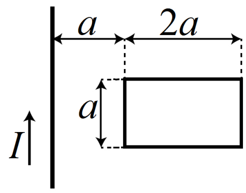
(a) $0.28\hat{k}$ (b) $-0.12\hat{k}$ (c) $-0.40\hat{k}$ (d) $0.06\hat{k}$ (e) $-0.06\hat{k}$

10. What is the magnetic force experienced by a 25 cm length of wire C in mN?

(a) 0.30 (b) 0.10 (c) 0.50 (d) 0.40 (e) 0.20

Questions 11-12

The long, straight wire in the figure has a current I flowing in it. A conducting rectangular loop of sides a and $2a$ and a resistance of R is positioned at a distance a away from the wire.



11. Which of the following gives the magnetic flux through the loop due to the current in the straight wire?

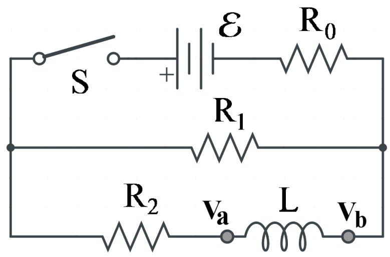
(a) $\frac{3\mu_o aI}{2\pi}$ (b) $\frac{2\mu_o a^2 I}{3\pi}$ (c) $\frac{\mu_o aI}{2\pi}\ln 2$ (d) $\frac{\mu_o aI}{2\pi}\ln 3$ (e) $\frac{\mu_o I}{2\pi a}\ln 6$

12. Which of the following is the mutual inductance of the system?

(a) $\frac{\mu_o a}{2\pi}\ln 3$ (b) $\frac{\mu_o}{2\pi a}\ln 6$ (c) $\frac{2\mu_o a^2}{3\pi}$ (d) $\frac{3\mu_o a}{2\pi}$ (e) $\frac{\mu_o a}{2\pi}\ln 2$

Questions 13-15

In the circuit shown in the figure, battery electromotive force $\mathcal{E} = 20$ V, resistances $R_0 = 2\,\Omega$, $R_1 = 12\,\Omega$, $R_2 = 4\,\Omega$, and inductance L=0.2 H. Long time after the switch S is closed find:



13. the current through the resistor R_2.

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

14. the potential difference $V_{ab} = V_a - V_b$ across the inductor L.

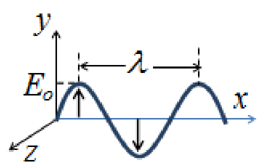
(a) 4 V (b) 20 V (c) 0 V (d) 2 V (e) 12 V

15. the energy stored in the inductor L.

(a) 0.2 J (b) 3 J (c) 1.44 J (d) 1.6 J (e) 0.9 J

Questions 16-20

The wavelength of an electromagnetic wave polarized along the y axis and traveling in the +x direction is $\lambda = 6\times10^{-7}$m , the frequency is $f = 5\times10^{14}$ Hz, and the amplitude of the wave is $E_0 = 180$ V/m. (Take $\pi = 3$)



16. Which of the following statements gives the electric field component of the wave in units of V/m?

(a) $E_x = 180\sin(10^7 z - 3\times10^{15}t)$
(b) $E_x = 180\sin(3\times10^{15}x - 10^7 t)$
(c) $E_y = 60\cos(4.2\times10^{15}x - 10^7 t)$
(d) $E_z = 60\cos(10^7 y - 4.2\times10^{15}t)$
(e) $E_y = 180\sin(10^7 x - 3\times10^{15}t)$

17. Which of the following statements gives magnetic field component of the wave in units of tesla?

(a) $B_y = 2\times10^{-7}\sin(4.2\times10^{15}x - 10^7 t)$ (b) $B_x = 6\sin(3\times10^{15}x - 10^7 t)$ (c) $B_x = 6\times10^{-6}\sin(10^7 z - 3\times10^{15}t)$
(d) $B_z = 6\times10^{-7}\sin(10^7 x - 3\times10^{15}t)$ (e) $B_z = 2\times10^{-7}\cos(10^7 y - 4.2\times10^{15}t)$

18. Which of the following is the energy density of the wave?

(a) $3\times10^{-7}\sin^2(4.2\times10^{15}x - 10^7 t)$ (b) $3\times10^{-7}\sin^2(10^7 x - 3\times10^{15}t)$ (c) $3\times10^{-7}\sin(10^7 x - 3\times10^{15}t)$
(d) $6\times10^{-7}\cos^2(10^7 x - 3\times10^{15}t)$ (e) $6\times10^{-7}\cos(10^7 x - 4.2\times10^{15}t)$

19. What is the average intensity of the wave in W/m^2?

(a) 15 (b) 45 (c) $\frac{50}{3}$ (d) $\frac{100}{3}$ (e) 18

20. Which of the following statements gives Poynting vector?

(a) $\frac{100}{3}\cos^2(10^7 x - 4.2\times10^{15}t)\hat{\imath}$ (b) $90\sin^2(10^7 x - 3\times10^{15}t)\hat{\imath}$ (c) $30\sin^2(10^7 y - 4.2\times10^{15}t)\hat{\jmath}$ (d) $\frac{50}{3}\sin^2(10^7 z - 3\times10^{15}t)\hat{k}$
(e) $72\cos^2(10^7 x - 3\times10^{15}t)\hat{\imath}$

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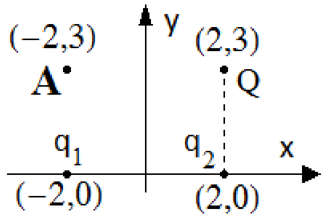
Student ID		Signature		

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.

For all questions take $\frac{1}{4\pi\epsilon_o} = 9\times 10^9\ N\,m^2/C^2$**.**

Questions 1-5



Three point charges are placed at the following (x,y) coordinates: charge $q_1 = 9\,nC$ at $(-2\,m, 0)$, charge $q_2 = 5\,nC$ at $(2\,m, 0)$, and charge Q$= -8\,nC$ at $(2\,m, 3\,m)$. Take the zero of potential to be at infinity. (Unit prefix n stands for nano $= 10^{-9}$, $\hat{\imath}$ and $\hat{\jmath}$ are unit vectors pointing in positive x and y axes respectively).

1. Which of the following is the electrical force that Q exerts on q_2 in nN units?

(a) $72\,\mathrm{nN}\hat{\imath}$ (b) $120\,\hat{\jmath}$ (c) $-40\,\hat{\jmath}$ (d) $40\,\hat{\jmath}$ (e) $-120\,\hat{\jmath}$

2. What is the electrical potential at point $\mathbf{A}(-2\,m, 3\,m)$ due to these three point charges?

(a) 9 V (b) 54 V (c) 15.3 V (d) 18 V (e) 6.3 V

3. Which of the following is the electric field in units of V/m at point $\mathbf{A}(-2\,m, 3\,m)$ due to the charges q_1 and Q only?

(a) $-4.5\,\hat{\imath} + 9\,\hat{\jmath}$ (b) $4.5\,\hat{\imath} - 6\,\hat{\jmath}$ (c) $4.5\,\hat{\imath} + 9\,\hat{\jmath}$ (d) $9\,\hat{\imath} + 6\,\hat{\jmath}$ (e) $-9\,\hat{\imath} + 9\,\hat{\jmath}$

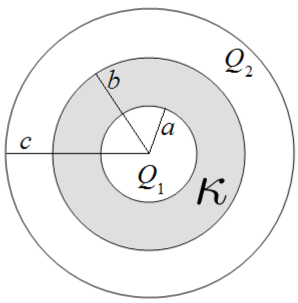
4. What is the potential at the (2 m,3 m) position of charge Q due to the charges q_1 and q_2?

(a) $72\,V$ (b) $-57.4\,V$ (c) $-18\,V$ (d) $14.4\,V$ (e) $-31.2\,V$

5. How much work is required to take the charge Q to infinity?

(a) $249.6\,J$ (b) $115.2\,J$ (c) $144\,J$ (d) $58.6\,J$ (e) $-576\,J$

Questions 6-10



A spherical capacitor consists of two concentric spherical conductors and a dielectric material filling the space between the conductors. The inner conductor is a solid sphere of radius $a = 2\,\mathrm{cm}$, the outer one is a spherical shell whose inner and outer radii are $b = 6\,\mathrm{cm}$ and $c = 10\,\mathrm{cm}$ respectively. Dielectric constant of the material between the conductors $\kappa = 3$. The total charge on the inner conductor $Q_1 = 20\,pC$ and that on the outer one $Q_2 = 40\,pC$. In the following, r represents the distance from the center of the spheres. (Unit prefix p stands for pico $= 10^{-12}$).

6. How much charge accumulates on the outermost surface?

(a) $-60\,pC$ (b) $-20\,pC$ (c) $60\,pC$ (d) 0 (e) $-40\,pC$

7. What is the potential on the inner surface of the outer conductor, namely at r$=$ 6 cm?

(a) 6 V (b) 5.4 V (c) 9 V (d) 0 (e) 3.6 V

8. What is the capacitance of the system?

(a) $10\,pF$ (b) $40\,pF$ (c) $54\,pF$ (d) $60\,pF$ (e) $12\,pF$

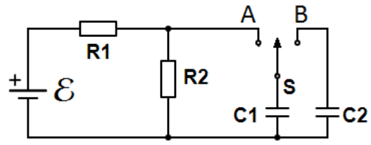
9. What is energy stored between the conductors?

(a) $30\,pJ$ (b) $20\,pJ$ (c) $54\,pJ$ (d) $45\,pJ$ (e) 0

10. What is total energy stored in the electric field outside the system where $c < r < \infty$?

(a) $18\,pJ$ (b) $162\,pJ$ (c) 0 (d) $72\,pJ$ (e) $54\,pJ$

Questions 11-15



The capacitors are initially uncharged and the battery has no internal resistance in the circuit given in the figure. $\mathcal{E} = 12\,\text{V}$, $C_1 = 50\,\mu\text{F}$, $C_2 = 100\,\mu\text{F}$, $R_1 = 2\,k\Omega$ and $R_2 = 4\,k\Omega$. (Unit prefixes μ, m and k stands for micro $= 10^{-6}$, milli $= 10^{-3}$ and kilo $= 10^3$ respectively).

11. What is the current flowing through the resistor R_1 immediately after the switch S is moved to position A?

(a) $3\,mA$ (b) $6\,mA$ (c) $1\,mA$ (d) $2\,mA$ (e) $4\,mA$

12. What is the potential difference across the capacitor C_1 long time after the switch S is moved to position A?

(a) 6 V (b) 0 V (c) 4 V (d) 8 V (e) 2 V

13. Which of the following is the time dependence of the charge stored in the capacitor C_1 in microcoulombs, assuming the switch S is moved to position A at t= 0?

(a) $200(1-e^{-12000t})$ (b) $100(1-e^{-30000t})$ (c) $300(1-e^{-5000t})$ (d) $500(1-e^{-1000t})$ (e) $400(1-e^{-15000t})$

Questions 14-15

At the instant when the potential difference across the capacitor C_1 is 6 V one moves the switch S to position B.

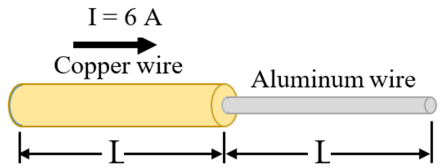
14. What is the potential difference across the capacitor C_2 after the circuit reaches equilibrium?

(a) 6 V (b) 9 V (c) 3 V (d) 2 V (e) 4 V

15. After the circuit reaches equilibrium, what is the total potential energy stored in the capacitors?

(a) $900\,\mu J$ (b) $450\,\mu J$ (c) $600\,\mu J$ (d) $200\,\mu J$ (e) $300\,\mu J$

Questions 16-20



A copper wire has a cross sectional area $A_1 = 10^{-6}\,m^2$ and has a density of charge carriers of 10^{29} electrons/m^3. As shown in the figure, the copper wire is attached to an equal length of aluminum wire with a cross sectional area $A_2 = 3 \times 10^{-8}\,m^2$, and density of charge carriers of 5×10^{28} electrons/m^3. A current of 6 A flows through the copper wire. Approximate resistivities of copper and aluminum are $\rho_{Cu} = 2 \times 10^{-8}\,\Omega.m$ and $\rho_{Al} = 3 \times 10^{-8}\,\Omega.m$ respectively.

16. Which of the following is the current flowing through the aluminum wire?

(a) 200 A (b) 0.18 A (c) 6 A (d) 1.2 A (e) 0.005 A

17. What is the ratio of the current densities in the two wires, J_{Cu}/J_{Al}?

(a) 3 (b) 0.0009 (c) 1 (d) 67 (e) 0.03

18. What is the ratio of the drift velocities in the two wires, v_D^{Cu}/v_D^{Al}?

(a) 0.015 (b) 67 (c) 0.03 (d) 3 (e) 0.0009

19. What is the ratio of the resistances of the two wires, R_{Cu}/R_{Al}?

(a) 3 (b) 1 (c) 0.02 (d) 50 (e) 1/3

20. What is the magnitude of the electric field in the copper wire?

(a) 0 (b) 0.12 V/m (c) 10^6 V/m (d) 9×10^9 V/m (e) 60 V/m

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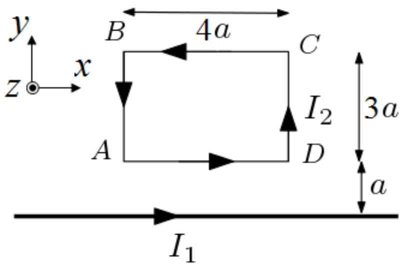
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

For all questions take: $c = 3 \times 10^8$ m/s, $\epsilon_o = 9 \times 10^{-12}$ F/m, $\mu_o = 4\pi \times 10^{-7}$ T.m/A

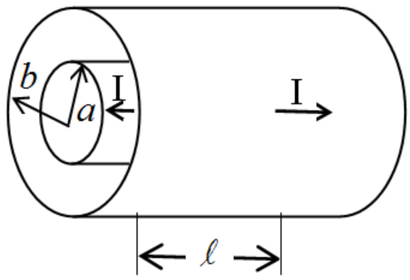
1. A rectangular current loop, carrying current I_2 and side lengths $3a$ and $4a$, is placed near a very long current carrying straight wire of current I_1, as shown in the figure. What is the magnetic force on the AB segment of the loop due to I_1?



(a) $-\frac{\mu_o I_1 I_2}{4\pi}\ln 3\,\hat{i}$ (b) $\frac{a\mu_o I_1 I_2}{2\pi}\ln 3\,\hat{k}$ (c) $\frac{2\mu_o I_1 I_2}{\pi}\ln 4\,\hat{k}$ (d) $-\frac{\mu_o I_1 I_2}{2\pi}\ln 4\,\hat{i}$ (e) $-\frac{\mu_o I_1 I_2}{2\pi a}\ln 4\,\hat{i}$

Questions 2-4

A long cable consists of two coaxial **thin walled** cylindrical **shells** with radii a and b. The inner and outer cylinders carry equal currents I in opposite directions as shown in the figure. (r is the distance from the axis of the cylinder.)



2. Find the magnitude of the magnetic field for $r < a$ (inside the inner cylinder).

(a) $\frac{\mu_0 I}{2\pi a}$ (b) $\frac{\mu_0 I \ell}{2\pi(b^2-a^2)}$ (c) $\frac{\mu_0 I}{2\pi r^2}$ (d) 0 (e) $\frac{\mu_0 I}{4\pi r}$

3. Find the magnitude of the magnetic field for $a < r < b$ (between the cylinders).

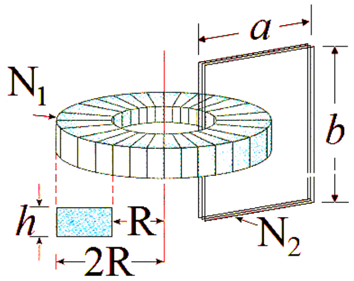
(a) $\frac{\mu_0 I}{2\pi(b-a)}$ (b) $\frac{\mu_0 I}{2\pi r}$ (c) $\frac{\mu_0 I}{2\pi a}$ (d) $\frac{\mu_0 I}{4\pi}$ (e) $\frac{\mu_0 I}{2\pi r^2}$

4. Find the energy density of the magnetic field in the region between the cylinders ($a < r < b$).

(a) $\frac{\mu_0 I^2}{8\pi^2 r^2}$ (b) $\frac{I^2}{4\pi^2 r^2 \mu_0}$ (c) $\frac{I^2}{4\pi^2(a+b)^2\mu_0}$ (d) $\frac{I^2}{2\mu_0 \ell(a+b)}$ (e) $\frac{\mu_0 I^2}{4\pi^2 \ell(b^2-a^2)}\ln(b/a)$

Questions 5-9

A toroid with a rectangular cross section has N_1 turns of wire. The inner and outer radii of the toroid are R and 2R, and h is the height of the toroid. A rectangular coil of sides a and b with N_2 turns of wire links with the toroid, as shown in the figure.



5. What is the self inductance "L" of this toroid?

(a) $\frac{\mu_o h N_1^2}{2\pi}$ (b) $\frac{\mu_o h N_1^2}{2\pi R^2}$ (c) $\frac{\mu_o h N_1^2}{2\pi}\ln 2$ (d) $\frac{\mu_o h N_1}{4\pi}\ln 2$ (e) $\frac{\mu_o h N_1^2}{2\pi R}\ln 2$

6. If a constant current of I is flowing in the wire of the toroid what is the energy stored in the toroid?

(a) $\frac{\mu_o h I N_1^2}{2\pi R^2}$ (b) $\frac{\mu_o h I^2 N_1^2}{2\pi}$ (c) $\frac{\mu_o h I^2 N_1^2}{4\pi}\ln 2$ (d) $\frac{\mu_o h I^2 N_1^2}{8\pi R}\ln 2$ (e) $\frac{\mu_o h I^2 N_1}{8\pi}\ln 2$

7. What is the mutual inductance "M" of this toroid-coil system?

(a) $\frac{\mu_o a b N_1 N_2}{2h\pi}$ (b) $\frac{\mu_o b h N_1^2}{2a\pi R}\ln 2$ (c) $\frac{\mu_o a h N_1^2}{2b\pi R^2}$ (d) $\frac{\mu_o a b N_1 N_2}{2h\pi}\ln 2$ (e) $\frac{\mu_o h N_1 N_2}{2\pi}\ln 2$

8. If a sinusoidal current $I = I_o\cos(\omega t)$ is flowing in the wire of the toroid, what is the induced emf in the coil?

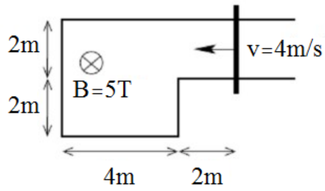
(a) $M\omega I_o\cos^2(\omega t)$ (b) $M\omega^2 I_o\sin(\omega t)$ (c) $M\omega^2 I_o\cos(\omega t)$ (d) $M\omega I_o\sin^2(\omega t)$ (e) $M\omega I_o\sin(\omega t)$

9. Now assume that the current in the toroid is set to zero, and a current i which is changing at a rate of di/dt is set in the coil. What is the induced emf in the toroid?

(a) $-LN_1\frac{di}{dt}$ (b) $-MN_1N_2\frac{di}{dt}$ (c) $-M\frac{di}{dt}$ (d) $-MN_1\frac{di}{dt}$ (e) $-MN_2\frac{di}{dt}$

Questions 10-13

A conducting frame with a moving conducting rod is located in a uniform magnetic field as shown in the figure.



10. Find the magnitude of the magnetic flux Φ_B through the frame at the instant shown

(a) 200 Wb (b) 800 Wb (c) 400 Wb (d) 100 Wb (e) 50 Wb

11. Find the magnitude of the induced emf $\mathcal{E}$ at the instant shown.

(a) 1 V (b) 80 V (c) 20 V (d) 10 V (e) 40 V

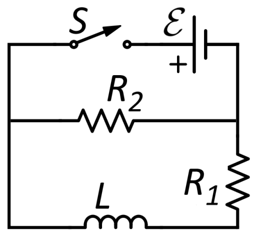
12. Find the direction of the induced current.

(a) In the direction of v (b) Into the page (c) Clockwise (d) Out the page (e) Counterclockwise

13. If the resistance of the frame at this instant is 50 Ω what is the magnitude of the magnetic force acting on the rod?

(a) 20 N (b) 8 N (c) 16 N (d) 12 N (e) 4 N

Questions 14-17



In the circuit shown in the figure, a battery supplies an emf of $\mathcal{E}$ and resistances are R_1, R_2, and inductance of the coil is L.

14. What is the magnitude of the current through R_1 immediately after the switch is closed?

(a) 0 (b) $\frac{\mathcal{E}}{R_1+R_2}$ (c) $\mathcal{E}\left(\frac{R_1+R_2}{R_1R_2}\right)$ (d) $\frac{\mathcal{E}}{R_1}$ (e) $\frac{\mathcal{E}}{R_2}$

15. What is the magnitude of the potential difference across L immediately after the switch is closed?

(a) $\mathcal{E}\frac{R_1}{R_2}$ (b) $\mathcal{E}\left(\frac{R_1}{R_1+R_2}\right)$ (c) $\mathcal{E}\frac{R_2}{R_1}$ (d) 0 (e) $\mathcal{E}$

16. What is the magnitude of rate of current change across R_1 immediately after the switch is closed?

(a) $\frac{\mathcal{E}}{L}$ (b) $\frac{\mathcal{E}}{4L}$ (c) $\frac{2\mathcal{E}}{L}$ (d) $\frac{\mathcal{E}}{2L}$ (e) $\frac{4\mathcal{E}}{L}$

17. What is the power dissipated on R_2 long time after the switch is closed?

(a) $\frac{\mathcal{E}^2}{4R_2}$ (b) $\frac{\mathcal{E}^2}{R_2}$ (c) $\frac{2\mathcal{E}^2}{R_2}$ (d) $\frac{4\mathcal{E}^2}{R_2}$ (e) $\frac{\mathcal{E}^2}{2R_2}$

Questions 18-20

An electromagnetic wave propagating in vacuum has an electric field vector given by $\vec{E}(y,t) = (30\,V/m)\cos\left[k\,y - (36\times10^{10}\,rad/s)t\right]\hat{i}$. (Take $\pi = 3$.)

18. What is the direction of propagation and wavelength of this electromagnetic wave?

(a) +y, 5×10^{-3} m (b) +z, 5×10^{-3} m (c) −x, 12×10^{-2} m (d) +y, 12×10^{2} m (e) −x, 5×10^{-3} m

19. What is the magnetic field vector of this wave?

(a) $-10^{-4}\cos\left[k\,y - 36\times10^{10}t\right]\hat{j}$ (b) $-10^{-7}\cos\left[k\,y - 36\times10^{10}t\right]\hat{k}$ (c) $-10^{-7}\cos\left[k\,y - 36\times10^{10}t\right]\hat{i}$
(d) $10^{-5}\cos\left[k\,y - 36\times10^{10}t\right]\hat{j}$ (e) $-10^{-4}\cos\left[k\,y - 36\times10^{10}t\right]\hat{k}$

20. What is the speed of this wave in a medium with a refractive index of 3/2?

(a) 4.5×10^{7} m/s (b) 4×10^{7} m/s (c) 2.25×10^{8} m/s (d) 2×10^{8} m/s (e) 4.5×10^{8} m/s

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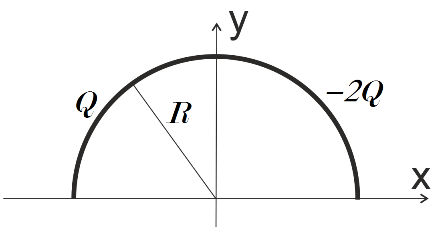
Questions 1-2

Positive charge Q for x<0 and negative charge $-2Q$ for x>0 is uniformly distributed around a semi-circle of radius R as shown in the figure.



1. Find the x-component of the electric field at the center of curvature.

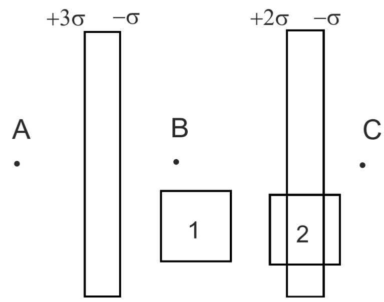
(a) $\frac{3kQ}{\pi R^2}$ (b) $\frac{6kQ}{\pi R^2}$ (c) $\frac{4kQ}{\pi R^2}$ (d) $\frac{kQ}{\pi R^2}$ (e) $\frac{2kQ}{\pi R^2}$

2. Find the y-component of the electric field at the center of curvature.

(a) $\frac{kQ}{\pi R^2}$ (b) $\frac{2kQ}{\pi R^2}$ (c) $\frac{3kQ}{\pi R^2}$ (d) $\frac{6kQ}{\pi R^2}$ (e) $\frac{4kQ}{\pi R^2}$

Questions 3-7

The surfaces of two thin nonconducting large planes are charged uniformly with different surface charge densities as shown in the figure.



3. Find the magnitude of the electric field at point A

(a) $\frac{3\sigma}{2\epsilon_o}$ (b) $\frac{3\sigma}{\epsilon_o}$ (c) $\frac{\sigma}{\epsilon_o}$ (d) $\frac{2\sigma}{\epsilon_o}$ (e) $\frac{\sigma}{2\epsilon_o}$

4. Find the magnitude of the electric field at point B

(a) $\frac{2\sigma}{\epsilon_o}$ (b) $\frac{3\sigma}{2\epsilon_o}$ (c) $\frac{3\sigma}{\epsilon_o}$ (d) $\frac{\sigma}{\epsilon_o}$ (e) $\frac{\sigma}{2\epsilon_o}$

5. Find the magnitude of the electric field at point C

(a) $\frac{3\sigma}{2\epsilon_o}$ (b) $\frac{3\sigma}{\epsilon_o}$ (c) $\frac{\sigma}{\epsilon_o}$ (d) $\frac{2\sigma}{\epsilon_o}$ (e) $\frac{\sigma}{2\epsilon_o}$

6. What is the flux through a cube (1) if the cube with a side length of b is placed between large planes (two surfaces of the cube are parallel to the plane).

(a) 0 (b) $\frac{3\sigma b^2}{\epsilon_o}$ (c) $\frac{3\sigma b^2}{2\epsilon_o}$ (d) $\frac{2\sigma b^2}{\epsilon_o}$ (e) $\frac{\sigma b^2}{\epsilon_o}$

7. What is the flux through a cube (2) if the cube is placed on the right plane so that the cube contains both faces of the plane (two surfaces of the cube are parallel to the plane).

(a) $\frac{3\sigma b^2}{\epsilon_o}$ (b) $\frac{\sigma b^2}{2\epsilon_o}$ (c) $\frac{\sigma b^2}{\epsilon_o}$ (d) $\frac{3\sigma b^2}{2\epsilon_o}$ (e) $\frac{2\sigma b^2}{\epsilon_o}$

Questions 8-9

An isolated conductor of arbitrary shape has a net charge of $10\,\mu C$. Inside the conductor there is a cavity within which there is a point charge of $3\,\mu C$.

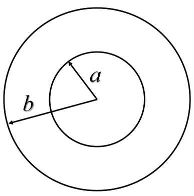
8. What is the charge on the cavity wall?

(a) 0 (b) $3\,\mu C$ (c) $-3\,\mu C$ (d) $7\,\mu C$ (e) $13\,\mu C$

9. What is the charge on the outer surface of the conductor?

(a) $-13\,\mu C$ (b) $13\,\mu C$ (c) $-3\,\mu C$ (d) $7\,\mu C$ (e) 0

10. Consider a conducting spherical shell with an inner radius a and outer radius b. If the space between two surfaces (surface a and surface b) be filled with a dielectric material of dielectric constant κ. What is the capacitance of this capacitor?



(a) $\frac{1}{4\pi\epsilon_o\kappa}\frac{ab}{b-a}$ (b) $4\pi\epsilon_o\kappa\frac{b-a}{ab}$ (c) $\frac{4\pi\epsilon_o}{\kappa}\frac{b-a}{ab}$ (d) $\frac{\kappa}{4\pi\epsilon_o}\frac{ab}{b-a}$ (e) $4\pi\epsilon_o\kappa\frac{ab}{b-a}$

Questions 11-12

A uniformly charged conducting sphere of 1 m radius has a surface charge density of $8\,\mu C/m^2$. Take $\pi = 3$ and $\epsilon_o = 9 \times 10^{-12}\, C^2/Nm^2$.

11. Find the net charge on the sphere, in units of μCs.

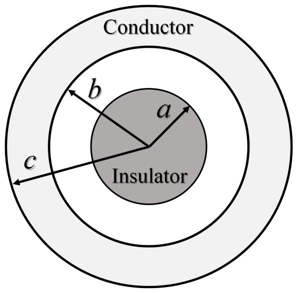
(a) 6 (b) 0 (c) 24 (d) 8 (e) 96

12. What is the total electric flux just outside surface of the sphere?

(a) $1.64 \times 10^6\, Nm^2/C$ (b) 0 (c) $8 \times 10^6\, Nm^2/C$ (d) $10.6 \times 10^6\, Nm^2/C$ (e) $0.1 \times 10^6\, Nm^2/C$

Questions 13-15

An insulating ball of dielectric constant κ and radius a carries a charge Q_1 and this charge is distributed non-uniformly with a volume charge density of the form $\rho(r) = \alpha r^2$ (here α is a constant). Then the ball is surrounded by a conducting spherical shell of inner radius b and outer radius c. The charge of the shell is Q_2. Find the magnitude of the electric field for the following regions:



13. $r < a$

(a) $\frac{\alpha r^3}{5\kappa\epsilon_o}$ (b) 0 (c) $\frac{\alpha r^3}{5\epsilon_o}$ (d) $\frac{\alpha r^5}{5\kappa\epsilon_o}$ (e) $\frac{\alpha a^3}{5\kappa\epsilon_o}$

14. $a < r < b$

(a) 0 (b) $\frac{2Q_1}{4\pi\kappa\epsilon_o r^2}$ (c) $\frac{Q_1}{4\pi\epsilon_o r^2}$ (d) $\frac{Q_1}{\kappa\epsilon_o r^2}$ (e) $\frac{Q_1}{4\pi\kappa\epsilon_o r^2}$

15. $b < r < c$

(a) 0 (b) $\frac{Q_1}{4\pi\kappa\epsilon_o r^2}$ (c) $\frac{Q_1}{4\pi\epsilon_o r^2}$ (d) $\frac{(Q_2-Q_1)}{4\pi\kappa\epsilon_o r^2}$ (e) $\frac{Q_1}{4\pi\kappa\epsilon_o (b-c)^2}$

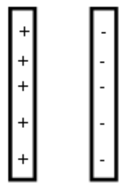
16. Which of the following arguments are true?

I. The external work done to increase the plate separation of a parallel-plate capacitor is positive.
II. If the potential difference across a capacitor is tripled the stored energy decreases to 1/3 of its initial value
III. The presence of a dielectric increases the maximum operating voltage of a capacitor.

(a) I,II (b) I, III (c) II,III (d) I,II,III (e) II

Questions 17-18

Two parallel plates are charged with opposite charges as in figure. The separation between the plates is 0.020 m. Charge of the electron is $-1.6 \times 10^{-19}\, C$, charge of the proton is $+1.6 \times 10^{-19}\, C$. Answer the following two questions



17. If an electron is accelerated, from the negatively charged plate to the positively charged plate, through a potential difference 20 V what will be the change in electric potential energy of the electron in unit of Joule? Is it increasing or decreasing?

(a) $+1.25 \times 10^{+18}$, decreasing (b) -3.2×10^{-19}, decreasing (c) $+3.2 \times 10^{-18}$, increasing (d) -3.2×10^{-18}, decreasing (e) $-1.25 \times 10^{+20}$, increasing

18. If the magnitude of the electric field between the plates is 500 Volt/meter. What is the change in potential energy of the proton, in unit of Joule, when accelerated from the positively charged plate to the negatively charged plate.

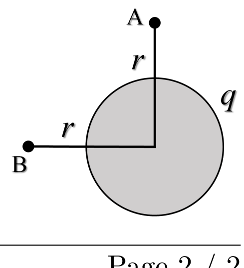
(a) 1.6×10^{-18} (b) $-6.25 \times 10^{+19}$ (c) -6.25×10^{-19} (d) -1.6×10^{-18} (e) $6.25 \times 10^{+19}$

19. If you increase the charge on a parallel-plate capacitor from $3\,\mu C$ to $9\,\mu C$ and increase the plate separation from 1 mm to 3 mm, the energy stored in the capacitor changes by a factor of

(a) $\frac{1}{3}$ (b) 8 (c) 9 (d) 27 (e) 3

20. Find the potential difference between points A and B, V_{AB} in terms of k, q, and r for a spherical charge distribution with charge q, as shown in figure.

(a) $\frac{kq}{2\sqrt{2}r}$ (b) $\frac{kq}{r}$ (c) 0 (d) $\frac{2kq}{r^2}$ (e) $\frac{kq}{\sqrt{2}r^2}$



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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)

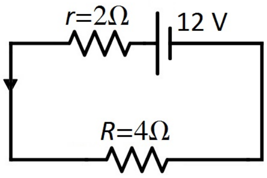
1. What is the current in the wire?

(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.

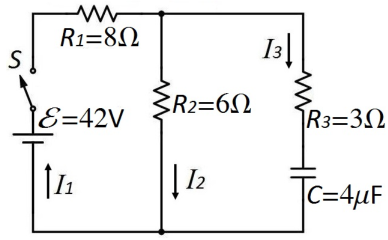
3. What is the rate of dissipation of electrical energy in the internal resistance of the battery?

(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

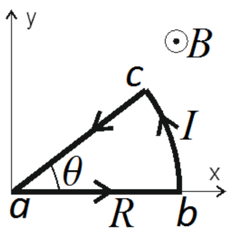
6. After the switch has been closed for a long time, find the current I_3 through the resistor R_3.

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

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

(a) $(0.24\hat{\imath} - 0.08\hat{\jmath})$ N (b) $(0.4\hat{\imath} + 0.32\hat{\jmath})$ N (c) $(0.24\hat{\imath} + 0.08\hat{\jmath})$ N (d) $(0.4\hat{\imath} - 0.32\hat{\jmath})$ 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,

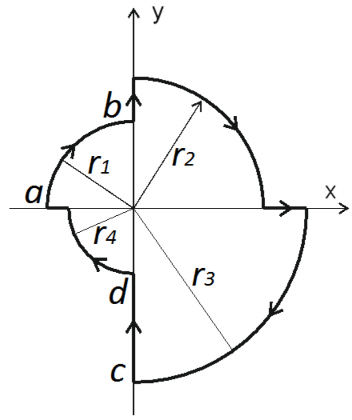
11. What is the magnetic potential energy of the loop?

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

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

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

Questions 13-15



A wire consist of four quarter circles with radii $r_1 = 4\,\mathrm{cm}$, $r_2 = 6\,\mathrm{cm}$, $r_3 = 10\,\mathrm{cm}$, $r_4 = 3\,\mathrm{cm}$ and straight sections as shown in the figure. The wire carries a current $I = 2\,\mathrm{A}$ in the direction shown. Take $\mu_o = 12\times10^{-7}\,\mathrm{T.m/A}$.

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

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

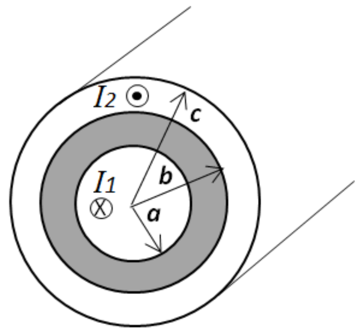
14. What is the magnitude of the magnetic field at the origin due to the part of *c*-*d*?

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

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

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

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 $\pi = 3$).

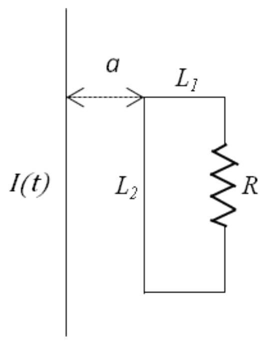
16. What is the magnitude of the magnetic field, in terms of μ_o, I and a, generated by these currents at the point $r = \frac{a}{2}$?

(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, $\omega_o = \frac{2\pi}{T}$, $T = 0.02\,\mathrm{s}$ 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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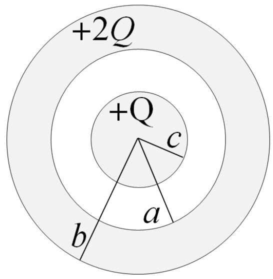
For all questions take: Speed of light in vacuum $c = 3 \times 10^8$ m/s, $\frac{1}{4\pi\epsilon_o} = 9 \times 10^9$ V.m/C, $\mu_o = 4\pi \times 10^{-7}\, T.m/A$

Questions 1-2

A hollow metal sphere has inner and outer radii of $a = 20$ cm and $b = 30$ cm, respectively. As shown in the figure, a solid, uniformly charged metal sphere of radius $c = 10$ cm is located at the center of hollow metal sphere. The solid sphere has a total charge of $+Q = 225$ nC and the spherical metal shell has a total charge of $+2Q$. (Take $V(\infty) = 0$).



1. What is the magnitude of the electric field at a distance of 15 cm from the center of the system in units of V/m?

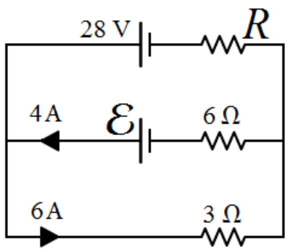
(a) 27 (b) 9×10^4 (c) 27×10^4 (d) 4.5×10^4 (e) 9

2. What is the potential difference V(r=5 cm)−V(r = 25 cm) in units of volts?

(a) 10125 (b) 9000 (c) −9000 (d) −18000 (e) 18000

Questions 3-4

In the circuit shown, find



3. the unknown resistance R in units of ohms

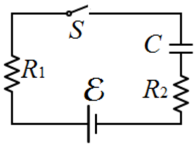
(a) 10 (b) 0 (c) 4 (d) 2 (e) 5

4. the unknown emf $\mathcal{E}$ in units of volts

(a) 0 (b) 42 (c) 32 (d) 2 (e) 14

Questions 5-6

The circuit shown in the figure has a switch, S, two resistors, $R_1 = 1\,\Omega$ and $R_2 = 2\,\Omega$, a 12 V battery, and a capacitor with $C = 20\,\mu F$. Initially the capacitor is uncharged.
(Take $ln(2) = 0.7$, unit prefix μ stands for micro $= 10^{-6}$).



5. After the switch is closed, what will the maximum charge on the capacitor be?

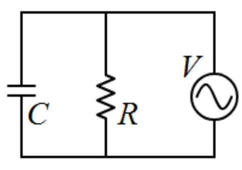
(a) 0.6×10^{-4} C (b) 0.8×10^{-4} C (c) 2.4×10^{-4} C (d) 240 C (e) 24 C

6. How long after the switch has been closed will the capacitor have 50% of this maximum charge?

(a) $42\,\mu s$ (b) $4.2\,\mu s$ (c) $21\,\mu s$ (d) $20\,\mu s$ (e) $7\,\mu s$

Questions 7-9

A parallel plate capacitor has circular plates of area A separated by a distance d. The exterior terminals of the plates are connected to a source with a voltage $V = V_o \sin(\omega t)$ over a parallel resistor of the resistance R, as in the figure.



7. What is the current in the resistance?

(a) $\frac{V_o \sin(\omega t)}{R}$ (b) $\frac{\sin(\omega t)}{R}$ (c) $\frac{V_o \sin(\omega t)}{2R}$ (d) $\frac{V_o \cos(\omega t)}{R}$ (e) 0

8. What is the displacement current through the capacitor?

(a) 0 (b) $\frac{\epsilon_o A\omega V_o \cos(\omega t)}{\pi d^2}$ (c) $\frac{\epsilon_o A\omega V_o \sin(\omega t)}{\pi d^2}$ (d) $\frac{\epsilon_o A\omega V_o \cos(\omega t)}{d}$ (e) $\frac{\epsilon_o A\omega V_o \sin(\omega t)}{d}$

9. What is the magnetic field between the capacitor plates at a distance r from the axis? Note that r is less than the radius of plates.

(a) 0 (b) $\frac{\mu_o r\omega V_o \cos(\omega t)}{2d}$ (c) $\frac{\mu_o \epsilon_o r V_o \sin(\omega t)}{2d}$ (d) $\frac{\mu_o \epsilon_o r\omega V_o \cos(\omega t)}{2d}$ (e) $\frac{V_o \epsilon_o \cos(\omega t)}{2d}$

Questions 10-12

Assume that a long solenoid with cross section area A. The number of turns is N, and turn density is n. The current inside the solenoid is $I(t) = I_o \cos(2\omega t)$.

10. Find magnetic field inside the solenoid.

(a) $\mu_o n I_o \sin(2\omega t)$ (b) $\mu_o n \cos(2\omega t)$ (c) 0 (d) $\mu_o I_o \cos(2\omega t)$ (e) $\mu_o n I_o \cos(2\omega t)$

11. Find magnetic flux through the solenoid.

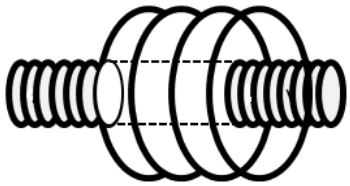
(a) $nNI_oA\cos(2\omega t)$ (b) $\mu_o n I_o A\cos(2\omega t)$ (c) $\mu_o nN\cos(2\omega t)$ (d) $\mu_o nNI_oA\cos(2\omega t)$ (e) $\mu_o nNI_o\cos(2\omega t)$

12. Find induced emf $\mathcal{E}$.

(a) $\mu_o n I_o A 2\omega\cos(2\omega t)$ (b) $\mu_o I_o A\omega\cos(2\omega t)$ (c) $\mu_o nNI_oA2\omega\sin(2\omega t)$ (d) 0 (e) $\mu_o n I_o A\cos(2\omega t)$

Questions 13-14

As seen in the figure, two coaxial coils made of conductive wires and whose radii are different are coiled over one another. Coils do not touch each other. The inner coil has a radius a, a length of $2L$, and a turn number of $2N$. The outer coil has a radius $2a$, a length L and a turn number of N. Constant current I flows through the inner coil. Answer the following 2 questions



13. What is the magnetic flux through the outer coil?

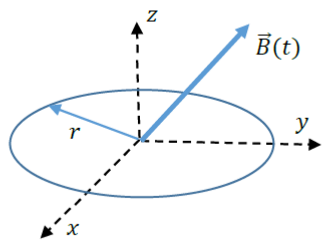
(a) $\dfrac{\mu_o N\pi a^2 I}{2L}$ (b) $\dfrac{\mu_o NLI}{4\pi a^2}$ (c) $\dfrac{\mu_o N\pi a^2 I}{L}$ (d) $\dfrac{\mu_o N4\pi a^2 I}{L}$ (e) $\dfrac{\mu_o NLI}{\pi a^2}$

14. What is the mutual inductance of coils?

(a) $\dfrac{\mu_o N^2 L}{\pi a^2}$ (b) $\dfrac{\mu_o N^2\pi a^2}{2L}$ (c) $\dfrac{\mu_o N^2 4\pi a^2}{L}$ (d) $\dfrac{\mu_o NL}{4\pi a^2}$ (e) $\dfrac{\mu_o N^2\pi a^2}{L}$

Questions 15-16

A conducting ring of radius r and total resistance R is kept fixed on the $xy-$plane. Starting at time $t = 0$, a uniform but increasing magnetic field $\vec{B}(t) = \alpha t(\hat{j} + \hat{k})$ is applied. Here α is a positive constant.



15. What is the magnitude of the current on the ring?

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

16. What is the net force on the ring?

(a) 0 (b) $\dfrac{\pi^2 r^3\alpha^2 t(\hat{i} - \hat{k})}{2R}$ (c) $\dfrac{2\pi^2 r^3\alpha^2 t(-\hat{i} + \hat{k})}{R}$ (d) $\dfrac{2\sqrt{2}\pi^2 r^3\alpha^2 t(\hat{i} - \hat{k})}{R}$ (e) $\dfrac{8\pi^2 r^3\alpha^2 t(-\hat{i} + \hat{j})}{3R}$

Questions 17-20

A carbon dioxide laser emits a sinusoidal electromagnetic wave that travels in vacuum in the negative x direction. The wavelength is 10 μm and the electric field, $\vec{E}$, is parallel to z-axis, with maximum magnitude 2 MV/m.
(Take $\pi = 3$, unit prefixes M, m and μ stand for mega$= 10^6$, milli$= 10^{-3}$ and micro$= 10^{-6}$ respectively.)

17. Which of the following answers give the correct values of the maximum value of the magnitude of the magnetic field, B_{max}, the wave number, k, and the angular frequency, ω?

(a) $B_{max} = 2\ mT,\ k = 3\times10^4\ rad/m,\ \omega = 2\times10^{14}\ rad/s$ (b) $B_{max} = \dfrac{3}{20}\ mT,\ k = 6\times10^5\ rad/m,\ \omega = 1.8\times10^{12}\ rad/s$

(c) $B_{max} = \dfrac{20}{3}\ mT,\ k = 6\times10^5\ rad/m,\ \omega = 1.8\times10^{14}\ rad/s$ (d) $B_{max} = 2\ mT,\ k = 6\times10^{-5}\ rad/m,\ \omega = 1.8\times10^{-14}\ rad/s$

(e) $B_{max} = \dfrac{20}{3}\ mT,\ k = \dfrac{10}{6}\times10^5\ rad/m,\ \omega = 2\times10^3\ rad/s$

18. Which of the following are correct vector equations for $\vec{E}$ and $\vec{B}$ as function of time and position?

(a) $\vec{E} = \hat{k}E_{max}\cos(kx - \omega t),\ \vec{B} = \hat{i}B_{max}\cos(kx - \omega t)$ (b) $\vec{E} = -\hat{i}E_{max}\cos(kx + \omega t),\ \vec{B} = \hat{j}B_{max}\cos(kx - \omega t)$
(c) $\vec{E} = -\hat{i}E_{max}\cos(kx - \omega t),\ \vec{B} = -\hat{j}B_{max}\cos(kx + \omega t)$ (d) $\vec{E} = \hat{k}E_{max}\cos(kx + \omega t),\ \vec{B} = \hat{j}B_{max}\cos(kx + \omega t)$
(e) $\vec{E} = \hat{k}E_{max}\cos(kx - \omega t),\ \vec{B} = \hat{j}B_{max}\cos(kx - \omega t)$

19. What is the average value of the Poynting vector, $\vec{S}_{av}$, (in units of W/m^2) over a complete cycle?

(a) $-\hat{i}\dfrac{5}{6}\times10^{10}$ (b) $\hat{j}\dfrac{5}{9}\times10^3$ (c) $-\hat{j}\dfrac{5}{6}\times10^{10}$ (d) $-\hat{i}\dfrac{5}{9}\times10^{10}$ (e) $-\hat{k}\dfrac{5}{6}\times10^{10}$

20. What is the intensity of the wave, in units of W/m^2?

(a) 6×10^{10} (b) $\dfrac{5}{6}\times10^7$ (c) $\dfrac{5}{9}\times10^3$ (d) $\dfrac{5}{6}\times10^{10}$ (e) $\dfrac{5}{9}\times10^{10}$

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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 considered.

$$\frac{1}{4\pi\epsilon_o} = 9\times10^9 \text{ m/F, unit prefixes } M=10^6,\ k=10^3,\ m=10^{-3},\ \mu=10^{-6},\ n=10^{-9},\ p=10^{-12}$$

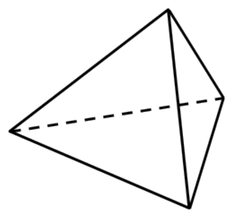
1. Two lightweight metal spheres are suspended near each other from insulating threads.The spheres are not allowed to touch each other. One of the spheres has a net charge while the other sphere is neutral (has no net charge). Which one of the following is correct?
I) The spheres will attract each other.
II) The spheres will exert no net electrostatic force on each other.
III) The spheres will repel each other.
IV) The spheres will share the charge.
V) The spheres will do any of those above, depending on the sign of the charge of the charged sphere.

(a) III (b) I (c) IV (d) V (e) II

2. Which of the following is/are true when the dielectric constant κ of the medium between the plates of a capacitor is increased while keeping the charges on the plates constant?
I) Potential difference between the plates decreases.
II) Electric field between the plates increases.
III) Potential energy of the capacitor increases.

(a) I and III (b) I and II (c) II and III (d) Only I (e) Only II

Questions 3-4



The equilateral triangular pyramid (or regular tetrahedron) in the figure is filled with a constant charge density of $\frac{1}{\pi}$ nC/m^3. Each edge of the pyramid is $\sqrt{2}$ m thus, its volume is $\frac{1}{3}$ m^3.

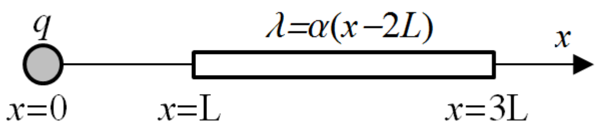
3. Determine the electric flux through the bottom surface of the pyramid.

(a) 0 (b) 6 V m (c) 3 V m (d) 2π V m (e) 12 V m

4. What is the value of $\oint \vec{E}\cdot d\vec{A}$ over the whole surface of the pyramid ($d\vec{A}$ is an infinitesimal element on the surface)?

(a) 0 (b) 6 V m (c) 2π V m (d) 3 V m (e) 12 V m

Questions 5-8



An insulating rod lies along the $x-$axis from $x = L$ to $x = 3L$. The linear charge density of the rod is given as $\lambda = \alpha(x - 2L)$. Here α is a positive constant.

5. Find the total charge on the rod.

(a) α (b) -2α (c) $-\alpha$ (d) 0 (e) 2α

6. Which of the following expressions gives the electric field generated by the rod at $x = 0$?

(a) $\frac{-\hat{\imath}\alpha}{4\pi\epsilon_o}\int_L^{3L}(x-2L)\,dx$ (b) 0 (c) $\frac{-\hat{\imath}\alpha}{4\pi\epsilon_o}\int_L^{3L}\frac{dx}{x^2}$ (d) $\frac{-\hat{\imath}\alpha}{4\pi\epsilon_o}\int_L^{3L}\frac{x-2L}{x^2}\,dx$ (e) $\frac{-\hat{\imath}\alpha}{4\pi\epsilon_o}\int_0^{2L}\frac{x-2L}{x^2}\,dx$

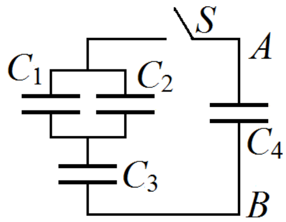
7. Which one of the following is the force that the charge q exerts on the rod?

(a) $\frac{\hat{\imath}\,q\,\alpha}{4\pi\epsilon_o}(\ln 3-\frac{4}{3})$ (b) $\frac{-\hat{\imath}\,q\,\alpha}{6\pi\epsilon_o}$ (c) 0 (d) $\frac{\hat{\imath}\,q\,\alpha}{6\pi\epsilon_o}$ (e) $\frac{\hat{\imath}\,q\,\alpha}{16\pi\epsilon_o L^2}$

8. By how much does the potential energy of the system change if one takes the charge q to infinity?

(a) $\frac{q\,\alpha}{4\pi\epsilon_o L}$ (b) $\frac{q\,\alpha}{2\pi\epsilon_o L}$ (c) $\frac{q\,\alpha}{6\pi\epsilon_o L}$ (d) $\frac{q\,\alpha\,L}{2\pi\epsilon_o}(\ln 3-1)$ (e) $\frac{q\,\alpha\,\ln 3}{2\pi\epsilon_o L}$

Questions 9-13



The capacitances of the capacitors in the figure are $C_1 = 20\,\mu$F, $C_2 = 30\,\mu$F, $C_3 = 50\,\mu$F and $C_4 = 15\,\mu$F. Initially C_1, C_2 and C_3 are uncharged and C_4 was charged with 20 V.

9. What is the equivalent capacitance between the points A and B after the switch S is closed?

(a) $\frac{930}{77}\,\mu$F (b) $50\,\mu$F (c) $75\,\mu$F (d) $115\,\mu$F (e) $40\,\mu$F

10. What is the initial charge stored in the capacitor C_4?

(a) 3 C (b) $300\,\mu C$ (c) $12\,\mu$C (d) 40 mC (e) 0.6 C

11. What is the initial energy stored in the capacitor C_4?

(a) 12 mJ (b) 30 mJ (c) 3 mJ (d) 6 mJ (e) 4 mJ

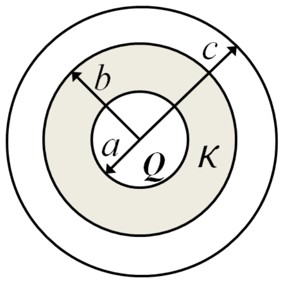
12. What is the potential difference V_{AB} after the switch S is closed?

(a) 7.5 V (b) $\sqrt{150}$ V (c) $\frac{800}{15}$ V (d) 10 V (e) 30 V

13. What is the total energy stored in the whole system after the switch S is closed?

(a) $\frac{9}{8}$ mJ (b) 12 mJ (c) 4 mJ (d) 6 mJ (e) 30 mJ

Questions 14-18



A solid spherical conductor of radius $a = 3$ cm is concentric with a spherical conducting shell. The inner and outer radii of the conducting shell are $b = 6$ cm and $c = 9$ cm, respectively. The space between these conductors is filled with a dielectric material of dielectric constant $\kappa = 3$. The total charge of the inner solid sphere is $Q = 0.6$ nC while the outer conducting shell and the dielectric material are uncharged. Assume that $V(\infty) = 0$.

14. What is the magnitude of the electric field at a point $r = 7\,cm$ away from the center?

(a) $\frac{3000}{7}$ V/m (b) $\frac{9000}{7}$ V/m (c) 0 (d) $\frac{54000}{49}$ V/m (e) 2160 V/m

15. What is the magnitude of the electric field at a point $r = 5\,cm$ away from the center?

(a) 720 V/m (b) 2160 V/m (c) 1800 V/m (d) 600 V/m (e) 0

16. What is the potential difference between the conductors?

(a) 60 V (b) 30 V (c) 15 V (d) 0 (e) 90 V

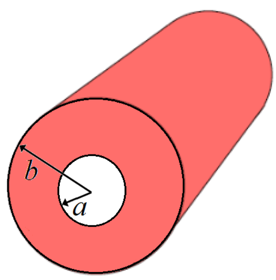
17. Which of the following is the capacitance of this system?

(a) 3 pF (b) 15 pF (c) 20 pF (d) 30 pF (e) 5 pF

18. Find the energy stored in the electric field outside the spherical shell in the region $c < r < \infty$.

(a) 3 nJ (b) 6 nJ (c) 5 nJ (d) 9 nJ (e) 18 nJ

Questions 19-20



The volume charge density ρ of a very long pipe is a positive constant. Inner and outer radii of the pipe are a and $b = 3\,a$ respectively.

19. Find the magnitude of the electric field at a distance $r = 2\,a$ from the axis.

(a) $\frac{9\rho a}{4\epsilon_o}$ (b) $\frac{3\rho a}{4\epsilon_o}$ (c) $\frac{3\rho a}{2\epsilon_o}$ (d) $\frac{4\rho a}{\epsilon_o}$ (e) $\frac{2\rho a}{\epsilon_o}$

20. Find the magnitude of the electric field at a distance $r = 4\,a$ from the axis.

(a) $\frac{15\rho a}{8\epsilon_o}$ (b) $\frac{15\rho a}{4\epsilon_o}$ (c) $\frac{9\rho a}{4\epsilon_o}$ (d) $\frac{9\rho a}{8\epsilon_o}$ (e) $\frac{\rho a}{\epsilon_o}$

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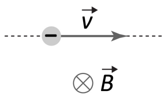
$\boldsymbol{\mu_o = 4\pi \times 10^{-7}}$ **T.m/A, unit prefixes** $\boldsymbol{M = 10^6,\ k = 10^3,\ m = 10^{-3},\ \mu = 10^{-6},\ n = 10^{-9},\ p = 10^{-12}}$

1. A particle with charge q and mass m moves in a circular trajectory with angular frequency ω_c in a constant, uniform magnetic field. What is the angular frequency of another particle with charge $2q$ and mass $m/2$?

(a) $2\omega_c$ (b) $\frac{1}{4}\omega_c$ (c) ω_c (d) $4\omega_c$ (e) $16\omega_c$

2.



An electron is moving with a constant velocity $\vec{v}$ directed to the right through a region of a uniform magnetic field $\vec{B}$ directed into the page (see figure). In which direction must an electric field be applied to keep the electron moving along a straight line?

(a) Upward (b) Downward (c) Out of the page (d) Into the page (e) To the left in the plane of the page

3. How does the magnetic field in an ideal solenoidal coil change if the number of turns in the coil is doubled? Assume the length of the coil is constant.

(a) The field increases 16 times (b) The field increases 4 times (c) The field decreases 4 times (d) The field increases 2 times (e) The field decreases 2 times

Questions 4-6

A cylindrical wire has a cross sectional area $A = 10^{-6}\,\mathrm{m}^2$ and has a density of charge carriers of 10^{29} electrons/m^3. A current of 0.4 A flows through the wire. Resistivity of the wire is $\rho = 2 \times 10^{-8}\,\Omega$.m and charge of the electron is approximately -1.6×10^{-19} C.

4. What is the magnitude of the drift velocity in the wire?

(a) 0.2 m/s (b) 4 m/s (c) 25×10^{-6} m/s (d) 0.08 m/s (e) 2.5×10^4 m/s

5. What is the magnitude of the electric field in the wire?

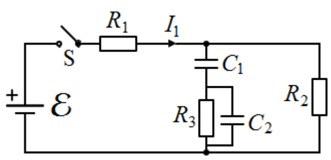
(a) 9×10^9 V/m (b) 60 V/m (c) 0.16 V/m (d) 8×10^{-3} V/m (e) 10^6 V/m

6. If the power dissipated in the wire is 0.16 W then what is the length of the wire?

(a) 2.5 m (b) 50 m (c) 40 m (d) 10 m (e) 20 m

Questions 7-10

The capacitors are initially uncharged and the battery has no internal resistance in the circuit given in the figure. $\mathcal{E} = 30$ V, $C_1 = 100\,\mu$F, $C_2 = 50\,\mu$F, $R_1 = 20\,\Omega$, $R_2 = 10\,\Omega$ and $R_3 = 30\,\Omega$.



7. What is the current I_1 flowing through the resistor R_1 immediately after the switch S is closed?

(a) 2 A (b) 0.5 A (c) 2.5 A (d) 1.5 A (e) 1 A

8. What is the current I_1 flowing through the resistor R_1 long after the switch S is closed?

(a) 0.5 A (b) 1.5 A (c) 2 A (d) 2.5 A (e) 1 A

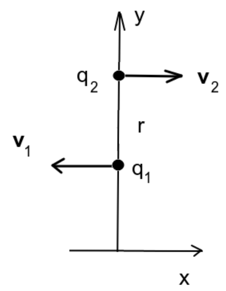
9. What is the charge accumulated in C_1 long after the switch S is closed?

(a) $\frac{1}{3}$ mC (b) 1.5 mC (c) $\frac{2}{3}$ mC (d) 0.5 mC (e) 1 mC

10. What is the energy stored in C_1 long after the switch S is closed?

(a) 5 mJ (b) $\frac{10}{3}$ mJ (c) 2.5 mJ (d) $\frac{5}{3}$ mJ (e) 0.3 mJ

Questions 11-12



Two particles with positive charges q_1 and q_2 are moving with speeds v_1 and v_2 parallel to the x-axis but in opposite directions as shown in figure.

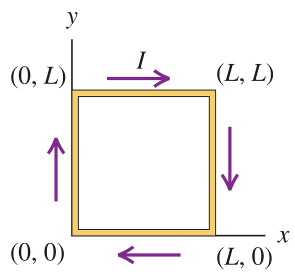
11. What is the magnetic field produced by q_1 at the position of q_2 when they are seperated by a distance r?

(a) $\frac{\mu_0 q_1 v_1}{4\pi r^2}\hat{\jmath}$ (b) $-\frac{\mu_0 q_1 v_1}{4\pi r^2}\hat{k}$ (c) $\frac{\mu_0 q_1 v_1}{4\pi r^2}\hat{k}$ (d) $-\frac{\mu_0 q_1 v_1}{4\pi r}\hat{k}$ (e) $\frac{\mu_0 q_1 v_1}{4\pi r^3}\hat{k}$

12. What is the magnetic force applied on q_2 due to the magnetic field produced by q_1 at that point?

(a) $\frac{\mu_0 q_1 q_2 v_1 v_2}{4\pi r}\hat{\jmath}$ (b) $\frac{\mu_0 q_1 q_2 v_1 v_2}{4\pi r^2}\hat{\jmath}$ (c) $-\frac{\mu_0 q_1 q_2 v_1 v_2}{4\pi r^2}\hat{\jmath}$ (d) $\frac{\mu_0 q_1 q_2 v_1 v_2}{4\pi r^2}\hat{\imath}$ (e) $\frac{\mu_0 q_1 q_2 v_1 v_2}{4\pi r^2}\hat{k}$

Questions 13-15



A square loop of side L lies in the $x-y$ plane with clockwise current I as shown in Figure. The loop is placed in a non-uniform magnetic field B given as $\vec{B} = B_0\left[(y/L)\hat{\imath} + (2x/L)\hat{\jmath}\right]$. Assume L, I, and B_0 are known.

13. What is the magnetic force on top segment of the loop $((0,L)-(L,L))$?

(a) $B_0 IL\hat{k}$ (b) $B_0 IL\hat{\jmath}$ (c) $2B_0 IL\hat{k}$ (d) $4B_0 IL\hat{k}$ (e) $\frac{1}{2}B_0 IL\hat{k}$

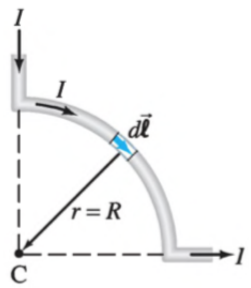
14. What is the magnetic force on the rightmost segment of the loop $((L,L)-(L,0))$?

(a) $B_0 IL\hat{k}$ (b) $4B_0 IL\hat{k}$ (c) $\frac{1}{4}B_0 IL\hat{k}$ (d) $2B_0 IL\hat{\jmath}$ (e) $\frac{1}{2}B_0 IL\hat{k}$

15. What is the net force on the loop?

(a) 0 (b) $B_0 IL\hat{\imath}$ (c) $2B_0 IL\hat{k}$ (d) $\frac{1}{8}B_0 IL\hat{k}$ (e) $\frac{1}{2}B_0 IL\hat{k}$

16. One quarter of a circular loop of wire carries a current I as shown in figure. The current I enters and leaves on straight segments of wire, as shown; the straight wires are along the radial direction from the center C of the circular portion. Find the magnitude of the magnetic field at point C.



(a) $\frac{\mu_0 I}{R}$ (b) $\frac{\mu_0 I}{2R}$ (c) $\frac{\mu_0 I}{4R}$ (d) $\frac{\mu_0 I}{6R}$ (e) $\frac{\mu_0 I}{8R}$

Questions 17-19

A copper wire of radius 2 mm carries a 20 A current (uniformly distributed across its cross section). Determine the magnetic field:

17. at the surface of the wire,

(a) 0.5 mT (b) 8.0 mT (c) 2.0 mT (d) 1.0 mT (e) 4.0 mT

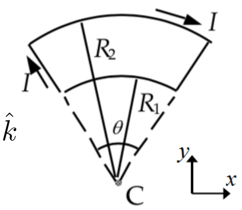
18. inside the wire, 0.50 mm below the surface,

(a) 1.0 mT (b) 2.0 mT (c) 1.5 mT (d) 3.0 mT (e) 6.0 mT

19. outside the wire 0.5 mm from the surface.

(a) 1.6 mT (b) 5.4 mT (c) 3.2 mT (d) 1.2 mT (e) 0.8 mT

20. A wire, in a plane, has the shape shown at right hand side, two arcs of a circle connected by radial lengths of wire. Determine B at point C in terms of R_1, R_2, θ, and the current I.



(a) $\frac{\mu_0 I\theta(R_1-R_2)}{2\pi R_1 R_2}\hat{k}$ (b) $\frac{\mu_0 I\theta R_1 R_2}{2\pi(R_1-R_2)}\hat{k}$ (c) $\frac{\mu_0 I\theta(R_2-R_1)}{4\pi R_1 R_2}\hat{k}$ (d) 0 (e) $\frac{\mu_0 I\theta R_1 R_2}{4\pi(R_2-R_1)}\hat{k}$

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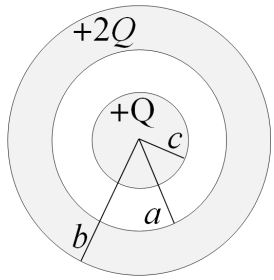
For all questions take: Speed of light in vacuum $c = 3 \times 10^8$ m/s, $\frac{1}{4\pi\epsilon_o} = 9 \times 10^9$ V.m/C, $\mu_o = 4\pi \times 10^{-7}$ T.m/A
unit prefixes $M = 10^6,\ k = 10^3,\ m = 10^{-3},\ \mu = 10^{-6},\ n = 10^{-9},\ p = 10^{-12}$

1. The magnetic field perpendicular to a circular wire loop 8.0 cm in diameter is changed from +0.55 T to −0.45 T in 160 ms, where + means the field points away from an observer and − toward the observer. What is the induced emf and what direction does the induced current flow? (Take $\pi = 3$, CW=clockwise, CCW=counterclockwise).

(a) 0.06 V / CCW (b) 0.06 V / CW (c) 0.003 V / CCW (d) 0.03 V / CCW (e) 0.03 V / CW

Questions 2-3

A hollow metal sphere has inner and outer radii of $a = 20$ cm and $b = 30$ cm, respectively. As shown in the figure, a solid, uniformly charged insulating sphere of radius $c = 10$ cm is located at the center of hollow metal sphere. The solid sphere has a total charge of $+Q = 9$ nC and the spherical metal shell has a total charge of $+2Q = 18$ nC. (Take V(∞) = 0).



2. What is the magnitude of the electric field at a distance of 15 cm from the center of the system?

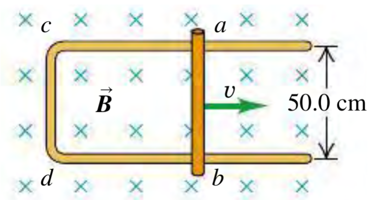
(a) 60 V/m (b) 3600 V/m (c) 9×10^4 V/m (d) 90 V/m (e) 4.5×10^4 V/m

3. What is the potential difference $V(r = 10\,\text{cm}) - V(r = 27\,\text{cm})$?

(a) 20 V (b) 405 V (c) 510 V (d) 200 V (e) 170 V

Questions 4-6

The conducting rod ab shown in the Figure makes contact with metal rails ca and db. The apparatus is in a uniform magnetic field of 0.800 T, perpendicular to the plane of the figure.



4. Find the magnitude and direction of the emf induced in the rod when it is moving toward the right with a speed 7.50 m/s.

(a) 1.5 V/from b to a (b) 3.0 V/from b to a (c) 6.5 V/from a to b (d) 3.0 V/from a to b (e) 6.0 V/from b to a

5. If the resistance of the circuit abdc is 1.50 Ohm (assumed to be constant), find the force (magnitude and direction) required to keep the rod moving to the right with a constant speed of 7.50 m/s. Ignore friction.

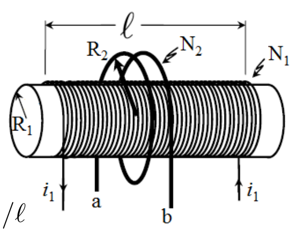
(a) 0.8 N/Left (b) 1.6 N/Left (c) 0.4 N/Right (d) 0.8 N/Right (e) 1.6 N/Right

6. What is the rate at which thermal energy is developed in the circuit?

(a) 3.0 W (b) 12.0 W (c) 4.0 W (d) 1.5 W (e) 6.0 W

Questions 7-9

A solenoid of N_1 turns (windings) has length ℓ and radius R_1. It's initial current is $i_1 = 2.5$ A. A shorter co-axial coil of radius R_2 and N_2 turns (heavy lines) is wrapped around the solenoid as shown.



7. If the current i_1 is reduced (at a constant rate) from 2.5 A to 1 A in 0.125 s , what voltage is induced between the ends a and b of the short coil ($V_a - V_b$)?

(a) $12\pi\mu_0 R_1^2 N_1 N_2/\ell$ (b) $\mu_0 R_2^2 N_1 N_2/\ell$ (c) $12\pi\mu_0 R_2^2 N_2/\ell$ (d) $\pi\mu_0 R_2^2 N_1 N_2/\ell$ (e) $\pi^2\mu_0 R_2^2 N_2/\ell$

8. What is the mutual inductance, M of this combination?

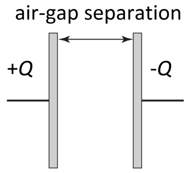
(a) $\pi\mu_0 N_1 N_2 R_1^2 \ell$ (b) $\pi\mu_0 N_1 R_1^2/\ell$ (c) $\pi\mu_0 N_1 N_2 R_1^2/\ell$ (d) $\mu_0 N_1 N_2 R_2^2 \ell$ (e) $\mu_0 N_1 N_2 R_2^2/\ell$

9. What is the self-inductance, L, of the inner solenoid?

(a) $\pi\mu_0 N_1^2 R_1^2/\ell$ (b) $\mu_0 N_1^2 R_1^2 \ell$ (c) $\pi\mu_0 N_1 R_1^2/\ell$ (d) $\pi\mu_0 N_1^2 R_1^2 \ell$ (e) $\mu_0 N_1^2 R_1^2/\ell$

Questions 10-11

A parallel-plate capacitor with plate area of $50\,\text{cm}^2$ and air-gap separation of 0.45 mm is connected to a 15 V battery, and fully charged. The battery is then disconnected.



10. With the battery disconnected, the capacitor plates are pulled to a separation of 0.90 mm. What is the potential difference V across the plates now?

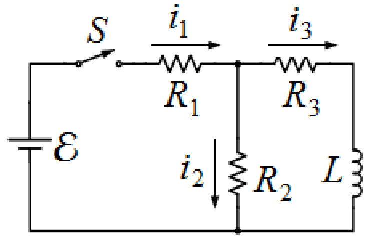
(a) 60 V (b) 10 V (c) 15 V (d) 45 V (e) 30 V

11. An insulating sheet with dielectric constant $K = 2$ is inserted between the plates with separation of 0.90 mm, completely filling the space between the plates. What is the potential difference V across the plates now?

(a) 15 V (b) 7.5 V (c) 60 V (d) 30 V (e) 120 V

Questions 12-15

In the figure, the EMF of the battery is $\mathcal{E} = 100\,\text{V}$, the resistences of the resistors are $R_1 = 10.0\,\Omega$, $R_2 = 20.0\,\Omega$, $R_3 = 30.0\,\Omega$, and the inductance of the inductor is $L = 2.00\,\text{H}$. Find the values of i_1 and i_2



12. *immediately after* the closing of switch S

(a) $i_1 = 40/11\,\text{A}$, $i_2 = 24/11\,\text{A}$ (b) $i_1 = 10/3\,\text{A}$, $i_2 = 10/3\,\text{A}$ (c) $i_1 = 30/11\,\text{A}$, $i_2 = 18/11\,\text{A}$ (d) $i_1 = 10/3\,\text{A}$, $i_2 = 5/3\,\text{A}$ (e) $i_1 = 50/11\,\text{A}$, $i_2 = 30/11\,\text{A}$

13. *a long time after* the closing of switch S

(a) $i_1 = 10/3\,\text{A}$, $i_2 = 10/3\,\text{A}$ (b) $i_1 = 50/11\,\text{A}$, $i_2 = 20/11\,\text{A}$ (c) $i_1 = 50/11\,\text{A}$, $i_2 = 30/11\,\text{A}$ (d) $i_1 = 40/11\,\text{A}$, $i_2 = 24/11\,\text{A}$ (e) $i_1 = 30/11\,\text{A}$, $i_2 = 18/11\,\text{A}$

14. immediately after reopening of switch S

(a) $i_1 = 10/3\,\text{A}$, $i_2 = 5/3\,\text{A}$ (b) $i_1 = 40/11\,\text{A}$, $i_2 = 24/11\,\text{A}$ (c) $i_1 = 50/11\,\text{A}$, $i_2 = 30/11\,\text{A}$ (d) $i_1 = 10/3\,\text{A}$, $i_2 = 10/3\,\text{A}$ (e) $i_1 = 0\,\text{A}$, $i_2 = 20/11\,\text{A}$

15. a long time after reopening of switch S

(a) $i_1 = 30/11\,\text{A}$, $i_2 = 18/11\,\text{A}$ (b) $i_1 = 10/3\,\text{A}$, $i_2 = 10/3\,\text{A}$ (c) $i_1 = 0\,\text{A}$, $i_2 = 0\,\text{A}$ (d) $i_1 = 50/11\,\text{A}$, $i_2 = 30/11\,\text{A}$ (e) $i_1 = 40/11\,\text{A}$, $i_2 = 24/11\,\text{A}$

Questions 16-20

A dipol antenna emits a sinusoidal electromagnetic wave that travels in vacuum in the positive z direction. The frequency of the wave is 200 MHz and the magnetic field $\vec{B}$ is pointing in the negative x-direction, with maximum magnitude $0.2\,\mu\text{T}$. (Take $\pi = 3$).

16. What is the wavelength of this wave?

(a) 1.5 m (b) 3 m (c) 9 m (d) 4 m (e) 6 m

17. Which of the following is the electric field $\vec{E}$ of this wave in SI units?

(a) $3\cos(4x - 12 \times 10^8 t)\,\hat{\imath}$ (b) $3\sin(12z + 1.5 \times 10^8 t)\,\hat{k}$ (c) $60\cos(1.5z - 2 \times 10^8 t)\,\hat{\imath}$ (d) $60\cos(4z - 12 \times 10^8 t)\,\hat{\jmath}$ (e) $-60\cos(1.5z - 2 \times 10^8 t)\,\hat{\jmath}$

18. What is the intensity of the wave?

(a) $10\,\text{W/m}^2$ (b) $16\,\text{W/m}^2$ (c) $8\,\text{W/m}^2$ (d) $5\,\text{W/m}^2$ (e) $2.5\,\text{W/m}^2$

19. What is the wavelength of this wave if it is traveling in a medium with a refractive index of $n = 1.5$?

(a) 9 m (b) 3 m (c) 1 m (d) 1.5 m (e) 6 m

20. If the wave is traveling in a medium with a refractive index of $n = 1.5$ and if the maximum value of the magnetic field is $0.2\,\mu\text{T}$ what is the maximum value of the electric field?

(a) 60 V/m (b) 10 V/m (c) 90 V/m (d) 40 V/m (e) $\frac{80}{3}$ V/m

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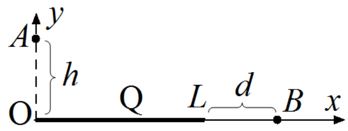
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be considered.

Unit prefixes $M = 10^6,\ k = 10^3,\ m = 10^{-3},\ \mu = 10^{-6},\ n = 10^{-9},\ p = 10^{-12}$

Questions 1-4



Positive charge Q is distributed uniformly on an insulating rod which lies along the $x-$axis from $x = 0$ to $x = L$. In the following $k\!\!\!/ = \dfrac{1}{4\pi\epsilon_o}$.

1. Which of the following gives the magnitude of the x component of the electric field at point A?

(a) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{x\,dx}{(x+h)^2}$ (b) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{x\,dx}{(x^2+h^2)^{3/2}}$ (c) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{x\,dx}{x^2+h^2}$ (d) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{dx}{(x^2+h^2)^{3/2}}$ (e) $\frac{k\!\!\!/ Q\,h}{L}\int_0^L \frac{dx}{(x^2+h^2)^{3/2}}$

2. Which of the following gives the magnitude of the y component of the electric field at point A?

(a) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{x\,dx}{(x^2+h^2)^{3/2}}$ (b) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{dx}{(x^2+h^2)^{3/2}}$ (c) $\frac{k\!\!\!/ Q\,h}{L}\int_0^L \frac{dx}{x^2+h^2}$ (d) $\frac{k\!\!\!/ Q\,h}{L}\int_0^L \frac{dx}{(x+h)^2}$ (e) $\frac{k\!\!\!/ Q\,h}{L}\int_0^L \frac{dx}{(x^2+h^2)^{3/2}}$

3. Which of the following gives the electric potential at point A? Assume V(∞)= 0.

(a) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{x\,dx}{\sqrt{x^2+h^2}}$ (b) $\frac{k\!\!\!/ Q\,h}{L}\int_0^L \frac{dx}{\sqrt{x^2+h^2}}$ (c) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{x\,dx}{(x^2+h^2)^2}$ (d) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{dx}{\sqrt{x^2+h^2}}$ (e) $\frac{k\!\!\!/ Q}{L}\int_0^L \frac{dx}{x^2+h^2}$

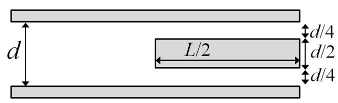
4. How much work does the electric field of this charge distribution do on a negative point charge q to bring it from ∞ to the point B?

(a) $\frac{2\,k\!\!\!/\,q\,Q}{L+2\,d}$ (b) $\frac{k\!\!\!/\,q\,Q\,L}{(x^2+d^2)^{3/2}}$ (c) $\frac{k\!\!\!/\,q\,Q}{\sqrt{x^2+d^2}}$ (d) $\frac{k\!\!\!/\,q\,Q}{L}\ln\frac{L+d}{d}$ (e) $\frac{k\!\!\!/\,q\,Q}{L+d}$

Questions 5-7

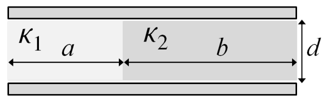
Consider a parallel plate capacitor of capacitance C_0. The distance between the plates is d and each plate is a square of side L.

5. If a conductor of thickness $d/2$ of width $L/2$ and of length L, is inserted between the plates of the capacitor as shown in the figure what will be the new capacitance?



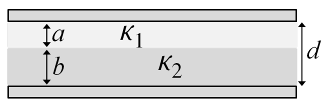
(a) $\dfrac{3\,C_0}{2}$ (b) $\dfrac{3\,C_0}{5}$ (c) $\dfrac{5\,C_0}{2}$ (d) $\dfrac{2\,C_0}{3}$ (e) $\dfrac{5\,C_0}{3}$

6. If two dielectric materials of dielectric constants κ_1 and κ_2 are inserted between the plates of the capacitor as shown in the figure what will be the new capacitance? Here $a + b = L$.



(a) $\dfrac{L\,\kappa_1\,\kappa_2}{a\,\kappa_2 + b\,\kappa_1}C_0$ (b) $\dfrac{L\,\kappa_1\,\kappa_2}{a\,\kappa_1 + b\,\kappa_2}C_0$ (c) $\dfrac{L\,(\kappa_1 + \kappa_2)}{a + b}C_0$ (d) $\dfrac{a\,\kappa_1 + b\,\kappa_2}{L}C_0$ (e) $\dfrac{a\,\kappa_2 + b\,\kappa_1}{L}C_0$

7. If two dielectric materials of dielectric constants κ_1 and κ_2 are inserted between the plates of the capacitor as shown in the figure what will be the new capacitance? Here $a + b = d$.



(a) $\dfrac{a + b}{d\,(\kappa_1 + \kappa_2)}C_0$ (b) $\dfrac{a\,\kappa_2 + b\,\kappa_1}{d}C_0$ (c) $\dfrac{d\,\kappa_1\,\kappa_2}{a\,\kappa_2 + b\,\kappa_1}C_0$ (d) $\dfrac{d\,\kappa_1\,\kappa_2}{a\,\kappa_1 + b\,\kappa_2}C_0$ (e) $\dfrac{a\,\kappa_1 + b\,\kappa_2}{d}C_0$

Questions 8-9

A 10 V power supply is connected to the terminals of a parallel plate capacitor of capacitance 60 μF.

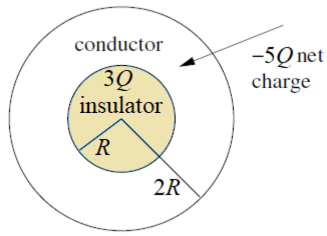
8. Without removing the power supply, the space between the plates is filled with an insulator of dielectric constant $\kappa = 4$. Which of the following is the energy stored in the capacitor after the insulator is inserted?

(a) 12 mJ (b) 6 mJ (c) 3 mJ (d) 1.5 mJ (e) 0.75 mJ

9. Assume that after fully charging the 60 μF capacitor the power supply is disconnected and the space between the plates is filled with an insulator of dielectric constant $\kappa = 4$. Which of the following is the energy stored in the capacitor after the insulator is inserted?

(a) 1.5 mJ (b) 0.75 mJ (c) 3 mJ (d) 12 mJ (e) 6 mJ

Questions 10-14



$3Q$ charge is uniformly distributed through a solid insulating sphere with radius R. This sphere is surrounded with an equicentered conducting spherical shell carrying $-5Q$ net charge and the thickness of it is given as R. If r is the distance measured from the center; (In the following $\not{k} = \frac{1}{4\pi\epsilon_o}$)

10. What is the charge density on the outer surface of the conducting sphere?

(a) $\frac{-Q}{8\pi R^2}$ (b) $\frac{-5Q}{16\pi R^2}$ (c) $\frac{-3Q}{16\pi R^2}$ (d) 0 (e) $\frac{-3Qr}{16\pi R^3}$

11. What are the electric fields for $r > 2R$, $R < r < 2R$ and $r < R$ regions, respectively?

(a) $\frac{-2\not{k}Q}{r^2}, 0, \frac{3\not{k}Qr}{R^3}$ (b) $\frac{-\not{k}Q}{r^2}, 0, \frac{3\not{k}Q}{R^2}$ (c) $\frac{-\not{k}Q}{r^2}, \frac{-2\not{k}Q}{r^2}, \frac{3\not{k}Qr}{R^3}$ (d) $\frac{-\not{k}Q}{r^2}, \frac{-5\not{k}Q}{4R^2}, \frac{3\not{k}Qr}{R^3}$ (e) $\frac{-\not{k}Q}{r^2}, 0, 0$

12. What are the electric potentials for $R < r < 2R$ and $r < R$ regions, respectively? Assume V(∞)= 0.

(a) $\frac{-\not{k}Q}{R}, \frac{-\not{k}Q}{2R}$ (b) $\frac{-\not{k}Q}{2R}, \frac{\not{k}Q}{2R}$ (c) $\frac{-\not{k}Q}{R}, \frac{\not{k}Q}{2R}(1 - 3\frac{r^2}{R^2})$ (d) $0, \frac{\not{k}Q}{2R}(5 - 6\frac{r^2}{R^2})$ (e) $\frac{-\not{k}Q}{2R}, \frac{\not{k}Q}{2R}(5 - 6\frac{r}{R})$

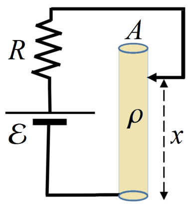
13. How much work is done to bring $-Q$ charge from the outer surface to the inner surface of the conducting shell?

(a) $\frac{2\not{k}Q^2}{r}$ (b) $\frac{-\not{k}Q^2}{r}$ (c) 0 (d) $\frac{-2\not{k}Q^2}{r}$ (e) $\frac{\not{k}Q^2}{r}$

14. If the charge in the inner sphere was concentrated at the center as a point charge instead of distributing throughout its volume, which one of the following would change?

(a) Electric potential for $r > 2R$ (b) Electric field for $r < R$ region (c) The work done to bring -Q charge from the outer surface to the inner surface of the conducting shell (d) Electric field for $R < r < 2R$ region (e) Charge densities on the inner and outer surfaces of the conducting shell

Questions 15-17



An ideal battery whose EMF is $\mathscr{E}$ is connected to a resistor with resistance R and a resistor with variable resistance as shown in the figure. The variable resistor is made up of a cylinder of cross sectional area A , and the material has resistivity ρ. The distance of the contact point from the end x can be adjusted to change the value of the resistance.

15. What is the current in the circuit in terms of the given quantities?

(a) $\frac{3A\mathscr{E}}{RA+2\rho x}$ (b) $\frac{2A\mathscr{E}}{RA+\rho x}$ (c) $\frac{A\mathscr{E}}{2RA}$ (d) $\frac{A\mathscr{E}}{RA+\rho x}$ (e) $\frac{3A\mathscr{E}}{2RA+\rho x}$

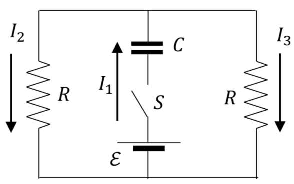
16. What is the power dissipated on the variable resistor?

(a) $\frac{3\rho A\mathscr{E}^2 x}{(2RA+\rho x)^2}$ (b) $\frac{3\rho A\mathscr{E}^2 x}{(RA+2\rho x)^2}$ (c) $\frac{2\rho A\mathscr{E}^2 x}{(RA+\rho x)^2}$ (d) $\frac{\rho A\mathscr{E}^2 x}{4R^2A^2}$ (e) $\frac{\rho\mathscr{E}^2 Ax}{(RA+\rho x)^2}$

17. What should be the value of x so that the power dissipated on the variable resistor is maximum?

(a) $\frac{2RA}{3\rho}$ (b) $\frac{2RA}{\rho}$ (c) $\frac{RA}{\rho}$ (d) $\frac{RA}{3\rho}$ (e) $\frac{3RA}{2\rho}$

Questions 18-20



Consider the circuit shown in the figure with the capacitor initially uncharged. The switch S is closed at time $t = 0$.

18. What is the current through each resistor at time $t = 0$?

(a) $I_1 = \frac{\mathscr{E}}{2R}, I_2 = I_3 = \frac{\mathscr{E}}{R}$ (b) $I_1 = I_2 = \frac{\mathscr{E}}{R}, I_3 = \frac{2\mathscr{E}}{R}$ (c) $I_1 = I_2 = \frac{2\mathscr{E}}{R}, I_3 = \frac{\mathscr{E}}{R}$
(d) $I_1 = 0, I_2 = I_3 = \frac{2\mathscr{E}}{R}$ (e) $I_1 = \frac{2\mathscr{E}}{R}, I_2 = I_3 = \frac{\mathscr{E}}{R}$

19. What is the final charge on the capacitor when it becomes fully charged?

(a) $2C\mathscr{E}$ (b) $C\mathscr{E}$ (c) $4C\mathscr{E}$ (d) $3C\mathscr{E}$ (e) 0

20. Find the current I_1 through the capacitor as a function of time.

(a) $\frac{\mathscr{E}}{2R}e^{-t/(RC)}$ (b) $\frac{2\mathscr{E}}{R}e^{-t/(RC)}$ (c) $\frac{\mathscr{E}}{2R}e^{-t/(RC/2)}$ (d) $\frac{2\mathscr{E}}{R}e^{-t/(2RC)}$ (e) $\frac{2\mathscr{E}}{R}e^{-t/(RC/2)}$

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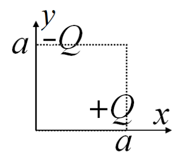
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

For all questions: Speed of light in vacuum $c = 3 \times 10^8$ m/s, $\frac{1}{4\pi\epsilon_o} = 9 \times 10^9$ V.m/C, $\mu_o = 4\pi \times 10^{-7}\, T.m/A$
Unit prefixes $M = 10^6$, $k = 10^3$, $m = 10^{-3}$, $\mu = 10^{-6}$, $n = 10^{-9}$, $p = 10^{-12}$

1. Electrical charges 1 nC and −1 nC have been placed at $(a,\ 0)$ and $(0,\ a)$, a=3 m. What is the electrical field (in full form) at the origin? (Take $\pi = 3$).



(a) $3(\hat{\imath} - \hat{\jmath})$ N/C (b) $(-\hat{\imath} + \hat{\jmath})$ N/C (c) 3 N/C (d) 0 (e) $(\hat{\imath} - \hat{\jmath})$ N/C

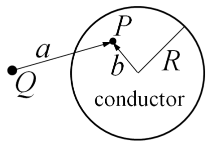
2. A line charge with uniform charge density λ, placed on the x-axis, extends from $x = 0$ to $x \to \infty$. Determine F_x, the $x-$component force acting on a point charge q placed at $(0, y)$.

(a) $-\frac{q\lambda}{4\pi\epsilon_0 y}$ (b) 0 (c) $\frac{q\lambda}{4\pi\epsilon_0 y}$ (d) $\frac{q\lambda}{2\pi\epsilon_0 y}$ (e) $-\frac{q\lambda}{2\pi\epsilon_0 y}$

3. Which of the following is the unit of $\sqrt{\mu_0/\epsilon_0}$ where μ_0 is the magnetic permeability and ϵ_0 is the electric permittivity of vacuum.

(a) Ohm (b) Ohm / s (c) Ohm m (d) kg m/C^2 s (e) Ohm / m

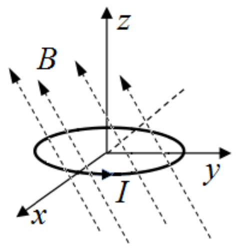
4. Point charge Q is placed out of an uncharged solid conducting sphere of radius $R = 4$ cm. Point P inside the sphere is $a = 6$ cm away from the charge Q and $b = 3$ cm away from the center of the sphere. $Q = 4$ pC. Find the magnitude of the electric field at point P.



(a) 10 V/m (b) 40 V/m (c) 22.5 V/m (d) 0 (e) 90 V/m

Questions 5-7

The axis of a ring shaped 100-turns coil is parallel to z-axis, as shown in the figure. In each of the turns a current $I = 0.5$ A flows and the area of the coil is 0.1 m^2. A homogeneous magnetic field $\vec{B} = 0.2\,(\hat{\imath} - 2\hat{\jmath} + 4\hat{k})$ T passes through the whole area of the ring.

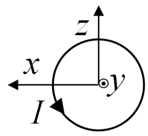


5. Find the magnetic moment (or magnetic dipole moment) $\vec{\mu}$ of this coil in units of A.m^2.

(a) $\hat{\imath} - 2\hat{\jmath} + 4\hat{k}$ (b) $-2\hat{\jmath}$ (c) $4\hat{k}$ (d) $\hat{\imath}$ (e) $5\hat{k}$

6. What is the net torque on the coil in units of N.m?

(a) $10\hat{\imath} + 5\hat{\jmath}$ (b) $-0.8\hat{\jmath} - 0.4\hat{k}$ (c) $-1.6\hat{\imath} + 0.4\hat{\jmath}$ (d) $2\hat{\imath} + \hat{\jmath}$ (e) $1.6\hat{\imath} + 0.8\hat{\jmath}$

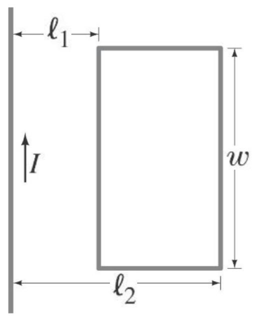


7. If the axis of the coil is directed toward the $+y$-direction as shown in the figure by how much its potential energy increase?

(a) 2.8 J (b) 2.2 J (c) 5.2 J (d) 6 J (e) 6.2 J

Question 8-9

A long straight wire and a small rectangular wire loop with total resistance R lie in the same plane, as illustrated in the figure.



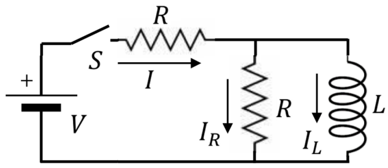
8. Determine the mutual inductance in terms of ℓ_1, ℓ_2 and ω. Assume that the wire is very long compared to ℓ_1, ℓ_2 and that the rest of its circuit is very far away compared to ℓ_1, ℓ_2 and ω.

(a) $\frac{\mu_0\omega}{2\pi}\ln\left(\frac{\ell_2}{\ell_1}\right)$ (b) $\frac{\mu_0\omega}{4\pi}$ (c) $\frac{\mu_0\omega}{4\pi}\ln\left(\frac{\ell_2}{\ell_1}\right)$ (d) $\frac{\mu_0\omega}{2\pi}\ln\left(\frac{\ell_2-\ell_1}{\ell_2}\right)$ (e) $\frac{\mu_0\omega}{4\pi}\ln\left(\frac{\ell_2-\ell_1}{\ell_1}\right)$

9. Assume that the current I in the long straight wire is decreasing at a constant rate $\frac{dI}{dt} = -\beta$. What is the magnitude of the net force on the rectangular wire loop?

(a) $\frac{\mu_0\omega}{2\pi}\ln\left(\frac{\ell_2}{\ell_1}\right)$ (b) $\frac{\mu_0\omega}{4\pi}$ (c) $\frac{\mu_0\omega}{4\pi}\ln\left(\frac{\ell_2}{\ell_1}\right)$ (d) $\frac{\mu_0\omega}{2\pi}\ln\left(\frac{\ell_2-\ell_1}{\ell_2}\right)$ (e) $\frac{\mu_0\omega}{4\pi}\ln\left(\frac{\ell_2-\ell_1}{\ell_1}\right)$

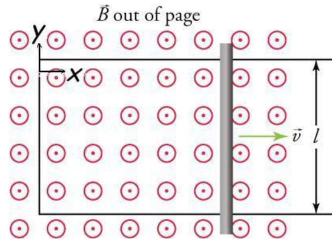
10. Consider the circuit in the figure with the switch S closed at time $t = 0$. What is the current $I_L(t)$ through the inductor L as a function of time?



(a) $\frac{V}{R}e^{-tR/2L}$ (b) $\frac{V}{R}\left(1-e^{-tR/L}\right)$ (c) $\frac{V}{R}e^{-2tR/L}$ (d) $\frac{V}{R}\left(1-e^{-tR/2L}\right)$
(e) $\frac{V}{R}\left(1-e^{-2tR/2L}\right)$

Questions 11-13

A U-shaped wire and rod of length ℓ forms a plane circuit in the $x-y$ plane. A magnetic field perpendicular to the plane of the figure and directed out of the page (z-direction) increases in the x-direction linearly as $\vec{B} = Kx\hat{k}$ where K is a constant. The bottom part of the U-shaped wire is at $x = 0$ and the rod starts its motion with velocity v from this position and continues with constant velocity. The resistance of the circuit is proportional to the length of the wire, L, through which current flows: $R = \alpha L$.



11. What is the magnetic flux through the circuit at any time t?

(a) $\Phi_m = \frac{1}{2}K\ell vt^2$ (b) $\Phi_m = \frac{1}{2}K\ell v^2t$ (c) $\Phi_m = K\ell vt$ (d) $\Phi_m = \ell vt^2$ (e) $\Phi_m = \frac{1}{2}K\ell v^2t^2$

12. What is the electromotive force induced in the circuit due to the motion of the rod?

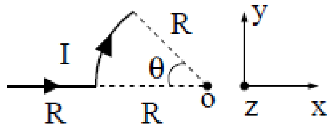
(a) $\mathcal{E} = -K\ell v^2 t$, clockwise (b) $\mathcal{E} = -K\ell v^2 t$, counter-clockwise (c) $\mathcal{E} = -\frac{1}{2}K\ell v^2 t$, counter-clockwise
(d) $\mathcal{E} = -\frac{1}{2}K\ell v^2 t$, clockwise (e) $\mathcal{E} = -K\ell vt$, counter-clockwise

13. What is the current in the circuit as a function of time?

(a) $I = -K\ell v^2 t/\alpha(\ell + 2vt)$ (b) $I = -K\ell v^2 t/2\alpha(\ell + 2vt)$ (c) $I = -K\ell v^2 t^2/2\alpha(\ell + 2vt)$
(d) $I = -K\ell vt^2/2\alpha(\ell + 2vt)$ (e) $I = -K\ell v^2 t^2/\alpha(\ell + 2vt)$

Questions 14-15

14. What is the contribution to the magnetic field at point **o** due to the straight section of the current carrying line?



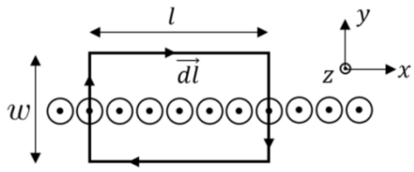
(a) $-\frac{2\mu_0 \mathrm{I}}{3\mathrm{R}}\hat{\mathrm{k}}$ (b) $-\frac{\mu_0 \mathrm{I}}{2\pi \mathrm{R}}\hat{\mathrm{k}}$ (c) 0 (d) $-\frac{\mu_0 \mathrm{I}}{2\mathrm{R}}\hat{\mathrm{i}}$ (e) $-\frac{\mu_0 \mathrm{I}}{\mathrm{R}}\hat{\mathrm{i}}$

15. What is magnitude and direction of magnetic field at point **o** due to the circular section of the current carrying line?

(a) $-\frac{\mu_0 \mathrm{I}\theta}{4\mathrm{R}}\hat{\mathrm{k}}$ (b) $-\frac{\mu_0 \mathrm{I}\theta}{\mathrm{R}}\hat{\mathrm{k}}$ (c) $-\frac{\mu_0 \mathrm{I}}{4\pi \mathrm{R}}\hat{\mathrm{k}}$ (d) $-\frac{\mu_0 \mathrm{I}\theta}{2\pi \mathrm{R}}\hat{\mathrm{k}}$ (e) $-\frac{\mu_0 \mathrm{I}\theta}{4\pi \mathrm{R}}\hat{\mathrm{k}}$

Questions 16-17

Assume very large number of parallel long cables each carrying current I toward z-direction as shown in the picture. n is the number of the current lines per unit length. A rectangular loop having width w and length l is placed on x-y plane.



16. What is $\oint \vec{B}.\vec{dl}$ for the entire rectangular loop?

(a) $2\,B\,l$ (b) $-B\,l$ (c) $-2\,B\,(l+w)$ (d) $2\,B\,(l+w)$ (e) $-2\,B\,l$

17. What is magnitude of the magnetic field near this current sheet?

(a) $\frac{\mu_0\,n\,l\,I}{2\,w}$ (b) $\frac{\mu_0\,n\,I}{4}$ (c) $\frac{\mu_0\,n\,I}{2}$ (d) $\frac{\mu_0\,n\,w\,I}{2}$ (e) $\frac{\mu_0\,n\,I}{l}$

Questions 18-20

Suppose the electric field part of an electromagnetic wave in vacuum is given as $\vec{E} = E_0\cos(-kx - \omega t)\hat{\jmath}$.

18. What is the direction of propagation for magnetic field part of this electromagnetic wave?

(a) $\hat{\jmath}$ (b) $-\hat{\imath}$ (c) $\hat{\imath}$ (d) $\hat{\jmath} - \hat{k}$ (e) $\hat{k} - \hat{\imath}$

19. Find the magnetic field vector of this wave. B_0 is the maximum value of magnetic field.

(a) $cE_0\sin(-kx-\omega t)\hat{\imath}$ (b) $-cB_0\cos(-x-\omega t)\hat{k}$ (c) $-(E_0/c)\sin(-kx-\omega t+\pi/2)\hat{k}$ (d) $(E_0/c)\cos(-kx-\omega t)\hat{k}$
(e) $-(B_0/c)\cos(-x-\omega t)\hat{\imath}$

20. What is the magnitude of the average of the Poynting vector over a complete cycle for this wave?

(a) ${E_0}^2/2c\epsilon_0$ (b) ${E_0}^2/2c\mu_0$ (c) ${B_0}^2/2c\mu_0$ (d) $E_0B_0/\epsilon_0\mu_0$ (e) $c{B_0}^2/\mu_0$

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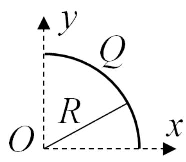
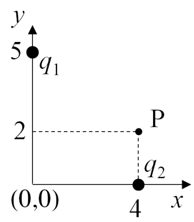
ATTENTION: Each question has only one correct answer. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

Questions 1-6



1. Charge Q is uniformly distributed over a thin quarter ring of radius R as shown in the figure. Which of the following is the magnitude of the electric field at point O?

(a) $\dfrac{2Q}{\pi^2\epsilon_0 R^2}$ (b) $\dfrac{Q}{4\pi^2\epsilon_0 R^2}$ (c) $\dfrac{Q}{\sqrt{2}\pi^2\epsilon_0 R^2}$ (d) $\dfrac{Q}{4\pi\epsilon_0 R}$ (e) $\dfrac{Q}{4\pi\epsilon_0 R^2}$



2. Two point charges q_1 and q_2 are placed at points (0 m, 5 m) and (4 m, 0 m), respectively, as shown in the figure. $q_1 = 25\,\text{nC}$, $q_2 = 4\,\text{nC}$. Find the electric field in N/C's at point P(4 m, 2 m) due to these charges. Take $k = 1/(4\pi\epsilon_0) = 9 \times 10^9\ \text{Nm}^2/\text{C}^2$.

(a) $7.2\hat{\imath} + 3.6\hat{\jmath}$ (b) $7.2\hat{\imath} + 14.4\hat{\jmath}$ (c) $3.6\hat{\imath} - 7.2\hat{\jmath}$ (d) $7.2\hat{\imath} + 1.8\hat{\jmath}$ (e) $5.4\hat{\imath} - 3.6\hat{\jmath}$

3. Two non-conducting uniformly charged identical spheres having the same total charge are seperated by a distance. Each one experiences a force of magnitude F_0. Half of the charge on one sphere is then moved to the other without changing the distance between the spheres and keeping the uniformity of the charge distribution. What is the magnitude of the force between the spheres now?

(a) $3F_0/2$ (b) $3F_0/4$ (c) $2F_0$ (d) $9F_0/4$ (e) $F_0/2$

4. A positive point charge is released from rest in an electric field experiencing only the electric force. At any later time, the acceleration of the point charge

(a) is directly opposite the direction of the electric field at the position of the point charge.
(b) is in the direction of the electric field at the position of the point charge.
(c) is zero.
(d) is perpendicular to the direction of the electric field at the position of the point charge.
(e) can not be decided with the information given.

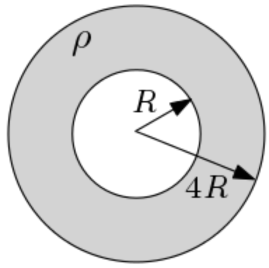
5. For which of the following charge distributions would Gauss's law not be **useful** for calculating the electric field?

(a) an infinite planar sheet having constant surface charge density
(b) a spherical shell of radius R with charge uniformly distributed over its surface
(c) a right circular cylinder of radius R and height h with charge uniformly distributed over its surface
(d) an infinitely long right circular cylinder of radius R with charge uniformly distributed over its surface
(e) a uniformly charged sphere of radius R

6. Consider a spherical insulator of radius R that has uniform charge distribution. Find the flux through a spherical surface of radius $R/2$ centered at the center of the sphere in terms of total charge Q of the sphere.

(a) $Q/(8\epsilon_0)$ (b) 0 (c) $Q/8$ (d) $Q/(4\epsilon_0)$ (e) $Q/4$

Questions 7-10



A thick spherical shell of inner radius R and outer radius $4R$, made of an insulator with dielectric constant $\kappa = 2$, has a uniform free charge density ρ. ($k \equiv \frac{1}{4\pi\epsilon_0}$, where ϵ_0 is the permittivity of the vacuum.)

7. What is the magnitude of the electric field at $r = 6R$?

(a) $\frac{5\rho R}{11\epsilon_0}$ (b) $\frac{7\rho R}{12\epsilon_0}$ (c) $\frac{9\rho R}{22\epsilon_0}$ (d) $\frac{7\rho R}{19\epsilon_0}$ (e) $\frac{5\rho R}{16\epsilon_0}$

8. What is the magnitude of the electric field at $r = 2R$?

(a) $\frac{7\rho R}{24\epsilon_0}$ (b) $\frac{9\rho R}{22\epsilon_0}$ (c) $\frac{5\rho R}{16\epsilon_0}$ (d) $\frac{7\rho R}{19\epsilon_0}$ (e) $\frac{5\rho R}{11\epsilon_0}$

9. What is the electric potential at $r = 6R$?
(Take the value of the potential at infinity zero, $V(\infty) = 0$.)

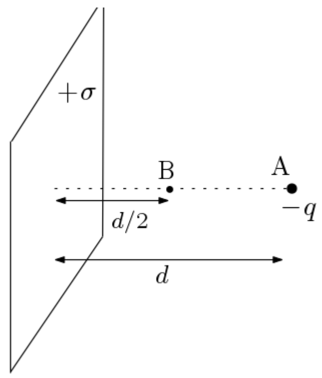
(a) $\frac{7\rho R^2}{2\epsilon_0}$ (b) $\frac{9\rho R^2}{4\epsilon_0}$ (c) $\frac{9\rho R^2}{2\epsilon_0}$ (d) $\frac{7\rho R^2}{8\epsilon_0}$ (e) $\frac{7\rho R^2}{4\epsilon_0}$

10. What is the electric potential at $r = 0$, at the center of the sphere?
(Take the value of the potential at infinity zero, $V(\infty) = 0$.)

(a) $\frac{21\rho R^2}{2\epsilon_0}$ (b) $\frac{51\rho R^2}{8\epsilon_0}$ (c) 0 (d) $\frac{47\rho R^2}{4\epsilon_0}$ (e) $\frac{39\rho R^2}{8\epsilon_0}$

Questions 11-13

A small test charge $-q$ is located at point A, at a distance d from a uniformly charged infinitely large nonconducting sheet, as shown in the figure. The charge is released from rest. The surface charge density of the sheet is $+\sigma$.



11. The point B is at a distance $d/2$ from the sheet. What is the potential difference between the points A and B, $V_A - V_B$, due to the large sheet?

(a) $\frac{\sigma d}{6\epsilon_0}$ (b) $-\frac{\sigma d}{6\epsilon_0}$ (c) $-\frac{\sigma d}{8\epsilon_0}$ (d) $\frac{\sigma d}{4\epsilon_0}$ (e) $-\frac{\sigma d}{4\epsilon_0}$

12. What is the work done by the electrostatic force while the test charge $-q$ moves from A to B?

(a) $-\frac{\sigma qd}{4\epsilon_0}$ (b) $\frac{\sigma qd}{6\epsilon_0}$ (c) $-\frac{\sigma qd}{6\epsilon_0}$ (d) $\frac{\sigma qd}{4\epsilon_0}$ (e) 0

13. What is the speed of the point charge at B? The mass of the test charge is m.

(a) $\sqrt{\frac{3\sigma qd}{2m\epsilon_0}}$ (b) $\sqrt{\frac{3\sigma qd}{5m\epsilon_0}}$ (c) $\sqrt{\frac{\sigma qd}{5m\epsilon_0}}$ (d) $\sqrt{\frac{\sigma qd}{6m\epsilon_0}}$ (e) $\sqrt{\frac{\sigma qd}{2m\epsilon_0}}$

Questions 14-20

Two concentric spherical conducting shells are separated by vacuum. The inner shell has total charge Q=$72\pi\times10^{-12}$C and radius a=5 cm, and the outer shell has charge $-Q$ and radius b=10 cm. Take $\epsilon_0 = 9 \times 10^{-12}$ F/m.

14. What is the potential difference between the conducting shells?

(a) 10 V (b) 15 V (c) 5 V (d) 20 V (e) 25 V

15. What is the potential difference between the inner conducting shell and a point at $r = 8$ cm from the center?

(a) 10 V (b) 25 V (c) 5 V (d) 15 V (e) 20 V

16. What is the capacitance of this capacitor?

(a) 0.9π pF (b) 7.2π pF (c) 1.8π pF (d) 0.4π pF (e) 3.6π pF

17. What is the potential energy stored in the capacitor?

(a) 360π pJ (b) 720π pJ (c) 90π pJ (d) 45π pJ (e) 180π pJ

The space between the conducting shells is filled with a dielectric material of the dielectric constant $\kappa = 2$.

18. What is the induced bound charge density on the dielectric at $r = a$?

(a) -7.2 nC/m^2 (b) -3.6 nC/m^2 (c) 0.45 nC/m^2 (d) -1.8 nC/m^2 (e) 0.9 nC/m^2

19. What is the change in the stored potential energy in the capacitor?

(a) 90π pJ (b) 45π pJ (c) 360π pJ (d) 720π pJ (e) 180π pJ

20. If the region between the conductors is filled with a dielectric of $\kappa = 2$ only between $r = 5$ cm and $r = 8$ cm, what is the capacitance of this new system?

(a) $0.72\pi\epsilon_0$ F (b) $0.64\pi\epsilon_0$ F (c) $1.44\pi\epsilon_0$ F (d) $0.36\pi\epsilon_0$ F (e) $0.32\pi\epsilon_0$ F

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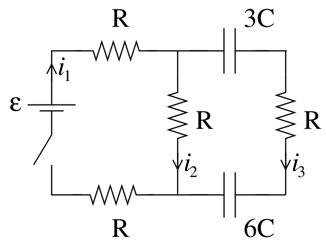
1. Which of the following combination cannot be a unit of the magnetic field?
(N: Newton, J: Joule, W: Watt, C: Coulomb, A: Ampere)

(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.

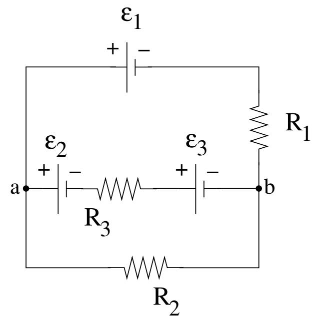
(a) $1/2, 1/4, 1/4$ (b) $2/5, 1/5, 1/5$ (c) $1/3, 1/3, 0$ (d) $0, 0, 0$ (e) $2/3, 1/3, 1/3$

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?

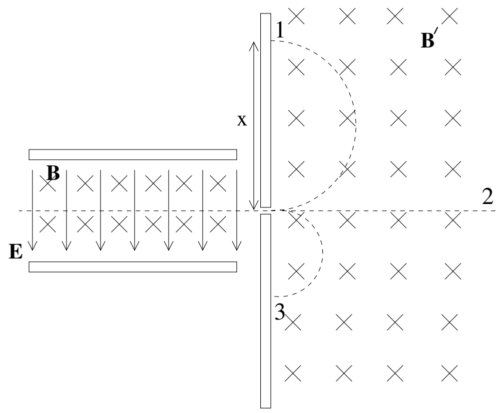
(a) 0 (b) $4\varepsilon/5R$ (c) $2\varepsilon/3R$ (d) $2\varepsilon/5R$ (e) $\varepsilon/5R$

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 −)

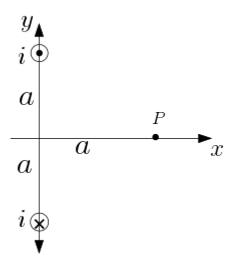
(a) +, 0, − (b) 0, 0, 0 (c) −, 0, + (d) −, 0, − (e) +, 0, +

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?

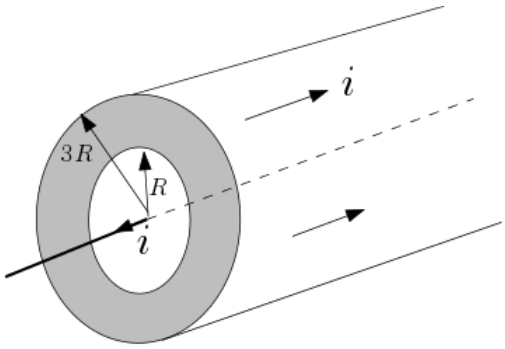
(a) $\frac{\mu_0 i}{2\pi a}\hat{k}$ (b) $\frac{\mu_0 i}{3\pi a}\hat{i}$ (c) $\frac{\mu_0 i}{2\pi a}\hat{i}$ (d) $-\frac{\mu_0 i}{3\pi a}\hat{j}$ (e) $\frac{\mu_0 i}{2\pi a}\hat{j}$

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 $r = 2R$?

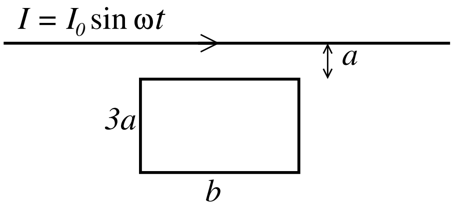
(a) $\frac{5\mu_0 i}{24\pi R}$ (b) $\frac{2\mu_0 i}{15\pi R}$ (c) $\frac{4\mu_0 i}{15\pi R}$ (d) $\frac{5\mu_0 i}{32\pi R}$ (e) $\frac{7\mu_0 i}{24\pi R}$

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?

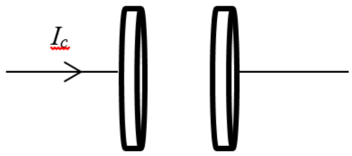
(a) $\frac{\mu_0 b I_0 \sin(\omega t)}{2\pi} \ln 2$ (b) $\frac{\mu_0 b I_0 \cos(\omega t)}{2\pi} \ln 4$ (c) $\frac{\mu_0 I_0 \sin(\omega t)}{\pi} \ln 4$ (d) $\frac{\mu_0 b I_0 \sin(\omega t)}{2\pi} \ln 4$ (e) $\frac{\mu_0 b I_0}{\pi} \ln 4$

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?

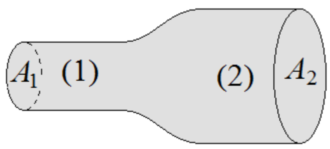
(a) $\frac{1}{3\epsilon_0} \times 10^4\ \frac{N}{C \cdot s}$ (b) $10^5 \epsilon_0\ \frac{N}{C \cdot s}$ (c) $\frac{1}{5\epsilon_0} \times 10^2\ \frac{N}{C \cdot s}$ (d) $\frac{4}{7\epsilon_0} \times 10^3\ \frac{N}{C \cdot s}$ (e) $\frac{1}{15\epsilon_0} \times 10^3\ \frac{N}{C \cdot s}$

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) $25 \times 10^{-6}\,\text{m/s}$

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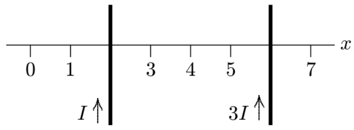
List Number		Surname		A
Student ID		Signature		
E-mail				

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 considered.

$\frac{1}{4\pi\epsilon_o} = 9 \times 10^9$ **V.m/C,** $\mu_o = 4\pi \times 10^{-7}$ **T.m/A, speed of light in vacuum** $c = 3 \times 10^8$ **m/s**

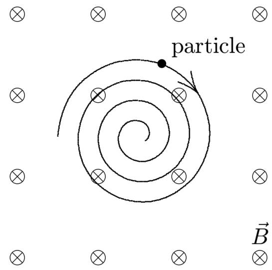
Unit prefixes: $M = 10^6,\ k = 10^3,\ m = 10^{-3},\ \mu = 10^{-6},\ n = 10^{-9},\ p = 10^{-12}$

1. Two long straight current-carrying parallel wires cross the x axis and carry currents I and $3I$ in the same direction, as shown. At what value of x is the net magnetic field zero? (x is in units of meter.)



(a) 1 (b) 3 (c) 5 (d) 7 (e) 0

2. A uniform magnetic field is directed into the page. A charged particle, moving in the plane of the page, follows a clockwise spiral of decreasing radius as shown. A reasonable explanation is:



(a) the charge is negative and slowing down
(b) the charge is positive and slowing down
(c) the charge is negative and speeding up
(d) the charge is positive and speeding up
(e) the charge is neutral and its acceleration is zero

3. An electron is launched with velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$. The angle θ between $\vec{v}$ and $\vec{B}$ is between 0° and 90°. As a result, the electron follows a helix, its velocity vector $\vec{v}$ returning to its initial value in a time interval of:

(a) $2\pi mv \tan\theta/(eB)$ (b) $2\pi mv \cos\theta/(eB)$ (c) $2\pi m/(eB)$ (d) $2\pi mv/(eB)$ (e) $2\pi mv \sin\theta/(eB)$

4. A laser emits a sinusoidal electromagnetic wave that travels in vacuum in the negative x-direction. The wavelength is $\pi \times 10^{-6}$ m and the electric field vector is parallel to the z-axis, with $E_{max} = 1.5$ MV/m. What are the vector equations for $\vec{E}$ and $\vec{B}$ as functions of time and position. All in the following are in the SI units.

(a) $\vec{E} = -\hat{k}\,(1.5 \times 10^6) \times \cos\left[(2 \times 10^6\,\mathrm{x}) + (6 \times 10^{14}\,\mathrm{t})\right]$ and $\vec{B} = \hat{\jmath}\,(5 \times 10^{-3}) \times \cos\left[(2 \times 10^6\,\mathrm{x}) + (6 \times 10^{14}\,\mathrm{t})\right]$
(b) $\vec{E} = -\hat{\imath}\,(1.5 \times 10^6) \times \cos\left[(2 \times 10^6\,x) + (6 \times 10^{14}\,t)\right]$ and $\vec{B} = \hat{\jmath}\,(5 \times 10^{-3}) \times \cos\left[(2 \times 10^6\,\mathrm{x}) + (6\mathrm{x}10^{14}\,\mathrm{t})\right]$
(c) $\vec{E} = \hat{\jmath}\,(1.5 \times 10^6) \times \cos\left[(2 \times 10^6\,\mathrm{x}) + (6 \times 10^{14}\,\mathrm{t})\right]$ and $\vec{B} = \hat{\jmath}\,(5 \times 10^6) \times \cos\left[(2 \times 10^6\,\mathrm{x}) + (6 \times 10^{14}\,\mathrm{t})\right]$
(d) $\vec{E} = \hat{k}\,(1.5 \times 10^6) \times \cos\left[(2 \times 10^6\,\mathrm{x}) + (6 \times 10^{14}\,\mathrm{t})\right]$ and $\vec{B} = \hat{\jmath}\,(5 \times 10^{-3}) \times \cos\left[(2 \times 10^6\mathrm{x}) + (6 \times 10^{14}\,\mathrm{t})\right]$
(e) $\vec{E} = \hat{\jmath}\,(5 \times 10^{-3}) \times \cos\left[(2 \times 10^6\,\mathrm{x}) + (6 \times 10^{14}\,\mathrm{t})\right]$ and $\vec{B} = \hat{k}\,(5 \times 10^{-3}) \times \cos\left[(2\mathrm{x}10^6\,\mathrm{x}) + (6\mathrm{x}10^{14}\,\mathrm{t})\right]$

Questions 5-6

An electromagnetic wave with frequency $f = 3/\pi \times 10^{14}$ Hz propagates with a speed of 2.4×10^8 m/s in a piece of glass.

5. What is the index of refraction n of the glass for an electromagnetic wave with this frequency?

(a) 5/3 (b) 6/5 (c) 7/4 (d) 5/2 (e) 5/4

6. What is the wave number k of the electromagnetic wave in the glass?

(a) 4.5×10^5 rad/m (b) 5.0×10^6 rad/m (c) 2.5×10^6 rad/m (d) 3.5×10^6 rad/m (e) 2.0×10^7 rad/m

Questions 7-9

A solenoid 30 cm long and with a cross-sectional area of 0.4 cm^2 contains 600 turns of wire and carries a current of 50 A. (For air take $\mu_0 = 12 \times 10^{-7}$ H/m.)

7. What is the magnetic field in the solenoid (in units of T (tesla))?

(a) 0.12 (b) 1.8 (c) 0.8 (d) 1.0 (e) 0.08

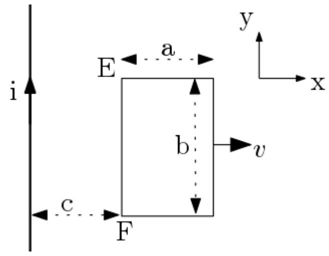
8. What is the energy density in the magnetic field (in units of J/m^3) if the solenoid is filled with air?

(a) 1.6×10^4 (b) 0.6×10^4 (c) 1.2×10^4 (d) 0.6×10^3 (e) 1.2×10^3

9. What is the inductance of the solenoid (in units of μH)?

(a) 48.0 (b) 4.8 (c) 17.3 (d) 57.6 (e) 14.4

Questions 10-12



In the figure shown, the rectangular loop is being pulled in the $+x$-direction with a constant speed v. The initial distance between the side EF and the long wire is c. The long wire is carrying a constant current i which is flowing in the $+y$-direction, as shown.

10. What is the magnetic flux through the rectangular loop directed into the page?

(a) $\frac{\mu_0 ib}{2\pi}\ln\left(\frac{c+a+vt}{b+vt}\right)$ (b) $\frac{\mu_0 ib}{2\pi}\ln\left(\frac{c+a+vt}{a+vt}\right)$ (c) $\frac{\mu_0 ib}{2\pi}\ln\left(\frac{c+a+vt}{c+vt}\right)$ (d) $\frac{\mu_0 ia}{2\pi}\ln\left(\frac{c+b+vt}{b+vt}\right)$
(e) $\frac{\mu_0 ib}{2\pi}\ln\left(\frac{c+b+vt}{c+vt}\right)$

11. What is the direction and magnitude of the induced current in the loop, assuming its total resistance is R? (cw: clockwise, ccw: counterclockwise.)

(a) ccw and $\frac{\mu_0 \text{ibav}}{2\pi\text{R}}\frac{1}{(\text{b+vt})(\text{a+vt})}$ (b) cw and $\frac{\mu_0 \text{ibav}}{2\pi\text{R}}\frac{1}{(\text{c+vt})(\text{c+a+vt})}$ (c) ccw and $\frac{\mu_0 \text{ibcv}}{2\pi\text{R}}\frac{1}{(\text{c+vt})(\text{a+vt})}$
(d) cw and $\frac{\mu_0 \text{ibcv}}{2\pi\text{R}}\frac{1}{(\text{a+vt})(\text{c+b+vt})}$ (e) cw and $\frac{\mu_0 \text{ibav}}{2\pi\text{R}}\frac{1}{(\text{c+vt})(\text{b+a+vt})}$

12. If the loop is pulled in the $+y$-direction with a constant speed v, what is the magnitude of the induced current in the loop?

(a) $\frac{\mu_0 ib}{2\pi R}\frac{v}{c+b+vt}$ (b) $\frac{\mu_0 ibav}{2\pi R}\frac{1}{(c+vt)(c+a+vt)}$ (c) $\frac{\mu_0 ibav}{2\pi R}\frac{1}{(c+vt)(b+a+vt)}$ (d) 0 (e) $\frac{\mu_0 ib}{2\pi R}\frac{v}{c+a+vt}$

Questions 13-14

A satellite at a distance 100 km from Earth's surface emits sinusoidal radio waves with average total power 60 kW. Assume that the transmitter radiates equally in all directions. (Take $\pi \approx 3$ and for air $\mu_0 = 1.2\times10^{-6}\ H/m$.)

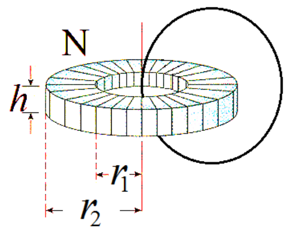
13. What is the intensity (in units of W/m^2) detected by a receiver on Earth's surface?

(a) 2×10^{-6} (b) 2×10^{-5} (c) 2×10^{-7} (d) 5×10^{-7} (e) 5×10^{-6}

14. What is the electric-field amplitude E_{max} (in units of V/m) detected by a receiver on Earth?

(a) 36×10^{-3} (b) $\sqrt{1.6}\times10^{-3}$ (c) $\sqrt{3.6}\times10^{-3}$ (d) $\sqrt{6}\times10^{-3}$ (e) 6×10^{-3}

Questions 15-16



A toroid shaped inductor with a rectangle profile has an inner radius r_1, an outer radius r_2 and a height h. The toroid has N windings and current I flows through it.

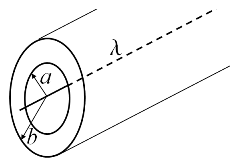
15. What is the magnitude of the magnetic field inside the toroid? (Use Ampere's law.)

(a) $\mu_0 NI/(2\pi r)$ (b) $\mu_0 NI/(\pi r^2)$ (c) $\mu_0 I/(Nr)$ (d) $\mu_0 I/r$ (e) $\mu_0 I/N$

16. What is the mutual inductance between the circular wire loop and the toroid?

(a) $\mu_0 Nh\log(r_2/r_1)/(2\pi)$ (b) $\mu_0 Nhr_2/(2\pi r_1)$ (c) $\mu_0 h\log(r_2/r_1)$ (d) $\mu_0 h\log(r_2/r_1)/(2N\pi)$
(e) $\mu_0 Nh\log(r_1/r_2)/(2\pi)$

Questions 17-18



A very long metal pipe has inner and outer radii of a and b, respectively. As shown in the figure, a uniformly charged thin wire lies along the axis of the pipe. Linear charge density of the wire is λ.

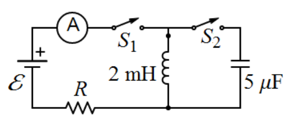
17. Which of the following is the magnitude of the electric field at a distance $r > b$ from the wire?

(a) $\frac{\lambda}{2\pi\epsilon_o r^2}$ (b) $\frac{\lambda}{4\pi\epsilon_o r^2}$ (c) $\frac{\lambda}{4\pi\epsilon_o r}$ (d) 0 (e) $\frac{\lambda}{2\pi\epsilon_o r}$

18. Which of the following is the potential difference $V_{a/2} - V_{2b}$?

(a) 0 (b) $\frac{\lambda(4b-a)}{8\pi\epsilon_o ab}$ (c) $\frac{\lambda}{\pi\epsilon_o}\ln\left(\frac{4b}{a}\right)$ (d) $\frac{\lambda(4b-a)}{4\pi\epsilon_o ab}$ (e) $\frac{\lambda\ln 2}{\pi\epsilon_o}$

Questions 19-20



In the circuit shown in the figure, switch S_1 has been closed for a long enough time so that the current reads a steady 3.50 A. Suddenly, switch S_2 is closed and S_1 is opened at the same instant.

19. What is the maximum charge that the capacitor will receive?

(a) 3.50 mC (b) 0.50 mC (c) 0.70 mC (d) 7.00 mC (e) 0.35 mC

20. What is the current in the inductor at this time when the capacitor has the maximum charge?

(a) 0.70 A (b) 0 (c) 7.00 A (d) 0.50 A (e) 3.50 A