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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. 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.

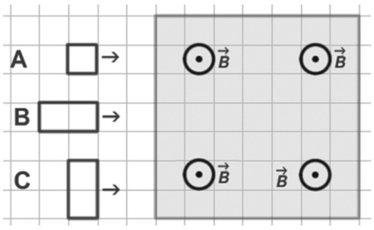
2. The number of turns in a solenoid is doubled, and its length is halved. How does its magnetic field change?

(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?

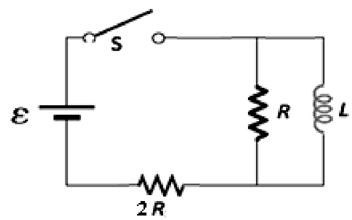
(a) none of them (b) electric charge (c) it is imposible to have a magnetic field, without a current (d) constant electric field (e) changing electric field

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 $2R$?

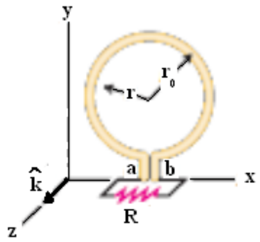
(a) $\varepsilon/2R$ (b) $\varepsilon/3R$ (c) $2\varepsilon/R$ (d) 0 (e) ε/R

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.

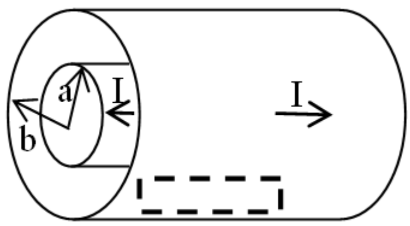
(a) $\varepsilon = \frac{B_0\pi r_0^2}{t_0}\left[1 - (\frac{t}{t_0})^2 - (\frac{t}{t_0})\right]$ (b) $\varepsilon = -B_0\pi r^2\left[(\frac{t}{t_0}) - (\frac{t}{t_0})^2\right]$ (c) $\varepsilon = \frac{B_0 r^2}{t_0}\left[(\frac{t}{t_0})^3 - (\frac{t}{t_0})^2\right]$ (d) $\varepsilon = \frac{-B_0\pi r_0^2}{t_0}(\frac{t}{t_0})^2$
(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 $\pi = 3$, $r_0 = 0.05\,\text{m}$, $t_0 = 0.01\,\text{s}$, $B_0 = 0.100\,\text{T}$, $R = 10.0\,\Omega$).

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

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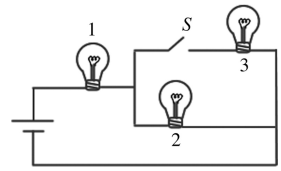
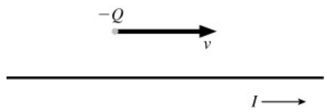
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. 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.

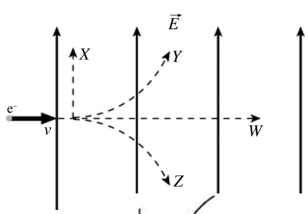
8. The current i through an ideal inductor with inductance L and zero resistance depends on time t according to $i(t) = Kt^2$, where K is a positive constant. The magnitude of the voltage across the inductor is

(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

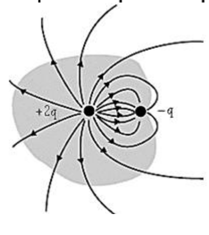
(a) $4Q$ (b) $2Q$ (c) $Q/2$ (d) $Q/4$ (e) Q

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.

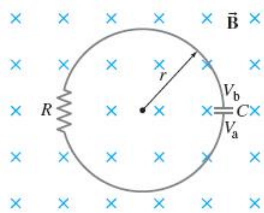
(a) 5 W/m^2 (b) 20 W/m^2 (c) 2.5 W/m^2 (d) 10 W/m^2 (e) 2 W/m^2

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?

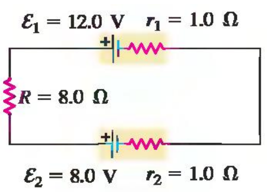
(a) $\varepsilon = V_0(1 - e^{-t/\tau})$ (b) $\varepsilon = V_0$ (c) $\varepsilon = V_0(1 - e^{-1})$ (d) $\varepsilon = V_0 e^{-t/\tau}$ (e) $\varepsilon = V_0(2e^{-t/\tau} - 1)$

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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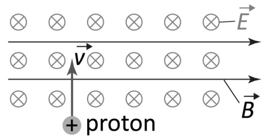
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account. Please take π=3, $m_{proton} \approx 1.6 \times 10^{-27} kg$, $q_{proton} \approx 1.6 \times 10^{-19} C$, $\mu_0 = 4\pi \times 10^{-7}$, $c = 3 \times 10^8 m/s$.

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

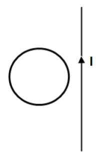
iii) When the wave moves between two media with different permittivity, frequency of the wave changes

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

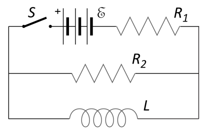
6. What is the unit of Poynting vector?

(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.

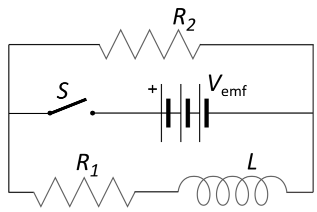
(a) 800 (b) 1000 (c) 600 (d) 400 (e) 200

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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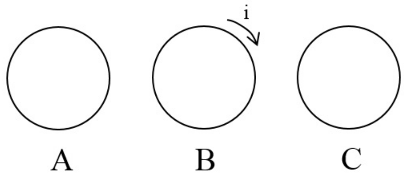
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account. Please take π=3, $\mu_0 = 4\pi \times 10^{-7} H/m$, $c = 3 \times 10^8 m/s$.

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

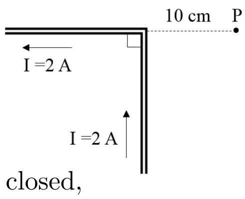
III) speed at which the magnet moves

(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

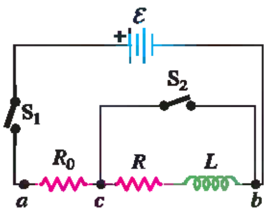
5. An infinitely long wire carrying a current of $2A$ is bent at a right angle as shown in the Figure. What is the magnetic field magnitude in Tesla a point P, 10 cm from the corner?



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

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

(a) $2\mu_0(aI_0 N)^2/l^2$ (b) 0 (c) $\mu_0 a(lI_0 N)^2/2$ (d) $2(\mu_0 aI_0 N)^2/l$ (e) $\mu_0 a(I_0 N)^2/2$

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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) $(\epsilon_0\mu_0)^2$

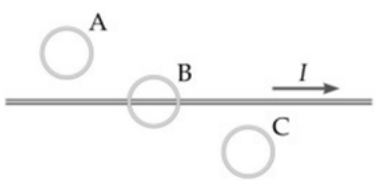
6. In the Ampere-Maxwell equation for vacuum $\oint \vec{B}.\vec{dl} = \mu_0(I + I_D)$. The displacement current I_D is given by;
(a) $\mu_0\frac{d}{dt}\oint \vec{B}.\vec{dl}$ (b) 0 (c) $\mu_0\frac{d}{dt}\iint \vec{B}.\vec{ds}$ (d) $\epsilon_0\frac{d}{dt}\iint \vec{E}.\vec{ds}$ (e) $\frac{\iint \vec{E}.\vec{ds}}{\epsilon_0}$

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.

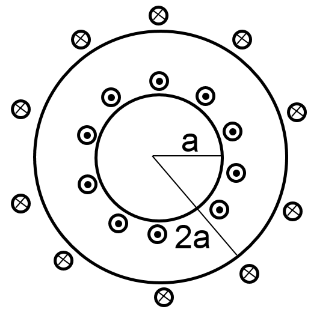
10. The long straight wire in the figure carries a current I that is decreasing with time at a constant rate. The circular loops A, B, and C all lie in a plane containing the wire. The induced emf in each of the loops A, B, and C is such that

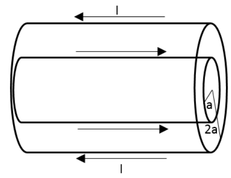


(a) all loops experience counterclockwise emf.
(b) no emf is induced in any of the loops.
(c) loop A has a counter-clockwise emf, loop B has no induced emf, and loop C has a clockwise emf.
(d) loop A has a clockwise emf, loop B has no induced emf, and loop C has a counterclockwise emf.
(e) a counterclockwise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

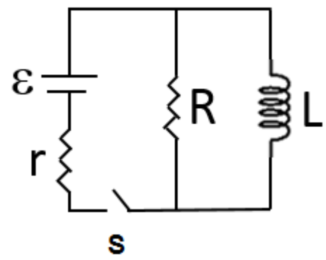
14. The magnetic flux in the inner region ($r < a$) of a section of length b is
(a) 0 (b) $\mu_0 Ib$ (c) $\mu_0 Ib/2\pi r$ (d) $2\pi r\mu_0 Ib\ln(a)$ (e) $2\mu_0 Ib\ln(a)$

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

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

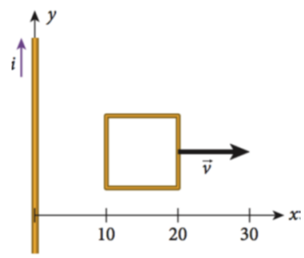
18. What is the current in the inductor L at $t = 0$ immediately after the switch is closed?
(a) $\varepsilon/(R+r)$ (b) ε/R (c) $\varepsilon/(R-r)$ (d) 0 (e) ε/r

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) $I_{ind}B_0L$ (b) $2I_{ind}B_0L$ (c) $3I_{ind}B_0L/2$ (d) $I_{ind}B_0L/2$ (e) $3I_{ind}B_0L$

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) $\mu_0 IAv/\pi x$ (b) $\mu_0 IAv/2\pi x^2$ (c) $\mu_0 IA/2\pi x$ (d) $\mu_0 IA/2\pi x^2$ (e) $\mu_0 IAx/2\pi v$

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

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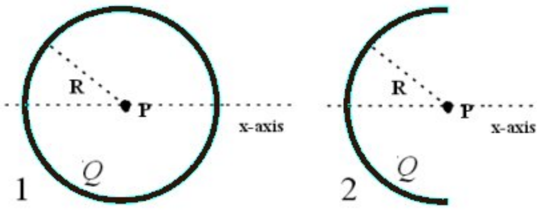
1. What is the unit of the electromotive force?

(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, $E_1(P)/E_2(P)$?

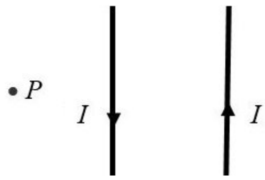
(a) 0 (b) $\pi/2$ (c) 1 (d) ∞ (e) $\pi/\sqrt{2}$

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

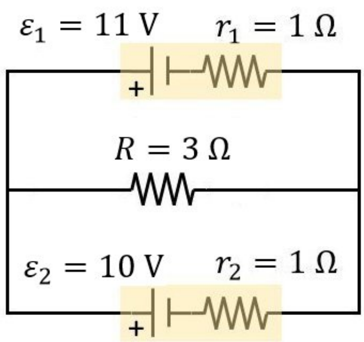
8. Which of the statements below are true for the poynting vector $\vec{S}$ defined for an electromagnetic wave?

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?

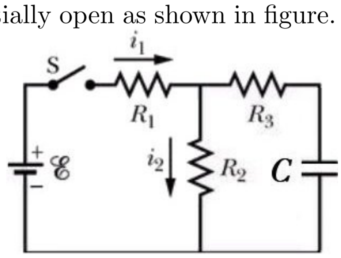
(a) 9 W (b) 12 W (c) 18 W (d) 27 W (e) 25 W

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 $C = 4\times10^{-6}$ 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?

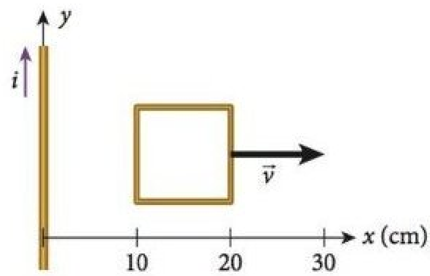
(a) i_2 reduces to its $1/e$ (b) i_2 is a steady current and does not change until there are no charges left on the capacitor. (c) i_2 reduces to its half. (d) i_2 reduces to its quarter. (e) i_2 reduces to its RC where $R = R_2 + R3$

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

(a) 1.8 $\times10^{-4}$ J (b) 6 $\times10^{-5}$ J (c) 1.8 $\times10^{-3}$ J (d) 4.5 $\times10^{-4}$ J (e) 3 $\times10^{-5}$ 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 $\mu_0 = 1.2\times10^{-6}$ 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) $\Omega\ \text{m}^2$ (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

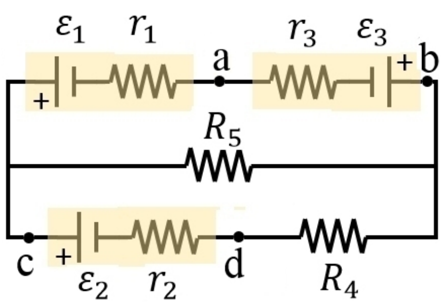
9. A charged particle is moving in a constant magnetic field. Assume that the magnetic field is neither parallel nor anti parallel to the velocity. Which of the followings is/are false for the magnetic field?

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?

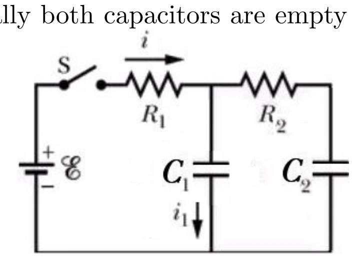
(a) 2.25 V (b) 3.75 V (c) 3.5 V (d) 1.25 V (e) 1.5 V

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) 4×10^{-4} J (c) 6×10^{-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 $|\, q\,|$, 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 1.8×10^{-10} T at a distance of 250 m from the antenna. Take $\mu_0 = 1.2 \times 10^{-6}$ Tm/A and c = 3×10^8 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,** $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \frac{N.m^2}{C^2}$

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

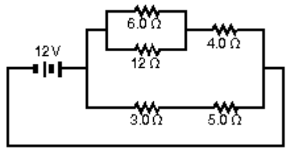
(a) Cx^3 (b) $2Cx$ (c) $-Cx^3/3$ (d) $-2Cx$ (e) $-3Cx^3$

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) $R_1R_2/(R_1-R_2)$ (c) $(R_1+R_2)/R_1R_2$ (d) $R_1R_2/(R_1+R_2)$ (e) $(R_1-R_2)/R_1R_2$

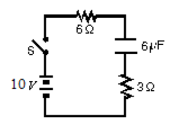


6. Two parallel plate capacitors are identical in terms of their dimensions except one is filled with air and the other one is filled with oil. Both capacitors carry the same charge. The ratio of the electric fields E_{air}/E_{oil} is:

(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)?

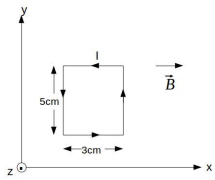
(a) 0 A (b) 10/6 A (c) 1.5 A (d) 10/3 A (e) 10/9 A

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

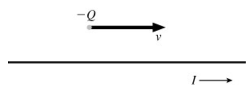
10. A rectangular coil with 20 windings carries a current of 2.0 mA flowing in the counterclockwise direction. This coil has two sides that are parallel to the y-axis and have length 5.0 cm and two sides that are parallel to the x-axis and have length 3.0 cm. A uniform magnetic field of 50 μT acts in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

(a) $(3.0{\times}10^{-9})\hat{\jmath}$ (b) $(4.7{\times}10^{-5})\hat{\jmath}$ (c) $(2.5{\times}10^{-8})\hat{k}$ (d) $(6.0{\times}10^{-5})\hat{k}$ (e) $(1.5{\times}10^{-5})\hat{\imath}$



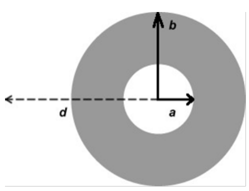
11. Two long parallel conductors are seperated by 5.0×10^{-3} m and each wire carries 3 A current in opposite directions. What is the type and magnitude of mutual force between 0.5 m long segments of each wire? Magnetic permeability in empty space is $\mu_0 = 4\pi \times 10^{-7} T \cdot m/A$ and take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

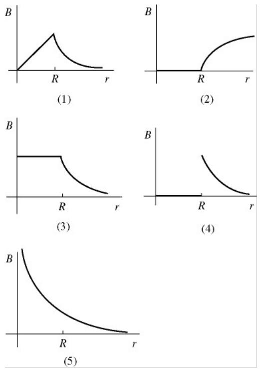
(a) The magnetic force is zero since the velocity is parallel to the current. (b) upward (c) out of the page (d) into the page (e) downward



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 · m/A). Take π=3.

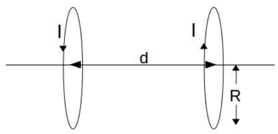
(a) 2.5×10^{-4}T (b) 1.44×10^{-4}T (c) 0.50×10^{-4}T (d) 4.5×10^{-4}T (e) 0.00 T

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 $\cdot$ 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.

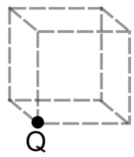
(a) $A(-6x\,\hat{\imath} + 4y\,\hat{\jmath} - 3z\,\hat{k})$ (b) $A(-3x\,\hat{\imath} + 2y\,\hat{\jmath} - 3z\,\hat{k})$ (c) $A(6x\,\hat{\imath} - 4y\,\hat{\jmath} + 6z\,\hat{k})$ (d) $A(3x\,\hat{\imath} - 2y\,\hat{\jmath} + 3z\,\hat{k})$
(e) $A(-6x\,\hat{\imath} + 4y\,\hat{\jmath} - 6z\,\hat{k})$

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) $C = 2\pi\epsilon_0 L\ln(r_2/r_1)$

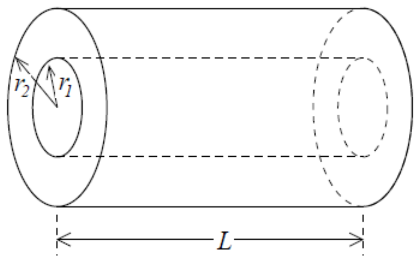
4. A single positive point charge, Q, is at one corner of a cube with sides of length L, as shown in the figure. The net electric flux through the three adjacent sides is zero. The net electric flux through each of the other three sides is

(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?

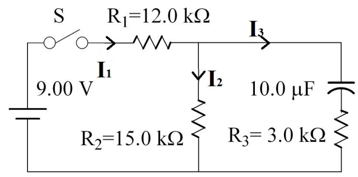
(a) $\frac{-\rho}{2\pi r L}\hat{r}$ (b) $\frac{2\rho I}{\pi r^2}\hat{r}$ (c) $\frac{\rho I}{2\pi r L}\hat{r}$ (d) $\frac{\rho}{\pi L^2}\hat{r}$ (e) $\frac{\rho I}{\pi r^2}\hat{r}$

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

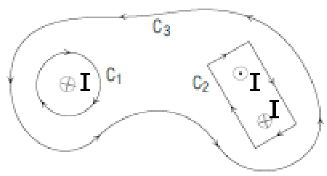
(a) 500 μC (b) 50 μC (c) 100 μC (d) 5 μC (e) 200 μC

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

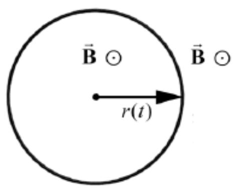
11. Three infinitely long parallel wires each carries a current I in the direction shown in the figure. What is the value of $\oint \vec{B}d\vec{l}$ for path C_3?

(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 $0 \le t \le T$, 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)

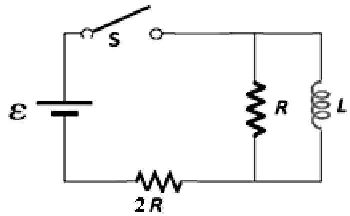
(a) $I = \pi r^2 Bv/2R$, CCW (b) $I = 2rBv^2/R$, CW (c) $I = 2\pi^2 r^2 Bv/R^2$, CW (d) $I = 2\pi rBv/R$, CW (e) $I = \pi RBv/r$, CCW

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

(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?

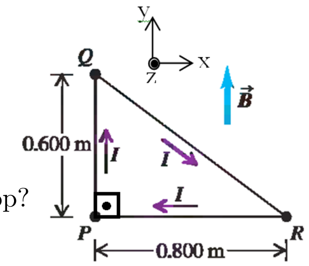
(a) $(9/2) \times 10^4 \epsilon_0$ (b) $(1/2) \times 10^4 \epsilon_0$ (c) $9 \times 10^4 \epsilon_0$ (d) $2 \times 10^4 \epsilon_0$ (e) $(9/2) \times 10^2 \epsilon_0$

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

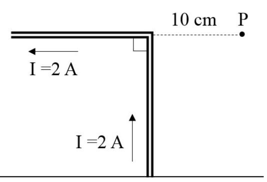
23. Calculate the magnetic moment of the loop.

(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, $\pi = 3$, $\mu_0 = 4\pi \times 10^{-7}$ 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

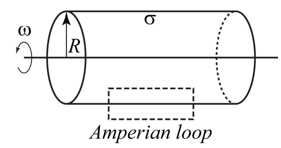
6. Which of the following combinations both have the units of time?

(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)



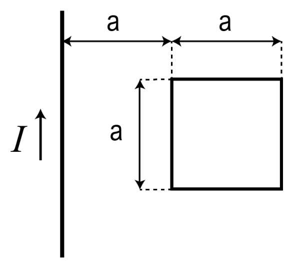
(a) $B = 2\pi\mu_0 R\sigma\omega$ (b) $B = \frac{1}{2}\mu_0 R\sigma\omega$ (c) $B = \frac{1}{2\pi}\mu_0 R\sigma\omega$ (d) $B = 2\mu_0 R\sigma\omega$ (e) $B = \mu_0 R\sigma\omega$

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

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 $b > 0$?

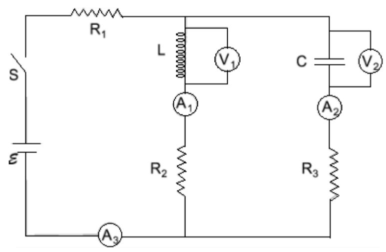
(a) Clockwise, $\frac{\mu_0}{4\pi R} I_0 a b e^{-bt}$ (b) Clockwise, $\frac{\mu_0}{2\pi R} I_0 a b e^{-bt}$ (c) Clockwise, $\frac{\mu_0}{2\pi R} I_0 a \ln 2 b e^{-bt}$ (d) Counterclockwise, $\frac{\mu_0}{4\pi R} I_0 a \ln 2 b e^{-bt}$ (e) Counterclockwise, $\frac{\mu_0}{2\pi R} I_0 a \ln 2 b e^{-bt}$

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) $2/3\ \mathrm{m}^{-1}$ (b) $1.5\ \mathrm{m}^{-1}$ (c) $6\ \mathrm{m}^{-1}$ (d) $1\ \mathrm{m}^{-1}$ (e) $0.5\ \mathrm{m}^{-1}$

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 please take: Speed of light $c = 3 \times 10^8$ m/s, $\pi = 3$, $\epsilon_0 = 9 \times 10^{-12}$ C^2/N.m^2, $\mu_0 = 12 \times 10^{-7}$ C^2/N.m^2, electron charge $e = 1.6 \times 10^{-19}$ (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.

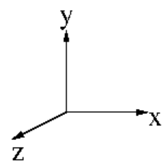
(d) The electric potential between two points can be calculated via the integral of the electric field between these two points.

(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) $\mu_0 n R^2 I$ (e) $\frac{\pi R^2 nI}{\mu_0}$

5. Electric field component of an electromagnetic (EM) wave is given as $\vec{E} = 150(V/m)\sin[1.5(rad/m)\ x - 4.5 \times 10^8(rad/s)\ t]\hat{j}$. 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.

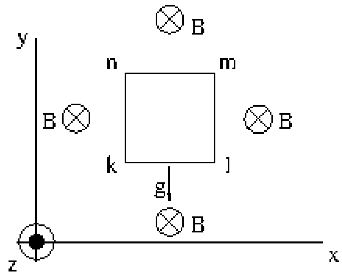
(a) No induced current is generated in this case.

(b) $\frac{Bbgt}{R}$; +x direction

(c) $\frac{Bbgt^2}{2R}$; +x direction

(d) $\frac{Bbgt^2}{2R}$; -x direction

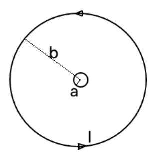
(e) $\frac{Bbgt}{R}$; -x direction



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 $\gg$ 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$\times 10^{-8}$ J/m^3 (c) 16 T/m^3 (d) 7.2$\times 10^{-11}$ J/m^3 (e) (2/3)$\times 10^7$ 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

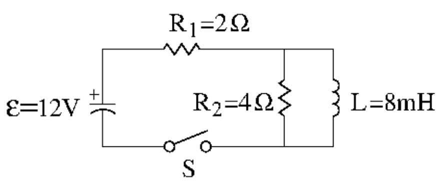
19. If the length of the solenoid is 10 cm, what is the volume of the solenoid
(a) 0.01/2 m^3 (b) 0.01/12 m^3 (c) 0.01/4 m^3 (d) 0.01/6 m^3 (e) 0.01/3 m^3

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, $\mu_0 = 4\pi \times 10^{-7}$ 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

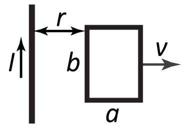
2. A flat rectangular coil consisting of 50 turns measures 20.0 cm by 15.0 cm. It is in a uniform 1.5 T magnetic field, with the plane of the coil parallel to the field. In 0.15 s, the coil is rotated uniformly so that the plane of the coil is now perpendicular to the field. What is the magnitude of 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}

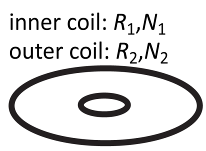
4. A rectangular loop with dimensions a and b is pulled to the right at a constant speed v with respect to a long wire carrying current I, as shown in the figure. What is the magnitude of the net emf ε induced in the loop?



(a) $\frac{\mu_0 Iabv}{2\pi r(r+a)}$ (b) $\frac{\mu_0 Iab}{2\pi r^2}$ (c) 0 (d) $\frac{\mu_0 2Iab}{\pi r}$ (e) $\frac{\mu_0 Iabv}{2\pi r^2}$

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 $d \ll R_1$.

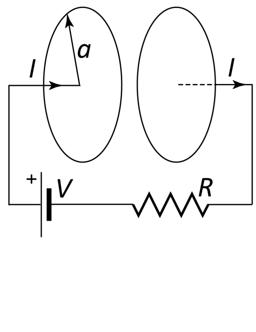
(a) $(9 \times 10^{-7}/8)d\cos(\omega t)\sin(\omega t)$ (b) $(9 \times 10^{-7}/8)d\sin^2(\omega t)$ (c) $(9 \times 10^{-7}/8)d\sin(\omega t)$ (d) $(9 \times 10^{-7}/8)d\cos^2(\omega t)$ (e) $(9 \times 10^{-7}/8)d\cos(\omega t)$

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.

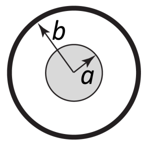
(a) $(4/27) \times 10^{16}$ V/ms (b) $(1/54) \times 10^{16}$ V/ms (c) $(2/27) \times 10^{16}$ V/ms (d) $(1/27) \times 10^{16}$ V/ms (e) None of the above

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

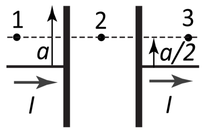
13. What is the electric field outside the cylindric shell ($r > b$)?

(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) $\vec{B} = [(3/2) \times 10^{-7}\,T]\cos(kx - \omega t)\hat{\imath}$ (b) $\vec{B} = [1 \times 10^{-7}\,T]\cos(ky - \omega t)\hat{k}$ (c) $\vec{B} = [4 \times 10^{-7}\,T]\cos(kx - \omega t)\hat{k}$ (d) $\vec{B} = [(5/3) \times 10^{-7}\,T]\cos(ky - \omega t)\hat{\jmath}$ (e) $\vec{B} = [9 \times 10^{-7}\,T]\cos(ky - \omega t)\hat{\imath}$

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) 9×10^{15} rad/s (b) 6×10^{15} rad/s (c) 1.5×10^{15} rad/s (d) 2×10^{15} rad/s (e) 3×10^{15} rad/s

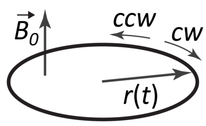
19. What is the average value of the Poynting vector magnitude over a full cycle?

(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.

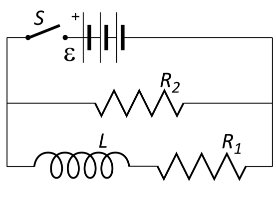
21. An elastic circular conducting loop expands at a constant rate over time such that its radius is given by $r(t) = r_0 + vt$, where r_0 and v are positive constants. The loop has a constant resistance of R and is placed in a uniform magnetic field of magnitude B_0, perpendicular to the plane of the 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).

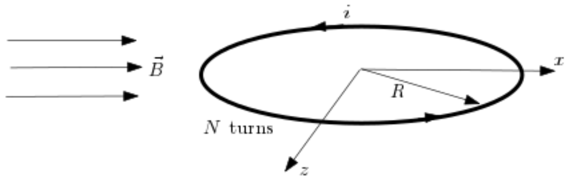
Questions 1-2

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 $\pi = 3$.)



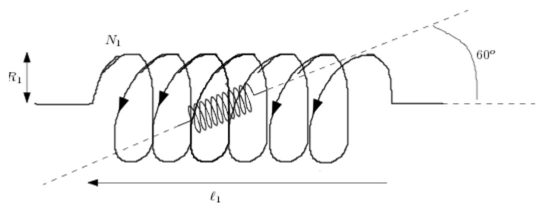
3. What is the magnetic dipole moment vector of the coil?
(a) $120\ Am^2\hat{k}$ (b) $60\ Am^2\hat{k}$ (c) $120\ Am^2\hat{j}$ (d) $30\ Am^2\hat{j}$ (e) $60\ Am^2\hat{j}$

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) $\mu_0 N_1(\ell_1+\ell_2)i/(\ell_1\ell_2)$ (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) $\mu_0N_2i/\sqrt{\ell_1\ell_2}$

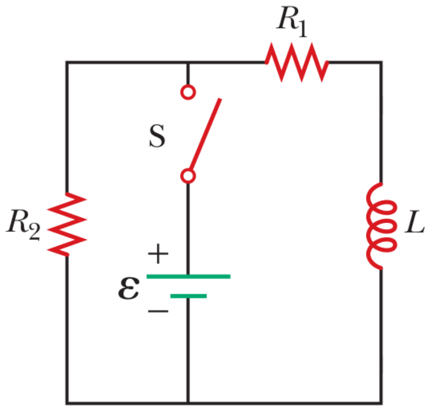
7. What is the magnetic flux generated by the outer solenoid in one loop of the inner (smaller) solenoid?
(a) $\mu_0N_1N_2i\pi R_1R_2/2\ell_1$ (b) $\mu_0N_2^2i\pi R_1R_2/2\ell_1$ (c) $\mu_0N_2^2i\pi R_2^2/2\ell_1$ (d) $\mu_0N_1i\pi R_2^2/2\ell_1$
(e) $\mu_0N_1^2i\pi R_2^2/2\ell_1$

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.

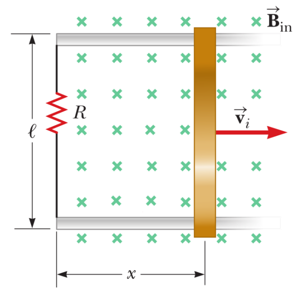
11. What are the currents on R_1 and R_2, respectively, just after the switch S is closed?
(a) $\mathcal{E}/R_1$, 0 (b) $\mathcal{E}/(R_1+L)$, $\mathcal{E}/R_2$ (c) $\mathcal{E}/R_{eq}$, $\mathcal{E}/R_{eq}$ where $R_{eq}=R_1R_2/(R_1+R_2)$ (d) $\mathcal{E}/R_1$, $\mathcal{E}/R_2$ (e) 0,$\mathcal{E}/R_2$

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 $\vec{B}=(3\sqrt{\pi}\times10^{-8}\ T)sin(\frac{\pi}{3}z+\omega t)\hat{\imath}$. ($c=3\times10^8\ m/s$ and $\mu_0=4\pi\times10^{-7}\ T.m/A$.)

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) $(9\sqrt{\pi}\ N/C)sin(\frac{\pi}{3}z+\omega t)\hat{\imath}$ (b) $(3\sqrt{\pi}\ N/C)sin(\frac{\pi}{3}z+\omega t)\hat{\jmath}$ (c) $(9\sqrt{\pi}\ N/C)sin(\frac{\pi}{3}z+\omega t)\hat{\jmath}$
(d) $(3\pi\ N/C)sin(\frac{\pi}{3}z+\omega t)\hat{k}$ (e) $(3\sqrt{\pi}\ N/C)sin(\frac{\pi}{3}z+\omega t)\hat{\imath}$

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.

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?

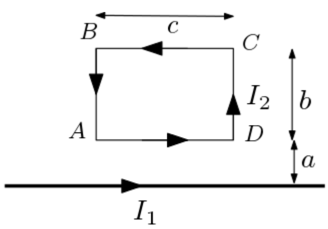
(a) $\frac{\rho_c R^2}{6\epsilon_0}$ (b) $\frac{\pi\rho_c R^2}{12\epsilon_0}$ (c) $\frac{\rho_c R^2}{12\epsilon_0}$ (d) $\frac{\rho_c R^2}{2\epsilon_0}$ (e) $\frac{\pi\rho_c R^2}{6\epsilon_0}$

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?

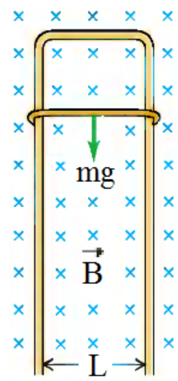
(a) $\frac{\mu_0 I_1 I_2}{2\pi}\frac{ac}{b(a+b)}$ (b) $\frac{\mu_0 I_1 I_2}{2\pi}\frac{bc}{a(a+b)}$ (c) $\frac{\mu_0 I_1 I_2}{3\pi}\frac{b}{(a+b)}$ (d) 0 (e) $\frac{\mu_0 I_1 I_2}{3\pi}\frac{bc}{a(a+b)}$

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) $\mathrm{BL}^2 v$ (b) $\mathrm{BL}^2 v/\mathrm{R}$ (c) $\mathrm{BL}v/\mathrm{R}$ (d) $\mathrm{BL}v$ (e) $\mathrm{BR}v$

10. What is the magnitude of the magnetic force on the slide wire, when the speed of the slide wire is v?

(a) $\mathrm{BL}v/\mathrm{R}$ (b) $\mathrm{BR}v$ (c) $\mathrm{BL}^2 v/\mathrm{R}^2$ (d) $\mathrm{BL}^2 v$ (e) $\mathrm{B}^2\mathrm{L}^2 v/\mathrm{R}$

11. What is the terminal speed of the slide wire?

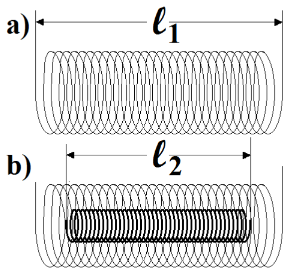
(a) $\mathrm{mg/BRL}^2$ (b) $\mathrm{mgR/4B^2L^2}$ (c) $\mathrm{2mg/BRL^2}$ (d) $\mathrm{mgR/B^2L^2}$ (e) $\mathrm{2mgR/B^2L^2}$

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) $\mathrm{BL^2mg/R}$, 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) $\mu_o\, A_2 N_1 N_2/l_1$ (b) $\mu_o\, A_2 N_1 N_2/l_1 l_2$ (c) $\mu_o\, A_1 N_1 N_2/l_1$ (d) $\mu_o\, A_1 N_1 N_2/l_2$ (e) $\mu_o\, A_1 N_1 N_2/l_1 l_2$

15. What is the induced emf in the inner solenoid?

(a) $-L_2 di_1/dt$ (b) $-M d\phi_{B2}/dt$ (c) $-L_1 di_1/dt$ (d) $-M d\phi_{B1}/dt$ (e) $-M di_1/dt$

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) $-M d\phi_{B2}/dt$ (b) $-L_2 di_2/dt$ (c) $-L_1 di_2/dt$ (d) $-M d\phi_{B1}/dt$ (e) $-M di_2/dt$

Questions 17-20

An electromagnetic wave propagating in vacuum has a magnetic field component given by

$$\vec{B}(z,t) = (6\times 10^{-8}\ T)\cos\left[(2\times 10^{3}\ rad/m)z - \omega t\right]\hat{\jmath}.$$

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

17. What is the direction of propagation and wavelength of this electromagnetic wave?

(a) $-y$-direction, $\lambda = 4\times 10^{-3}\ m$ (b) $+z$-direction, $\lambda = 4\times 10^{-3}\ m$ (c) $+y$-direction, $\lambda = 5\times 10^{-3}\ m$
(d) $+y$-direction, $\lambda = 3\times 10^{-3}\ m$ (e) $+z$-direction, $\lambda = 3\times 10^{-3}\ m$

18. What is the electric field component of this wave?

(a) $\vec{E}(y,t) = (18\ V/m)\cos\left[(2\times 10^3\ rad/m)y - \omega t\right]\hat{\imath}$
(b) $\vec{E}(z,t) = (18\ V/m)\cos\left[(2\times 10^3\ rad/m)z - \omega t\right]\hat{\imath}$
(c) $\vec{E}(x,t) = (18\ V/m)\cos\left[(2\times 10^3\ rad/m)x - \omega t\right]\hat{\imath}$
(d) $\vec{E}(x,t) = (18\ V/m)\cos\left[(2\times 10^3\ rad/m)x - \omega t\right]\hat{k}$
(e) $\vec{E}(z,t) = (18\ V/m)\cos\left[(2\times 10^3\ rad/m)z + \omega t\right]\hat{k}$

19. If the speed of this wave in a medium is $v = 6\times 10^7\ m/s$, 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) $1.3\times 10^{-9}\ N$ (b) $1.2\times 10^{-9}\ N$ (c) $1.5\times 10^{-9}\ N$ (d) $4.5\times 10^{-10}\ N$ (e) $1.4\times 10^{-9}\ N$

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.

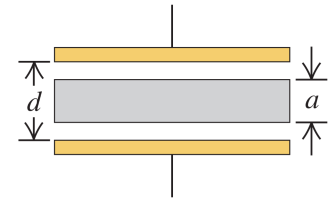
For all questions please take: Speed of light in vacuum c = 3$\times 10^8$ **m/s,** $\frac{1}{4\pi\epsilon_o} = 9\times 10^9$ **m/F,** $\mu_o = 4\pi\times 10^{-7}$ **H/m.**

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?

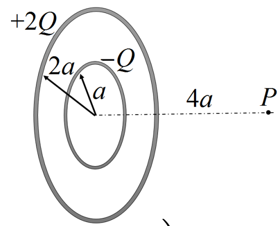
(a) 3/4 (b) 2 (c) 4 (d) 4/3 (e) 1/4

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) $\frac{Q}{4\pi\epsilon_o a}\left(\frac{-1}{\sqrt{17}} + \frac{2}{\sqrt{20}}\right)$

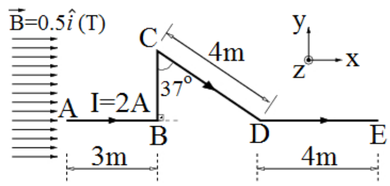
5. Which one of the following gives the magnitude of the electric field at point P?

(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?

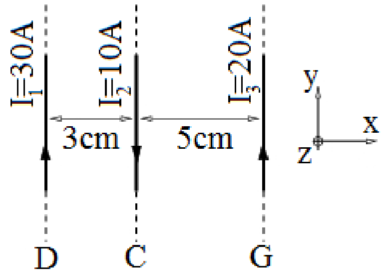
(a) 0 (b) $\sqrt{3.2^2 - 2.4^2}$ (c) 3.2 (d) 2.4 (e) $\sqrt{3.2^2 + 2.4^2}$

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?

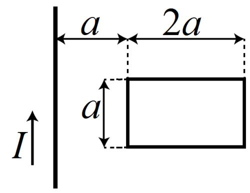
(a) $0.28\hat{k}$ (b) $-0.12\hat{k}$ (c) $-0.40\hat{k}$ (d) $0.06\hat{k}$ (e) $-0.06\hat{k}$

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?

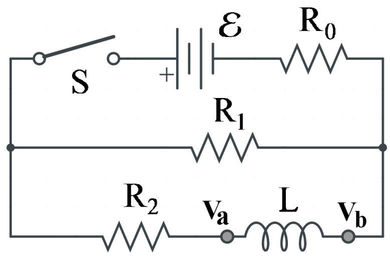
(a) $\frac{3\mu_o aI}{2\pi}$ (b) $\frac{2\mu_o a^2 I}{3\pi}$ (c) $\frac{\mu_o aI}{2\pi}\ln 2$ (d) $\frac{\mu_o aI}{2\pi}\ln 3$ (e) $\frac{\mu_o I}{2\pi a}\ln 6$

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.

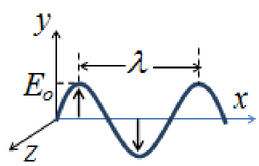
(a) 4 V (b) 20 V (c) 0 V (d) 2 V (e) 12 V

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 $\lambda = 6 \times 10^{-7}$m , the frequency is $f = 5 \times 10^{14}$ 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) $E_x = 180\,\sin(10^7 z - 3 \times 10^{15} t)$
(b) $E_x = 180\,\sin(3 \times 10^{15} x - 10^7 t)$
(c) $E_y = 60\,\cos(4.2 \times 10^{15} x - 10^7 t)$
(d) $E_z = 60\,\cos(10^7 y - 4.2 \times 10^{15} t)$
(e) $E_y = 180\,\sin(10^7 x - 3 \times 10^{15} t)$

17. Which of the following statements gives magnetic field component of the wave in units of tesla?

(a) $B_y = 2 \times 10^{-7}\,\sin(4.2 \times 10^{15} x - 10^7 t)$ (b) $B_x = 6\,\sin(3 \times 10^{15} x - 10^7 t)$ (c) $B_x = 6 \times 10^{-6}\,\sin(10^7 z - 3 \times 10^{15} t)$
(d) $B_z = 6 \times 10^{-7}\,\sin(10^7 x - 3 \times 10^{15} t)$ (e) $B_z = 2 \times 10^{-7}\,\cos(10^7 y - 4.2 \times 10^{15} t)$

18. Which of the following is the energy density of the wave?

(a) $3 \times 10^{-7}\,\sin^2(4.2 \times 10^{15} x - 10^7 t)$ (b) $3 \times 10^{-7}\,\sin^2(10^7 x - 3 \times 10^{15} t)$ (c) $3 \times 10^{-7}\,\sin(10^7 x - 3 \times 10^{15} t)$
(d) $6 \times 10^{-7}\,\cos^2(10^7 x - 3 \times 10^{15} t)$ (e) $6 \times 10^{-7}\,\cos(10^7 x - 4.2 \times 10^{15} t)$

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) $\frac{100}{3}\cos^2(10^7 x - 4.2 \times 10^{15} t)\hat{\imath}$ (b) $90\,\sin^2(10^7 x - 3 \times 10^{15} t)\hat{\imath}$ (c) $30\,\sin^2(10^7 y - 4.2 \times 10^{15} t)\hat{\jmath}$ (d) $\frac{50}{3}\sin^2(10^7 z - 3 \times 10^{15} t)\hat{k}$
(e) $72\,\cos^2(10^7 x - 3 \times 10^{15} t)\hat{\imath}$

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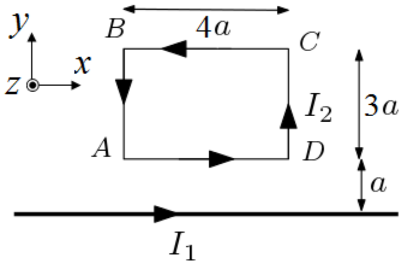
For all questions take: $c = 3\times10^8$ m/s, $\epsilon_o = 9\times10^{-12}$ F/m, $\mu_o = 4\pi\times10^{-7}$ T.m/A

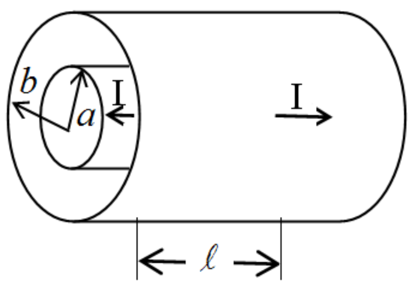
1. A rectangular current loop, carrying current I_2 and side lengths $3a$ and $4a$, is placed near a very long current carrying straight wire of current I_1, as shown in the figure. What is the magnetic force on the AB segment of the loop due to I_1?



(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).

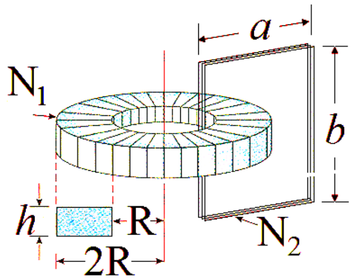
(a) $\frac{\mu_0 I}{2\pi(b-a)}$ (b) $\frac{\mu_0 I}{2\pi r}$ (c) $\frac{\mu_0 I}{2\pi a}$ (d) $\frac{\mu_0 I}{4\pi}$ (e) $\frac{\mu_0 I}{2\pi r^2}$

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) $\frac{\mu_o ab N_1 N_2}{2h\pi}$ (b) $\frac{\mu_o bh N_1^2}{2a\pi R}\ln 2$ (c) $\frac{\mu_o ah N_1^2}{2b\pi R^2}$ (d) $\frac{\mu_o ab N_1 N_2}{2h\pi}\ln 2$ (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?

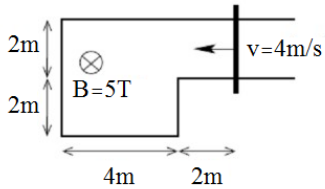
(a) $M\omega I_o\cos^2(\omega t)$ (b) $M\omega^2 I_o\sin(\omega t)$ (c) $M\omega^2 I_o\cos(\omega t)$ (d) $M\omega I_o\sin^2(\omega t)$ (e) $M\omega I_o\sin(\omega t)$

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.

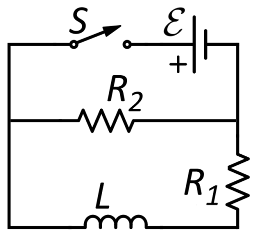
(a) In the direction of v (b) Into the page (c) Clockwise (d) Out the page (e) Counterclockwise

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

Group Number		Name		Type
List Number		Surname		A
Student ID		Signature		
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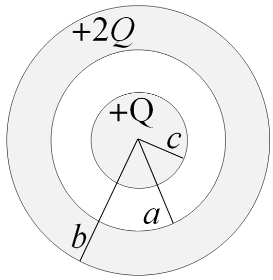
For all questions take: Speed of light in vacuum $c = 3 \times 10^8$ **m/s,** $\frac{1}{4\pi\epsilon_o} = 9 \times 10^9$ **V.m/C,** $\mu_o = 4\pi \times 10^{-7}\, T.m/A$

Questions 1-2

A hollow metal sphere has inner and outer radii of $a = 20\,\text{cm}$ and $b = 30\,\text{cm}$, respectively. As shown in the figure, a solid, uniformly charged metal sphere of radius $c = 10\,\text{cm}$ is located at the center of hollow metal sphere. The solid sphere has a total charge of $+Q = 225\,\text{nC}$ and the spherical metal shell has a total charge of $+2Q$. (Take $\text{V}(\infty) = 0$).



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?

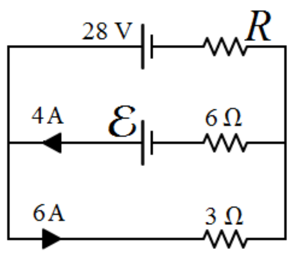
(a) 27 (b) 9×10^4 (c) 27×10^4 (d) 4.5×10^4 (e) 9

2. What is the potential difference $\text{V}(\text{r}{=}5\,\text{cm}) - \text{V}(\text{r} = 25\,\text{cm})$ 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

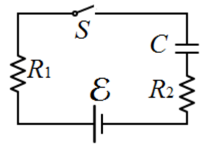
(a) 10 (b) 0 (c) 4 (d) 2 (e) 5

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?

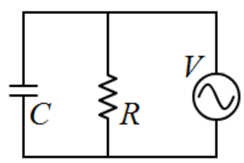
(a) 0.6×10^{-4} C (b) 0.8×10^{-4} C (c) 2.4×10^{-4} C (d) 240 C (e) 24 C

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.

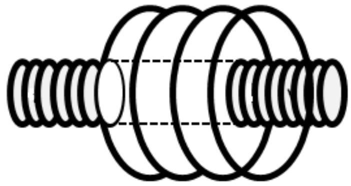
(a) $nNI_oA\cos(2\omega t)$ (b) $\mu_o n I_o A \cos(2\omega t)$ (c) $\mu_o n N \cos(2\omega t)$ (d) $\mu_o n N I_o A \cos(2\omega t)$ (e) $\mu_o n N I_o \cos(2\omega t)$

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) $\mu_o n N I_o A 2\omega \sin(2\omega t)$ (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?

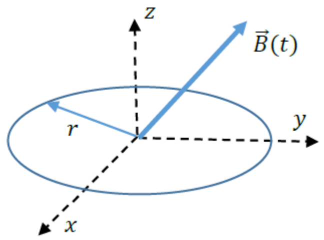
(a) $\frac{\mu_o N\pi a^2 I}{2L}$ (b) $\frac{\mu_o NLI}{4\pi a^2}$ (c) $\frac{\mu_o N\pi a^2 I}{L}$ (d) $\frac{\mu_o N 4\pi a^2 I}{L}$ (e) $\frac{\mu_o NLI}{\pi a^2}$

14. What is the mutual inductance of coils?

(a) $\frac{\mu_o N^2 L}{\pi a^2}$ (b) $\frac{\mu_o N^2 \pi a^2}{2L}$ (c) $\frac{\mu_o N^2 4\pi a^2}{L}$ (d) $\frac{\mu_o NL}{4\pi a^2}$ (e) $\frac{\mu_o N^2\pi a^2}{L}$

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

16. What is the net force on the ring?

(a) 0 (b) $\frac{\pi^2 r^3\alpha^2 t(\hat{i} - \hat{k})}{2R}$ (c) $\frac{2\pi^2 r^3 \alpha^2 t(-\hat{i} + \hat{k})}{R}$ (d) $\frac{2\sqrt{2}\pi^2 r^3\alpha^2 t(\hat{i} - \hat{k})}{R}$ (e) $\frac{8\pi^2 r^3\alpha^2 t(-\hat{i} + \hat{j})}{3R}$

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) $B_{max} = 2\ mT,\ k = 3\times 10^4\ rad/m,\ \omega = 2\times 10^{14}\ rad/s$ (b) $B_{max} = \frac{3}{20}\ mT,\ k = 6\times 10^5\ rad/m,\ \omega = 1.8\times 10^{12}\ rad/s$

(c) $B_{max} = \frac{20}{3}\ mT,\ k = 6\times 10^5\ rad/m,\ \omega = 1.8\times 10^{14}\ rad/s$ (d) $B_{max} = 2\ mT,\ k = 6\times 10^{-5}\ rad/m,\ \omega = 1.8\times 10^{-14}\ rad/s$

(e) $B_{max} = \frac{20}{3}\ mT,\ k = \frac{10}{6}\times 10^5\ rad/m,\ \omega = 2\times 10^3\ rad/s$

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) $-\hat{i}\frac{5}{6}\times 10^{10}$ (b) $\hat{j}\frac{5}{9}\times 10^3$ (c) $-\hat{j}\frac{5}{6}\times 10^{10}$ (d) $-\hat{i}\frac{5}{9}\times 10^{10}$ (e) $-\hat{k}\frac{5}{6}\times 10^{10}$

20. What is the intensity of the wave, in units of W/m^2?

(a) 6×10^{10} (b) $\frac{5}{6}\times 10^7$ (c) $\frac{5}{9}\times 10^3$ (d) $\frac{5}{6}\times 10^{10}$ (e) $\frac{5}{9}\times 10^{10}$

Group Number		Name		Type
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 taken into account.

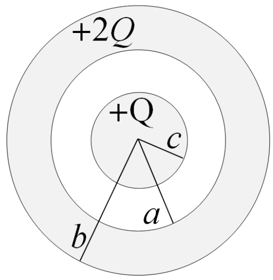
For all questions take: Speed of light in vacuum $c = 3 \times 10^8$ m/s, $\frac{1}{4\pi\epsilon_o} = 9 \times 10^9$ V.m/C, $\mu_o = 4\pi \times 10^{-7}$ T.m/A unit prefixes $M = 10^6$, $k = 10^3$, $m = 10^{-3}$, $\mu = 10^{-6}$, $n = 10^{-9}$, $p = 10^{-12}$

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 $V(\infty) = 0$).



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

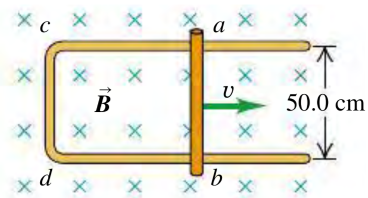
(a) 60 V/m (b) 3600 V/m (c) 9×10^4 V/m (d) 90 V/m (e) 4.5×10^4 V/m

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.

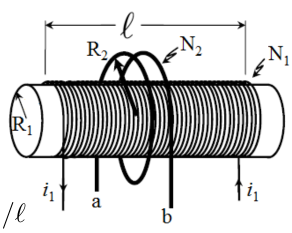
(a) 0.8 N/Left (b) 1.6 N/Left (c) 0.4 N/Right (d) 0.8 N/Right (e) 1.6 N/Right

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) $\pi^2\mu_0 R_2^2 N_2/\ell$

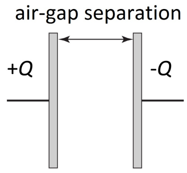
8. What is the mutual inductance, M of this combination?

(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.

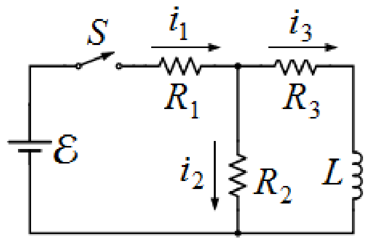
10. With the battery disconnected, the capacitor plates are pulled to a separation of 0.90 mm. What is the potential difference V across the plates now?

(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) $3\cos(4x - 12\times10^8 t)\,\hat{\imath}$ (b) $3\sin(12z + 1.5\times10^8 t)\,\hat{k}$ (c) $60\cos(1.5z - 2\times10^8 t)\,\hat{\imath}$ (d) $60\cos(4z - 12\times10^8 t)\,\hat{\jmath}$ (e) $-60\cos(1.5z - 2\times10^8 t)\,\hat{\jmath}$

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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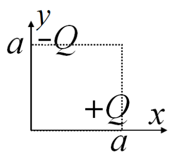
For all questions: Speed of light in vacuum $c = 3 \times 10^8$ m/s, $\frac{1}{4\pi\epsilon_o} = 9 \times 10^9$ V.m/C, $\mu_o = 4\pi \times 10^{-7}\, T.m/A$
Unit prefixes $M = 10^6$, $k = 10^3$, $m = 10^{-3}$, $\mu = 10^{-6}$, $n = 10^{-9}$, $p = 10^{-12}$



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 $\pi = 3$).

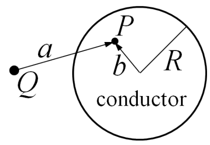
(a) $3(\hat{\imath} - \hat{\jmath})$ N/C (b) $(-\hat{\imath} + \hat{\jmath})$ N/C (c) 3 N/C (d) 0 (e) $(\hat{\imath} - \hat{\jmath})$ N/C

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.

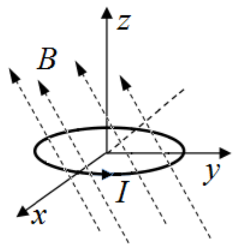
(a) Ohm (b) Ohm / s (c) Ohm m (d) kg m/C^2 s (e) Ohm / m



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



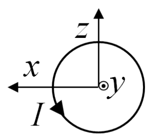
The axis of a ring shaped 100-turns coil is parallel to z-axis, as shown in the figure. In each of the turns a current $I = 0.5$ A flows and the area of the coil is 0.1 m^2. A homogeneous magnetic field $\vec{B} = 0.2\,(\hat{\imath} - 2\hat{\jmath} + 4\hat{k})$ T passes through the whole area of the 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?

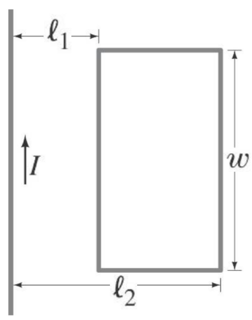
(a) $10\hat{\imath} + 5\hat{\jmath}$ (b) $-0.8\hat{\jmath} - 0.4\hat{k}$ (c) $-1.6\hat{\imath} + 0.4\hat{\jmath}$ (d) $2\hat{\imath} + \hat{\jmath}$ (e) $1.6\hat{\imath} + 0.8\hat{\jmath}$



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.

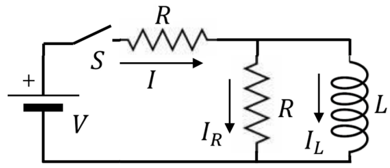
8. Determine the mutual inductance in terms of ℓ_1, ℓ_2 and ω. Assume that the wire is very long compared to ℓ_1, ℓ_2 and that the rest of its circuit is very far away compared to ℓ_1, ℓ_2 and ω.

(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) $\frac{\mu_0\omega}{4\pi}\ln\left(\frac{\ell_2-\ell_1}{\ell_1}\right)$

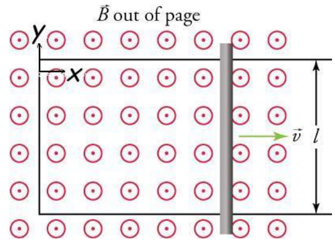
10. Consider the circuit in the figure with the switch S closed at time $t = 0$. What is the current $I_L(t)$ through the inductor L as a function of time?



(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) $\Phi_m = \frac{1}{2}K\ell v^2 t$ (c) $\Phi_m = K\ell vt$ (d) $\Phi_m = \ell vt^2$ (e) $\Phi_m = \frac{1}{2}K\ell v^2 t^2$

12. What is the electromotive force induced in the circuit due to the motion of the rod?

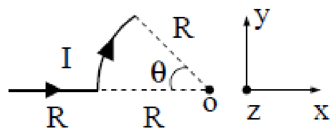
(a) $\mathcal{E} = -K\ell v^2 t$, clockwise (b) $\mathcal{E} = -K\ell v^2 t$, counter-clockwise (c) $\mathcal{E} = -\frac{1}{2}K\ell v^2 t$, counter-clockwise
(d) $\mathcal{E} = -\frac{1}{2}K\ell v^2 t$, clockwise (e) $\mathcal{E} = -K\ell vt$, counter-clockwise

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?



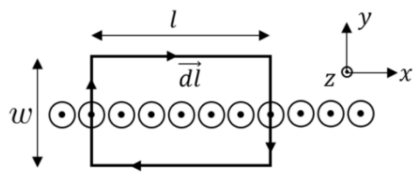
(a) $-\frac{2\mu_0 \mathrm{I}}{3\mathrm{R}}\hat{\mathrm{k}}$ (b) $-\frac{\mu_0 \mathrm{I}}{2\pi \mathrm{R}}\hat{\mathrm{k}}$ (c) 0 (d) $-\frac{\mu_0 \mathrm{I}}{2\mathrm{R}}\hat{\mathrm{i}}$ (e) $-\frac{\mu_0 \mathrm{I}}{\mathrm{R}}\hat{\mathrm{i}}$

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) $E_0 B_0/\epsilon_0\mu_0$ (e) $c{B_0}^2/\mu_0$

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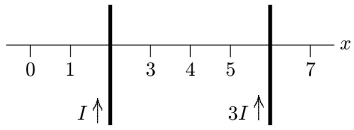
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be considered.

$$\frac{1}{4\pi\epsilon_o} = 9\times10^9\ \mathrm{V.m/C},\ \mu_o = 4\pi\times10^{-7}\ \mathrm{T.m/A},\ \text{speed of light in vacuum } c = 3\times10^8\ \mathrm{m/s}$$

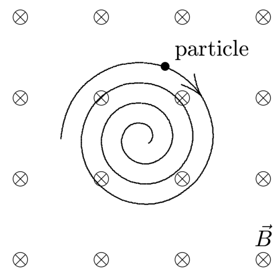
Unit prefixes: $M = 10^6,\ k = 10^3,\ m = 10^{-3},\ \mu = 10^{-6},\ n = 10^{-9},\ p = 10^{-12}$

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 $\pi\times10^{-6}\ m$ 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) $\vec{E} = -\hat{k}\left(1.5\times10^6\right)\times\cos\left[\left(2\times10^6\,\mathrm{x}\right)+\left(6\times10^{14}\,\mathrm{t}\right)\right]$ and $\vec{B} = \hat{\jmath}\left(5\times10^{-3}\right)\times\cos\left[\left(2\times10^6\,\mathrm{x}\right)+\left(6\times10^{14}\,\mathrm{t}\right)\right]$
(b) $\vec{E} = -\hat{\imath}\left(1.5\times10^6\right)\times\cos\left[\left(2\times10^6\,x\right)+\left(6\times10^{14}\,t\right)\right]$ and $\vec{B} = \hat{\jmath}\left(5\times10^{-3}\right)\times\cos\left[\left(2\times10^6\,\mathrm{x}\right)+\left(6\mathrm{x}10^{14}\,\mathrm{t}\right)\right]$
(c) $\vec{E} = \hat{\jmath}\left(1.5\times10^6\right)\times\cos\left[\left(2\times10^6\,\mathrm{x}\right)+\left(6\times10^{14}\,\mathrm{t}\right)\right]$ and $\vec{B} = \hat{\jmath}\left(5\times10^{6}\right)\times\cos\left[\left(2\times10^6\,\mathrm{x}\right)+\left(6\times10^{14}\,\mathrm{t}\right)\right]$
(d) $\vec{E} = \hat{k}\left(1.5\times10^6\right)\times\cos\left[\left(2\times10^6\,\mathrm{x}\right)+\left(6\times10^{14}\,\mathrm{t}\right)\right]$ and $\vec{B} = \hat{\jmath}\left(5\times10^{-3}\right)\times\cos\left[\left(2\times10^6\mathrm{x}\right)+\left(6\times10^{14}\,\mathrm{t}\right)\right]$
(e) $\vec{E} = \hat{\jmath}\left(5\times10^{-3}\right)\times\cos\left[\left(2\times10^6\,\mathrm{x}\right)+\left(6\times10^{14}\,\mathrm{t}\right)\right]$ and $\vec{B} = \hat{k}\left(5\times10^{-3}\right)\times\cos\left[\left(2\mathrm{x}10^6\,\mathrm{x}\right)+\left(6\mathrm{x}10^{14}\,\mathrm{t}\right)\right]$

Questions 5-6

An electromagnetic wave with frequency $f = 3/\pi\times10^{14}\ Hz$ propagates with a speed of $2.4\times10^8\ m/s$ 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) $4.5\times10^5\ rad/m$ (b) $5.0\times10^6\ rad/m$ (c) $2.5\times10^6\ rad/m$ (d) $3.5\times10^6\ rad/m$ (e) $2.0\times10^7\ rad/m$

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 $\mu_0 = 12\times10^{-7}\ H/m$.)

7. What is the magnetic field in the solenoid (in units of T (tesla))?

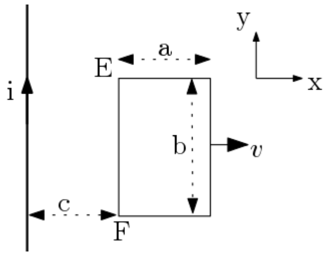
(a) 0.12 (b) 1.8 (c) 0.8 (d) 1.0 (e) 0.08

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 $\frac{\mu_0 \mathrm{ibav}}{2\pi \mathrm{R}}\frac{1}{(\mathrm{b+vt})(\mathrm{a+vt})}$ (b) cw and $\frac{\mu_0 \mathrm{ibav}}{2\pi \mathrm{R}}\frac{1}{(\mathrm{c+vt})(\mathrm{c+a+vt})}$ (c) ccw and $\frac{\mu_0 \mathrm{ibcv}}{2\pi \mathrm{R}}\frac{1}{(\mathrm{c+vt})(\mathrm{a+vt})}$
(d) cw and $\frac{\mu_0 \mathrm{ibcv}}{2\pi \mathrm{R}}\frac{1}{(\mathrm{a+vt})(\mathrm{c+b+vt})}$ (e) cw and $\frac{\mu_0 \mathrm{ibav}}{2\pi \mathrm{R}}\frac{1}{(\mathrm{c+vt})(\mathrm{b+a+vt})}$

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

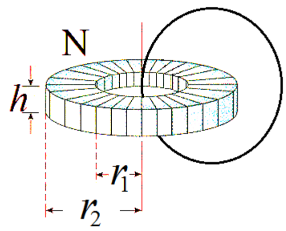
A satellite at a distance 100 km from Earth's surface emits sinusoidal radio waves with average total power 60 kW. Assume that the transmitter radiates equally in all directions. (Take $\pi \approx 3$ and for air $\mu_0 = 1.2 \times 10^{-6}\ H/m$.)

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

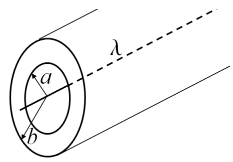
A toroid shaped inductor with a rectangle profile has an inner radius r_1, an outer radius r_2 and a height h. The toroid has N windings and current I flows through it.

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

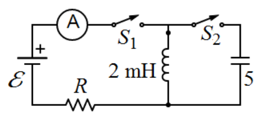
A very long metal pipe has inner and outer radii of a and b, respectively. As shown in the figure, a uniformly charged thin wire lies along the axis of the pipe. Linear charge density of the wire is λ.

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