Electricity & Magnetism – Problem Set # 3

TABLE OF INFORMATION

Rest mass of the electron	$m_e = 9.11 \times 10^{-31}$ kilogram $= 9.11 \times 10^{-28}$ gram
Magnitude of the electron charge	$e = 1.60 \times 10^{-19}$ coulomb $= 4.80 \times 10^{-10}$ statcoulomb (esu)
Avogadro's number	$N_0 = 6.02 \times 10^{23}$ per mole
Universal gas constant	$R = 8.31$ joules/(mole · K)
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ joule/K $= 1.38 \times 10^{-16}$ erg/K
Speed of light	$c = 3.00 \times 10^{8}$ m/s $= 3.00 \times 10^{10}$ cm/s
Planck's constant	$h = 6.63 \times 10^{-34}$ joule · second $= 4.14 \times 10^{-15}$ eV · second
	$\hbar = h/2\pi$
Vacuum permittivity	$\epsilon_0 = 8.85 \times 10^{-12}$ coulomb^2/(newton · meter^2)
Vacuum permeability	$\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere · meter)
Universal gravitational constant	$G = 6.67 \times 10^{-11}$ meter^3/(kilogram · second^2)
Acceleration due to gravity	$g = 9.80$ m/s^2 $= 980$ cm/s^2
1 atmosphere pressure	1 atm $= 1.0 \times 10^{5}$ newton/meter^2 $= 1.0 \times 10^{5}$ pascals (Pa)
1 angstrom	1 Å $= 1 \times 10^{-10}$ meter

1 weber/m^2 = 1 tesla = 10^4 gauss

Moments of inertia about center of mass

Rod	$\frac{1}{12}M\ell^2$
Disc	$\frac{1}{2}MR^2$
Sphere	$\frac{2}{5}MR^2$

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

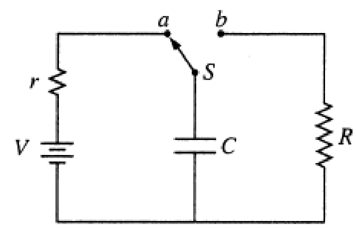


Figure 1

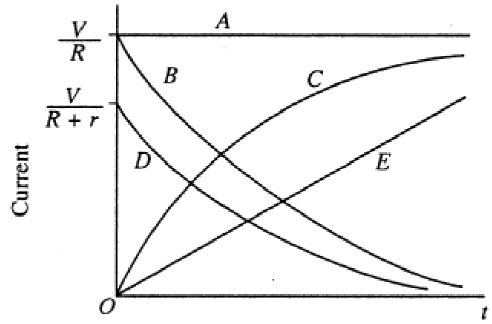
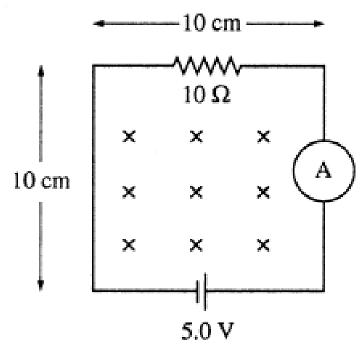


Figure 2

1. The capacitor shown in Figure 1 above is charged by connecting switch S to contact a. If switch S is thrown to contact b at time $t = 0$, which of the curves in Figure 2 above represents the magnitude of the current through the resistor R as a function of time?

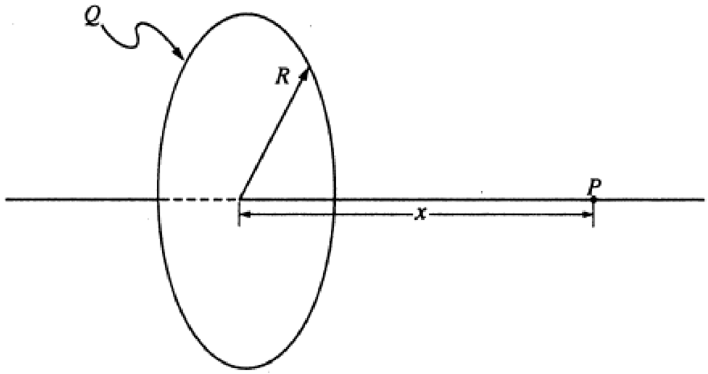
(A) A
(B) B
(C) C
(D) D
(E) E



2. The circuit shown above is in a uniform magnetic field that is into the page and is decreasing in magnitude at the rate of 150 tesla/second. The ammeter reads

(A) 0.15 A
(B) 0.35 A
(C) 0.50 A
(D) 0.65 A
(E) 0.80 A

Questions 3-4 refer to a thin, nonconducting ring of radius R, as shown below, which has a charge Q uniformly spread out on it.



3. The electric potential at a point P, which is located on the axis of symmetry a distance x from the center of the ring, is given by

(A) $\dfrac{Q}{4\pi\varepsilon_0 x}$

(B) $\dfrac{Q}{4\pi\varepsilon_0\sqrt{R^2 + x^2}}$

(C) $\dfrac{Qx}{4\pi\varepsilon_0(R^2 + x^2)}$

(D) $\dfrac{Qx}{4\pi\varepsilon_0(R^2 + x^2)^{3/2}}$

(E) $\dfrac{QR}{4\pi\varepsilon_0(R^2 + x^2)}$

4. A small particle of mass m and charge $-q$ is placed at point P and released. If $R >> x$, the particle will undergo oscillations along the axis of symmetry with an angular frequency that is equal to

(A) $\sqrt{\dfrac{qQ}{4\pi\varepsilon_0 mR^3}}$

(B) $\sqrt{\dfrac{qQx}{4\pi\varepsilon_0 mR^4}}$

(C) $\dfrac{qQ}{4\pi\varepsilon_0 mR^3}$

(D) $\dfrac{qQx}{4\pi\varepsilon_0 mR^4}$

(E) $\sqrt{\dfrac{qQx}{4\pi\varepsilon_0 m}}\dfrac{1}{R^2 + x^2}$

19. When alpha particles are directed onto atoms in a thin metal foil, some make very close collisions with the nuclei of the atoms and are scattered at large angles. If an alpha particle with an initial kinetic energy of 5 MeV happens to be scattered through an angle of 180°, which of the following must have been its distance of closest approach to the scattering nucleus? (Assume that the metal foil is made of silver, with $Z = 50$.)

(A) $1.22 \times 50^{1/3}$ fm
(B) 2.9×10^{-14} m
(C) 1.0×10^{-12} m
(D) 3.0×10^{-8} m
(E) 1.7×10^{-7} m

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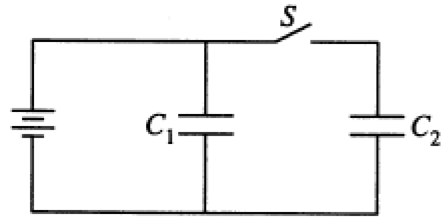
24. Two identical conducting spheres, A and B, carry equal charge. They are initially separated by a distance much larger than their diameters, and the force between them is F. A third identical conducting sphere, C, is uncharged. Sphere C is first touched to A, then to B, and then removed. As a result, the force between A and B is equal to

(A) 0
(B) $F/16$
(C) $F/4$
(D) $3F/8$
(E) $F/2$



25. Two real capacitors of equal capacitance ($C_1 = C_2$) are shown in the figure above. Initially, while the switch S is open, one of the capacitors is uncharged and the other carries charge Q_0. The energy stored in the charged capacitor is U_0. Sometime after the switch is closed, the capacitors C_1 and C_2 carry charges Q_1 and Q_2, respectively; the voltages across the capacitors are V_1 and V_2; and the energies stored in the capacitors are U_1 and U_2. Which of the following statements is INCORRECT?

(A) $Q_0 = \frac{1}{2}(Q_1 + Q_2)$

(B) $Q_1 = Q_2$

(C) $V_1 = V_2$

(D) $U_1 = U_2$

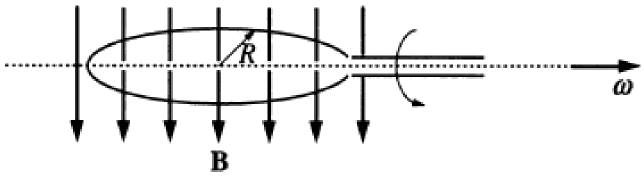
(E) $U_0 = U_1 + U_2$

26. A series RLC circuit is used in a radio to tune to an FM station broadcasting at 103.7 MHz. The resistance in the circuit is 10 ohms and the inductance is 2.0 microhenries. What is the best estimate of the capacitance that should be used?

(A) 200 pF
(B) 50 pF
(C) 1 pF
(D) 0.2 pF
(E) 0.02 pF

43. The line integral of $\mathbf{u} = y\mathbf{i} - x\mathbf{j} + z\mathbf{k}$ around a circle of radius R in the xy-plane with center at the origin is equal to

(A) 0
(B) $2\pi R$
(C) $2\pi R^2$
(D) $\pi R^2/4$
(E) $3R^3$



46. A circular wire loop of radius R rotates with an angular speed ω in a uniform magnetic field **B**, as shown in the figure above. If the emf $\mathcal{E}$ induced in the loop is $\mathcal{E}_0 \sin \omega t$, then the angular speed of the loop is

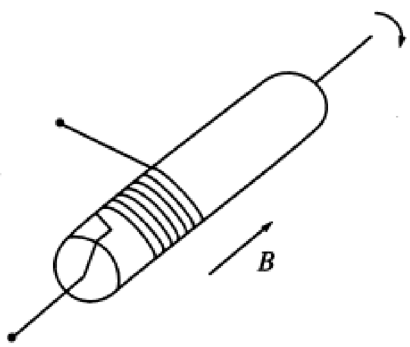
(A) $\mathcal{E}_0 R/B$

(B) $2\pi \mathcal{E}_0/R$

(C) $\mathcal{E}_0/(B\pi R^2)$

(D) $\mathcal{E}_0^2/(BR^2)$

(E) $\tan^{-1}(\mathcal{E}_0/Bc)$



47. A wire is being wound around a rotating wooden cylinder of radius R. One end of the wire is connected to the axis of the cylinder, as shown in the figure above. The cylinder is placed in a uniform magnetic field of magnitude B parallel to its axis and rotates at N revolutions per second. What is the potential difference between the open ends of the wire?

(A) 0

(B) $2\pi NBR$

(C) πNBR^2

(D) BR^2/N

(E) πNBR^3

49. The infinite xy-plane is a nonconducting surface, with surface charge density σ, as measured by an observer at rest on the surface. A second observer moves with velocity $v\hat{\mathbf{x}}$ relative to the surface, at height h above it. Which of the following expressions gives the electric field measured by this second observer?

(A) $\frac{\sigma}{2\epsilon_0}\ \hat{\mathbf{z}}$

(B) $\frac{\sigma}{2\epsilon_0}\sqrt{1 - v^2/c^2}\ \hat{\mathbf{z}}$

(C) $\frac{\sigma}{2\epsilon_0\sqrt{1 - v^2/c^2}}\ \hat{\mathbf{z}}$

(D) $\frac{\sigma}{2\epsilon_0}\left(\sqrt{1 - v^2/c^2}\ \hat{\mathbf{z}} + v/c\ \hat{\mathbf{x}}\right)$

(E) $\frac{\sigma}{2\epsilon_0}\left(\sqrt{1 - v^2/c^2}\ \hat{\mathbf{z}} - v/c\ \hat{\mathbf{y}}\right)$