E&M

Problem 1:

A long, thin, vertical wire has a net positive charge λ per unit length. In addition, there is a current I in the wire. A charged particle moves with speed u in a straight-line trajectory, parallel to the wire and at a distance r from the wire. Assume that the only forces on the particle are those that result from the charge on and the current in the wire and that u is much less than c, the speed of light.

Suppose that the current in the wire is reduced to $I/2$. Which of the following changes, made simultaneously with the change in the current, is necessary if the same particle is to remain in the same trajectory at the same distance r from the wire?

(A) Doubling the charge per unit length on the wire only
(B) Doubling the charge on the particle only
(C) Doubling both the charge per unit length on the wire and the charge on the particle
(D) Doubling the speed of the particle
(E) Introducing an additional magnetic field parallel to the wire

Problem 2:

The particle is later observed to move in a straight-line trajectory, parallel to the wire but at a distance $2r$ from the wire. If the wire carries a current I and the charge per unit length is still λ , the speed of the particle is

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

Problem 3:

Positive charge is brought from far away and gradually assembled on the surface of an initially uncharged sphere of radius R. The work required to place total charge Q on a sphere in this manner is

(A) $\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R^2}$

(B) $\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R^2}$

(C) $\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R}$

(D) $\frac{3}{5}\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R}$

(E) $\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R}$

Problem 4:

Which of the following occurs as the temperature of a current-carrying wire increases?

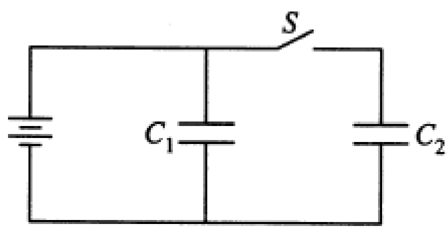
(A) The resistance decreases because thermal energy frees more electrons.
(B) The resistance increases because the wire expands and gets longer.
(C) The resistance decreases because the electrons move faster.
(D) The resistance increases because the free electrons collide more frequently with the metal atoms.
(E) The resistance does not change.

Problem 5:

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) $F/2$

Problem 6:



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) $V_1 = V_2$

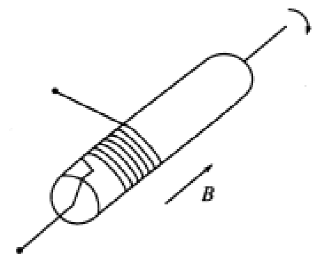
(D) $U_1 = U_2$

(E) $U_0 = U_1 + U_2$

Problem 7:

Equal charges of value -Q each are arranged at the eight vertices of a non-conducting skeleton cube of side ‘a’. If a point charge +Q is placed at the center of the cube, the electrostatic force exerted by the eight negative charges on the positive charge at the centre is
(A) $Q^2/3\pi\varepsilon_0 a^2$
(B) $4Q^2/3\pi\varepsilon_0 a^2$
(C) $8Q^2/3\pi\varepsilon_0 a^2$
(D) $16Q^2/3\pi\varepsilon_0 a^2$
(E) zero

Problem 8:



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

Problem 9:

A charged particle is released from rest in a region where there is a constant electric field and a constant magnetic field. If the two fields are parallel to each other, the path of the particle is a

(A) circle
(B) parabola
(C) helix
(D) cycloid
(E) straight line

Problem 10:

A negative test charge is moving near a long straight wire in which there is a current. A force will act on the test charge in a direction parallel to the direction of the current if the motion of the charge is in a direction

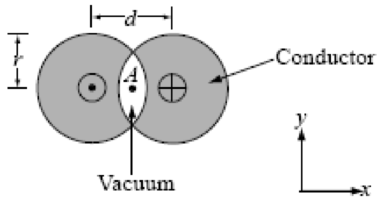
(A) toward the wire
(B) away from the wire
(C) the same as that of the current
(D) opposite to that of the current
(E) perpendicular to both the direction of the current and the direction toward the wire

Problem 11:

Two capacitors of capacitances 1.0 microfarad and 2.0 microfarads are each charged by being connected across a 5.0-volt battery. They are disconnected from the battery and then connected to each other with resistive wires so that plates of opposite charge are connected together. What will be the magnitude of the final voltage across the 2.0-microfarad capacitor?

(A) 0 V
(B) 0.6 V
(C) 1.7 V
(D) 3.3 V
(E) 5.0 V

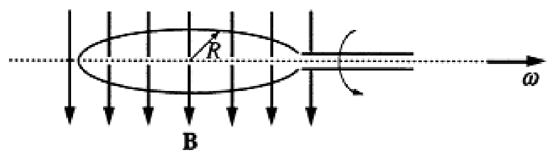
Problem 12:



Two long conductors are arranged as shown above to form overlapping cylinders, each of radius r, whose centers are separated by a distance d. Current of density J flows into the plane of the page along the shaded part of one conductor and an equal current flows out of the plane of the page along the shaded portion of the other, as shown. What are the magnitude and direction of the magnetic field at point A?

(A) $(\mu_0/2\pi)\pi dJ$, in the $+y$-direction
(B) $(\mu_0/2\pi)d^2J/r$, in the $+y$-direction
(C) $(\mu_0/2\pi)4d^2J/r$, in the $-y$-direction
(D) $(\mu_0/2\pi)Jr^2/d$, in the $-y$-direction
(E) There is no magnetic field at A.

Problem 13:



A circular wire loop of radius R rotates with an angular speed ω in a uniform magnetic field $\mathbf{B}$, 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

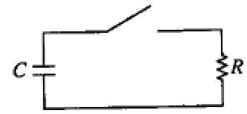
(A) $\mathcal{E}_0 R/B$
(B) $2\pi\mathcal{E}_0/R$
(C) $\mathcal{E}_0/(B\pi R^2)$
(D) $\mathcal{E}_0^2/(BR^2)$
(E) $\tan^{-1}(\mathcal{E}_0/Bc)$

Problem 14:

When the number of turns in a coil is made 2.5 times the original number without changing the area, the self inductance increases by a factor of

(A) 2.5
(B) 5
(C) 6.25
(D) 1.25
(E) 10

Problem 15:



The capacitor in the circuit shown above is initially charged. After closing the switch, how much time elapses until one-half of the capacitor's initial stored energy is dissipated?

(A) RC

(B) $\frac{RC}{2}$

(C) $\frac{RC}{4}$

(D) $2RC\ln(2)$

(E) $\frac{RC\ln(2)}{2}$