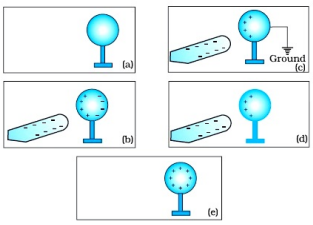
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Answers Key:

5 Marks

1. $I_1 = 2\ I3$
2. Given, I_1 = 4 A, I_2 = 6 A, r = 3 cm = 0.03 m
   $F = \frac{\mu_0}{4\pi} \cdot \frac{2I_1I_2}{r} = \frac{10^{-7} \times 2 \times 4 \times 6}{0.03}$
   = 1.6 $\times 10^{-4}$ N/m
3. Radius of sphere A = R
   Surface charge density on sphere A = σ
   Radius of sphere B = 2R
   Surface charge density on sphere B = σ
   Before contact, the charge on sphere A is
   Q_1 = Surface charge density x Surface area
   $\Rightarrow Q_1 = \sigma . 4\pi R^2 \quad \ldots (i)$
   Before contact, the charge on sphere B is
   Q_2 = Surface charge density x Surface area
   $Q_2 = \sigma 4\pi (2R)^2 = \sigma . 16\pi R^2 \ldots (ii)$
   Let after the contact, the charge on A be Q'_1 and the charge on B Q'_2 .
   According to the conservation of charge, the charge before contact is equal to charge after contact.
   $Q'_1 + Q'_2 = Q_1 + Q_2$
   Putting the values of Q_1 and Q_2 from Eqs. (i) and (ii), we get
   $Q'_1 + Q'_2 = 4\pi R^2\sigma + 16\pi R^2\sigma = 20\pi R^2\sigma \quad \ldots (iii)$
   As they are in contact. So, they have same potential.
   Potential on sphere A is $V_A = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q'_1}{R}$
   Potential on sphere B is $V_B = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q'_2}{2R}$
   So, $V_A = V_B$
   $\Rightarrow \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q'_1}{R} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q'_2}{2R}$
   $\Rightarrow \frac{Q'_1}{R} = \frac{Q'_2}{2R}$
   $\Rightarrow 2Q'_1 = Q'_2$ .....(iv)
   Putting the value of Q'_2 in Eq. (iii), we get
   $Q'_1 + 2Q'_1 = 20\pi R^2\sigma \Rightarrow 3Q'_1 = 20\pi R^2\sigma$
   $\Rightarrow Q'_1 = \frac{20}{3}\pi R^2\sigma$
   and $Q'_2 = \frac{40}{3}\pi R^2\sigma$ [from eq.(iv)]
   Let the new charge densities be σ_1 and σ_2
   $\sigma_1 = \frac{Q'_1}{4\pi R^2} = \frac{20\pi R^2\sigma}{3 \times 4\pi R^2} = \frac{5}{3}\sigma$
   $\sigma_2 = \frac{Q'_2}{4\pi(2R)^2} = \frac{40\pi R^2\sigma}{3 \times 4\pi \times 4R^2} = \frac{40\sigma}{16 \times 3}$
   $\sigma_2 = \frac{10\sigma}{4 \times 3} = \frac{5}{6}\sigma$
   Thus, the surface charge densities on spheres after contact are $\frac{5}{3}\sigma$ and $\frac{5}{6}\sigma$.
4. In the Figure (a) shows an uncharged metallic sphere on an insulating metal stand. Bring a negatively charged rod close to the metallic sphere, as shown in Figure (b). As the rod is brought close to the sphere, the free electrons in the sphere move away due to repulsion and start piling up at the farther end. The near end becomes positively charged due to deficit of electrons. This process of charge distribution stops when the net force on the free electrons inside the metal is zero. Connect the sphere to the ground by a conducting wire. The electrons will flow to the ground while the positive charges at the near end will remain held there due to the attractive force of the negative charges on the rod, as shown in Figure (c). Disconnect the sphere from the ground. The positive charge continues to be held at the near end [Figure (d)]. Remove the electrified rod. The positive charge will spread uniformly over the sphere as shown in Figure (e).



   In this experiment, the metal sphere gets charged by the process of induction and the rod does not lose any of its charge.
   Similar steps are involved in charging a metal sphere negatively by induction, by bringing a positively charged rod near it. In this case the electrons will flow from the ground to the sphere when the sphere is connected to the ground with a wire.

3 Marks

5. Potential gradient $= \frac{2.5}{8} = 0.3125$ V/m. As potential drop across the balancing length is equal to the emf of the cell, i.e. emf = 0.3125 x 1 = 0.3125 V.
6.

Given,$m = 50Am;\ d = 0.2m:\ 2l = 0.1m\ or\ l = 0.05m$

$Therefore, M = m(2l) = 50 \times 0.1 = 5Am^2$

$(a) B_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{2Md}{(d^2-l^2)^2} = \frac{10^{-7}\times 2\times 5\times 0.2}{(0.2^2-0.05^2)^2} = 1.42 \times 10^{-4}T$

$(b)\ B_{equa} = \frac{\mu_0}{4\pi} \cdot \frac{M}{(d^2+l^2)^{3/2}} = \frac{10^{-7}\times 5}{(0.2^2+0.05^2)^{3/2}}$

$= \frac{10^{-7}\times 5}{(0.0425)^{3/2}}$

$= \frac{5\times 10^{-7}}{0.00876} = 5.707 \times 10^{-5}T$

7. No, Coulomb's law is not applicable in all situations. It is applicable only when:
   (i) The electric charges are stationary.
   (ii) The electric charges are point in size.
   (iii) Both the charges should lie in an isolated system.
   Thus we find if two charges are finite in size like two charged spheres, the Coulomb's law does not apply because when the charged spheres are brought together, the distribution of charge do not remain uniform.
8. Yes, two balls having same kind of charge can attract each other if charge possessed by one ball is very large as compared to that on the other ball because when two charged balls are placed near each other, they induced opposite charges on the faces of each other. On the ball having small amount of charge, very large amount of induced charge is produced, two balls get attracted towards each other.
9. Current in each bulb,
   I = $\frac{P}{V} = \frac{60}{220} = \frac{3}{11}A$
   No. of bulbs used,
   n = $\frac{9}{3/11}$ = 33
10. (i) A toroid can be viewed as a solenoid which has been bent into circular shape to close on itself.
11. Given, p = 4 $\times 10^{-9}$ C-m, E = 5 $\times$ 10^4,
    θ = 30°
    $\therefore \tau$ = pE sin θ
    = 4 $\times 10^{-9} \times 5 \times 10^4 \times$ sin 30°
    $= 4 \times 10^{-9} \times 5 \times 10^4 \times \frac{1}{2}$ [$\because$ sin 30° = $\frac{1}{2}$]
    = 10 $\times 10^{-5}$ = 10^{-4} N-m
12. If the field is non-uniform, the net force will be non-zero.
13. The terminal potential difference of the cell becomes greater than the emf of the cell during charging of the cell. In this process, current flows from positive electrode to negative electrode of the cell.
    Hence, V = E + Ir.
14. Given: n = 8, r = 1 mm = 10-3 m, q = 10 x 10^{-10} C, V = ?
    Volume of 8 drops = Volume of a single drop
    $8 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \Rightarrow R = 2r$
    As electric charge is conserved,
    $\therefore\ nq = Q =$ Charge on a single drop.
    8 x 10 x 10^{-10} = Q
    $\Rightarrow\ Q = 8 \times 10^{-9}$C
    Potential of bigger drop = $\frac{kQ}{R}$
    $V = \frac{9\times 10^9 \times 8\times 10^{-9}}{2\times 10^{-3}} = 3.6 \times 10^4$ V

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