1. Consider two identical dipoles D_1 and D_2. Charges – q and q of dipole D_1 are located at (0, 0) and (a, 0) and that of dipole D_2 at (0, a) and (0, 2a) in x-y plane, respectively. The net dipole moment of the system is 1

(A) $qa(\hat{i}+\hat{j})$ (B) $-qa(\hat{i}+\hat{j})$ (C) $qa(\hat{i}-\hat{j})$ (D) $-qa(\hat{i}-\hat{j})$

2. A solid copper sphere of radius R is uniformly charged with charge density σ. The electric potential at its centre is 1

(A) $\frac{\sigma}{\pi\varepsilon_0}$ (B) $\frac{\sigma R}{\varepsilon_0}$ (C) zero   (D) $\frac{\sigma R}{2\varepsilon_0}$

3. A charged sphere of radius r has surface charge density σ. The electric field on its surface is E. The electric field at a point 2r distant from the centre of the sphere will be

(A) E   (B) 2E   (C) $\frac{E}{4}$ (D) $\frac{E}{2}$ 1

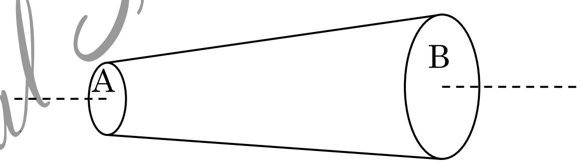
4. A wire has a non-uniform cross-section as shown in the figure. A steady current is flowing through it. Then the drift speed of the free electrons 1

(A) is constant throughout the wire

(B) decreases from A to B

(C) increases from A to B

(D) varies randomly



5. Two identical point charges are placed at the two vertices A and B of an equilateral triangle of side l. The magnitude of the electric field at the third vertex P is E. If a hollow conducting sphere of radius $(l/4)$ is placed at P, the magnitude of the electric field at point P now becomes 1

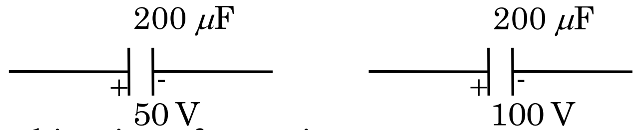
(A) > E   (B) E   (C) $\frac{E}{2}$ (D) zero

6. Two cells of emfs 1.5 V and 2.0 V having internal resistances 0.2 Ω and 0.3 Ω respectively are connected in parallel to each other in a circuit. Calculate the effective emf and internal resistance of the equivalent cell. 2

7. Deduce the relation between internal resistance, emf, terminal potential difference and the total current in the circuit? 2

8. Draw V-I graph for ohmic and non-ohmic materials. Give one example for each. 2

9. Two capacitors are charged as shown. When the positive terminal and negative terminal of one capacitor are connected to positive and negative terminals respectively of the other capacitor, then what will be



(a) common potential across the combination of capacitors,

(b) Energy loss in the process as heat? 3

10. Name the factors on which electrical conductivity of a material depends. Obtain the relation between current density in a conductor and the conductivity of its material. 3

11. Three point charges 2 μC, 4 μC and 16 μC are placed at (4 cm, 0, 0), (1 cm, 0, 0) and (10 cm, 0, 0) respectively. Determine the electrostatic potential energy of the system of charges. How much work is to be done externally to dissociate the system of charges to infinity? 3

ANSWERS

1. (A) $qa(\hat{i}+\hat{j})$ $\vec{p}_1 = qa\hat{i}$, $\vec{p}_2 = qa\hat{j}$ $\Rightarrow \vec{p} = \vec{p}_1 + \vec{p}_2$

2. (B) $\dfrac{\sigma R}{\varepsilon_0}$ $V = \dfrac{kQ}{R} = \dfrac{1}{4\pi\varepsilon_0 R} \times \sigma \times 4\pi R^2 = \dfrac{\sigma R}{\varepsilon_0}$

3. (C) $\dfrac{E}{4}$ $E = \dfrac{\sigma}{\varepsilon_0}$, $E_1 = \dfrac{\sigma r^2}{\varepsilon_0 r_1^2} = \dfrac{Er^2}{(2r)^2} = \dfrac{E}{4}$

4. (C) increases from A to B I = $n a e \upsilon$ = constant $\Rightarrow \upsilon \propto 1/a$

5. (D) zero

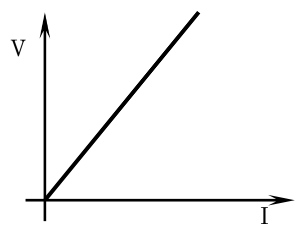
6. $r_{eq} = \dfrac{r_1 r_2}{r_1 + r_2} = \dfrac{0.2 \times 0.3}{0.2 + 0.3} = \dfrac{0.06}{0.5} = 0.12\ \Omega$

$E_{eq} = \dfrac{E_1 r_2 + E_2 r_1}{r_1 + r_2} = \dfrac{1.5 \times 0.3 + 2 \times 0.2}{0.2 + 0.3} = \dfrac{0.45 + 0.4}{0.5} = \dfrac{0.85}{0.5} = 1.7$ V

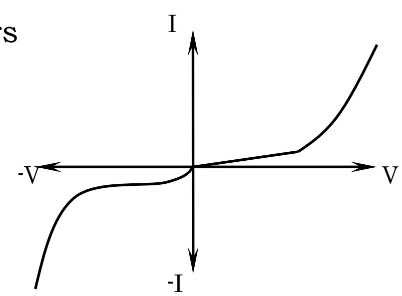
7. If R is external resistance connected across the terminals of a cell of emf E ands internal resistance r then the current tin the circuit is $I = \dfrac{E}{R+r}$

$\Rightarrow IR = E - Ir$, IR = V = terminal potential; difference of cell then
V = E – Ir

8. *Ohmic devices* –
alloys like manganin, constantan, nichrome



Non-ohmic devices –
p-n junction diode, semiconductors



9. Common potential $V_0 = \dfrac{Q_1 + Q_2}{C_p} = \dfrac{200 \times 50 + 200 \times 100}{200 + 200} = 75\,\text{V}$

Energy loss $\Delta U = \dfrac{C_1 C_2}{2(C_1 + C_2)}(V_1 - V_2)^2$

$$= \frac{200\times200\times10^{-12}}{2(200+200)\times10^{-6}}(50-100)^2 = \frac{4\times10^{-8}\times2500}{2\times4\times10^{-4}} = 0.125\,\text{J}$$

10. *Factors* on which electrical conductivity of a material depends are:

Nature of material, temperature

Current density $\vec{J} = \frac{I}{A}\hat{n} \quad \Rightarrow J = \frac{nAe\upsilon_d}{A} = ne\upsilon_d$

$$\because \upsilon_d = \frac{eE\tau}{m} \qquad \Rightarrow J = ne\left(\frac{eE\tau}{m}\right) = \left(\frac{ne^2\tau}{m}\right)E$$

$$\because \sigma = \frac{ne^2\tau}{m} = \text{conductivity of conductor} \quad \text{Therefore,} \quad \vec{J} = \sigma\vec{E}$$

11. $U = \frac{kq_1q_2}{r_{12}} + \frac{kq_1q_3}{r_{13}} + \frac{kq_2q_3}{r_{23}}$

$$= 9\times10^9\left(\frac{4\times2\times10^{-12}}{3\times10^{-2}} + \frac{4\times16\times10^{-12}}{9\times10^{-2}} + \frac{2\times16\times10^{-12}}{6\times10^{-2}}\right)$$

$$= \frac{9\times10^{-1}\times8}{3}\times\left(1+\frac{8}{3}+2\right) = 0.8\times17 = 13.6\,\text{J}$$

External work to be done to dissociate the charge system is

$W = \Delta U = U_\infty - U$

$= 0 - 13.6$ J

$= -13.6$ J