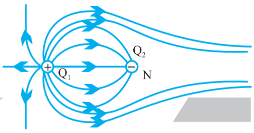



Unit I and II

# Section - 1

## KEY POINTS

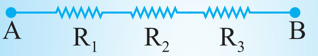
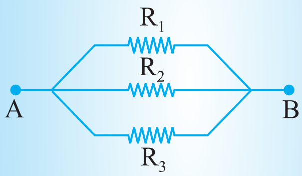
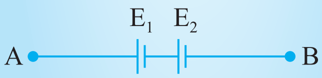
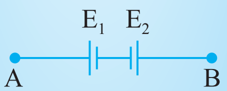
| Physical Quantity | Formulae Used | SI Unit |
|---|---|---|
| Quantization of charge | $q = \pm ne$ | C |
| Coulomb's force | $\lvert F \rvert = \dfrac{kq_1q_2}{r^2}$ | N |
| In vector form | $\vec{F}_{12} = \dfrac{kq_1q_2}{r_{21}^3}\vec{r}_{21} = \dfrac{kq_1q_2}{r_{21}^2}.\hat{r}_{21}$ | |
| Dielectric constant (or relative permitivity) Hence $F_0 \geq F_m$ as free space has minimum permitivity | $K_D = \in_r = \dfrac{F_0}{F_m} = \dfrac{\in_m}{\in_0} = \dfrac{C_m}{C_0} = \dfrac{\phi_0}{\phi_m} = \dfrac{E_0}{E_m}$ | Unit less |
| Linear charge density | $\lambda = \dfrac{q}{L}$ | $Cm^{-1}$ |
| Surface charge density | $\sigma = \dfrac{q}{A}$ | $Cm^{-2}$ |
| Volume charge density | $\rho = \dfrac{q}{V}$ | $Cm^{-3}$ |
| Electric field due to a point charge | $\vec{E} = \underset{q_0 \to 0}{Lt} \dfrac{\vec{F}}{q_0}$ (theoretical) $\left(\text{In numerical, we use } E = \dfrac{kq_1}{r^2}\right)$ | |

| | | |
|---|---|---|
| The components of electric field, | $E_x = \frac{1}{4\pi\epsilon_0}\frac{q\hat{x}}{r^3}, E_y = \frac{1}{4\pi\epsilon_0}\frac{q\hat{y}}{r^3},$ $E_z = \frac{1}{4\pi\epsilon_0}\frac{q\hat{z}}{r^3}$ | $NC^{-1}$ |
| Torque on a dipole in a uniform electric field | $\vec{\tau} = \vec{p} \times \vec{E}$ (or $\tau = pE \sin\theta$) | Nm |
| Electric dipole moment | $\vec{p} = q\cdot(2\vec{a})$ or $\lvert\vec{p}\rvert = q(2a)$ | Cm |
| Potential energy of a dipole in a uniform electric field | $U = -\vec{p}\cdot\vec{E}$ (or $U = -pE\cos\theta$) | J |
| Electric field on axial line of an electric dipole | $E_{axial} = \frac{1}{4\pi\epsilon_0}\frac{2pr}{(r^2-a^2)^2}$ When $2a << r$, $E_{axial} = \frac{1}{4\pi\epsilon_0}\frac{2p}{r^3}$ | $NC^{-1}$ |
| Electric field on equatorial line of an electric dipole | $E_{equatorial} = \frac{1}{4\pi\epsilon_0}\frac{q2a}{(r^2+a^2)^{\frac{3}{2}}}$ When $2a << r$, $E_{equatorial}$ $= \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}$ | |
| Electric field as a gradient of potential | $E = -\frac{dV}{dr}$ or $\vec{E}\cdot d\vec{r} = -dV$ | |
| Electric potential differences between ponts A & B | $V_A - V_B = -\frac{W_{AB}}{q_0}$ | Volts (or $JC^{-1}$) |
| Electric potential at a point | $V_A = \frac{1}{4\pi\epsilon_0}\frac{q}{r_A} = \frac{W_{A\infty}}{q}$ | |

| | | |
|---|---|---|
| Common potential | $V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$ | |
| Electric potential due to a system of charges | $V = \dfrac{1}{4\pi \epsilon_0} \sum_{i=1}^{n} \dfrac{q_i}{r_i}$ | |
| Electric potential at any point due to an electric dipole | $V = \dfrac{1}{4\pi \varepsilon_0} \dfrac{p\cos\theta}{(r^2 - a^2\cos^2\theta)}$<br>When, $\theta = 0°$ or $\theta = 180°$,<br>$V = \dfrac{\pm 1}{4\pi \epsilon_0} \dfrac{p}{(r^2 - a^2)}$<br>If $r >> a$, $V = \dfrac{1}{4\pi \epsilon_0} \dfrac{p}{r^2}$<br>When, $\theta = 90°$, $V_{equi} = 0$ | |
| Total electric flux through a closed surface S | $\phi_e = \oint \vec{E} . d\vec{S} = \dfrac{q_{net}}{\epsilon_0}$<br>$q_{net}$ = Net charge enclosed by a<br>⇒ Gaussian surface | $Nm^2C^{-1}$ |
| Electric field due to line charge | $E = \dfrac{1}{2\pi \epsilon_0} \dfrac{\lambda}{r}$ | $NC^{-1}$ (or V/m) |
| Electric field due to an infinite plane sheet of charge | $E = \dfrac{\sigma}{2\epsilon_0}$ | |
| Electric field between two infinitely charged plane parallel sheets having change density +s and –s | $E = \dfrac{\sigma}{\epsilon_0}$ | |
| Electric field due to a uniformly charged spherical shell | $E = \dfrac{\sigma}{\epsilon_0} \dfrac{R^2}{r^2}$<br>When $r = R$, $E_0 = \dfrac{\sigma}{\epsilon_0}$<br>When $r < R$, $E \times 4\pi r^2 = 0$<br>$\therefore E = 0$ | |

| | | |
|---|---|---|
| Loss of energy (in Parallel compinaton of two capacitors | $\Delta U = \frac{1}{2}\frac{C_1C_2}{(C_1+C_2)}(V_1-V_2)^2$ | |
| Electrical capacitance | $C = \frac{q}{V}$ | F(SI Unit) |
| Capacitance of an isolated sphere | $C_0 = 4\pi\in_0 r$ | |
| Capacitance of a parallel plate | $C = \frac{A\in_0}{d}$ | |
| Capacitors in series | $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ | |
| Capacitors in parallel | $C = C_1 + C_2 + C_3$ | |
| Capacitance of a parallel plate capacitor with dielectric slab between plates | $C = \frac{\in_0 A}{d - t\left(1 - \frac{1}{K_D}\right)}$ | |
| Capacitance of a parallel plate capacitor with conducting slab between plates | $C = \frac{C_0}{\left(1 - \frac{t}{d}\right)}$ | |
| Energy stored in a charged capacitor | $U = \frac{q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}qV$ | J |
| Resultant electric field in a polarised dielectric slab | $\vec{E} = \vec{E}_0 - \vec{E}_p$, where | $Cm^{-1}$ |
| | $\overline{E}_0$ = Applied electric field and | |
| | $\overline{E}_p$ = Electric field due to | |
| polarization | | |
| Polarization density | $P = \in_0 \chi E$ | $Vm^{-1}$ or $Nc^{-1}$ |
| Dielectric constant (in terms of electric susceptibility or atomic polarisability) | $K_D = 1 + \chi$ Where K is dieletric Contant | |

# CURRENT ELECTRICITY
# IMPORTANT FORMULA

| | | |
|---|---|---|
| 1. Drift Velocity | $\vec{v}_d = -\frac{e\vec{E}}{m}\tau$ | $\vec{E}$ – electric fluid |
| | | $\tau$ = Relaxation time |
| 2. Relation b/w current and Drift Velocity | $I = neA\upsilon_d$ | $e$ = charge on electrons.<br>$m$ = mass of electron<br>$n$ = number density of electrons |
| 3. Ohm's Law | $V = RI$ | A = Cross Section Area |
| 4. Resistance | $R = \frac{\rho l}{A}$ | V = potential difference across conductor |
| 5. Specific Resistance or Resistivity | $\rho = \frac{RA}{l} = \frac{m}{ne^2\tau}$ | $l$ = length of conductor |
| 6. Current density | $j = I/A = neV_d$ | |
| 7. Electrical Conductivity | $\sigma = 1/\rho$ | |
| 8. Resistances in Series | $R_{eq} = R_1 + R_2 + R_3$ |  |
| Parallel Combination | $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ |  |
| 9. Temperature Dependance of Resistance | $R_t = R_0(1 + \alpha t)$ | $R_t$ = Resistance at $t$°C<br>a = Cofficent of temprature<br>$t$ = Temperature |
| 10. Internal Resistance of a cell | $r = \left(\frac{E}{V} - 1\right)R$ | $R_o$ = Resistance at 0°C |
| 11. Power | $P = VI = I^2R = \frac{V^2}{R}$ | |
| 12. Cells in Series | $Eq = E_1 + E_2$ |  |
| Equivalent emf | $Eeq = E_1 - E_2$ | $E_1 > E_2$  |
| Equivalent Internal Resistance | $r_{eq} = r_1 + r_2$ | $E_1$ & $E_2$ are emf of two cells |
| Mobility ( $\mu$ ) | $\frac{v_d}{E}$ | CGS unit $\rightarrow Cm^2s^{-1}v^{-1}$<br>SI unit $\rightarrow M^2s^{-1}s^{-}v^{-1}$ |

| | | |
|---|---|---|
| | | $r_1$ and $r_2$ are their internal resistances respectively |
| Equivalent Current | $I = \frac{nE}{R + nr}$ | $n$ = no. of cells in series. |
| 13. Cells in parallel | Equivalent e.m.f. $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ | |
| | Equivalent resistance $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$ | |
| Equivalent Current | $I = \frac{mE}{mR + r}$ | $m$ = number of cells in parallel |
| 14. Kirchoff's Laws | $\Sigma i = o$ (at a junction) | $i$ = Current |
| | $\Sigma i R = \Sigma E$ or $\Sigma i R = 0$ | R = Resistance |
| | (in a closed loop) | |
| | | E = e.m.f. |
| 15. Wheatstone Bridge (balanced condition) | $\frac{P}{Q} = \frac{R}{S}$ | P, Q, R and S are resistances in Ohm in four arms of Wheatstone Bridge. |
| 16. Slide wire Bridge or metre Bridge | $S = \left(\frac{100 - l}{l}\right) R$ | |
| 17. Potentiometer | | |
| Comparison of Emf | $\frac{E_1}{E_2} = \frac{l_1}{l_2}$ | $l_1$ and $l_2$ are balancing lengths on potentiometer wire for cells $E_1$ and $E_2$ |
| Internal Resistance | $r = \left(\frac{l_1 - l_2}{l_2}\right) R$ $= \left(\frac{E}{V} - 1\right) R$ | $l_1$ and $l_2$ are balancing lengths on potentiometer wire for emt E and Pot. diff. V across R. |

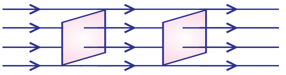
# UNIT–I & UNIT–II

# ELECTROSTATICS AND CURRENT ELECTRICITY

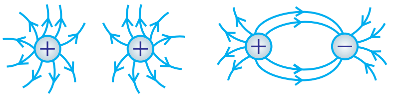
## QUESTIONS

## VERY SHORT ANSWER QUESTIONS (1 MARK)

1. Draw schematically an equipotential surface of a uniform electrostatic field along *x*-axis.

**Ans.** 

2. Sketch field lines due to (i) two equal positive charges near each other (ii) a dipole.

**Ans.** 

3. Name the physical quantity whose SI unit is volt/meter. Is it a scalar or a vector quantity ?

**Ans.** Electric field intensity. It is a vector quantity.

4. Two point charges repel each other with a force F when placed in water of dielectric constant 81. What will be the force between them when placed the same distance apart in air ?

**Ans.** $\in_r = \frac{F_0}{F_m} \Rightarrow F_0 = \in_r F_m \Rightarrow F_0 = 81 F_m$

5. Electric dipole moment of $CuSO_4$ molecule is $3.2 \times 10^{-28}$ Cm. Find the separation between copper and sulphate ions.

**Ans.** $p = q(2a) \Rightarrow$ Length of dipole $a = \frac{3.2 \times 10^{-28}}{2 \times 1.6 \times 10^{-19}} = 10^{-9}$ cm

6. Net capacitance of three identical capacitors connected in parallel is 12 microfarad. What will be the net capacitance when two of them are connected in (i) parallel (ii) series ?

**Ans.**

$$C_p = 12\mu f \Rightarrow C = \frac{12}{3} = 4\mu F.$$

$$C_p = C_1 + C_2 = 8\mu F$$

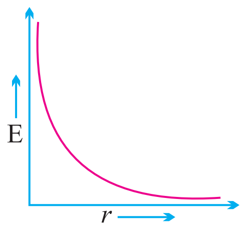
$$C_s = \frac{C_1C_2}{C_1+C_2} = \frac{16}{8} = 2\mu F$$

**7.** A charge $q$ is placed at the centre of an imaginary spherical surface. What will be the electric flux due to this charge through any half of the sphere.

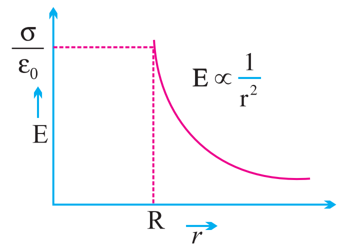
**Ans.**
$$\phi = \frac{q}{\epsilon_0}$$
$$\phi' = \frac{\phi}{2} = \frac{q}{2\epsilon_0}$$

**8.** Draw the electric field vs distance (from the centre) graph for (i) a long charged rod having linear charge density $\lambda > 0$ (ii) spherical shell of radius R and charge $Q > 0$.

**Ans.**



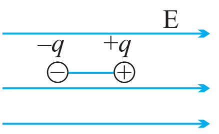

Linear Charge



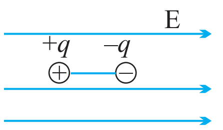

Charged conducting spherical shall

**9.** Diagrammatically represent the position of a dipole in (i) stable (ii) unstable equilibrium when placed in a uniform electric field.

**Ans.**




Stable equilibrium




Unstable equilibrium

**10.** A charge Q is distribution over a metal sphere of radius R. What is the electric field and electric potential at the centre ? **Ans.** $E = 0$, $V = kQ/R$

**Ans.** Electric field inside conductor $E = 0$

$$E = \frac{dV}{dr} = 0 \Rightarrow V = \text{Constant} = \frac{Q}{4\pi\epsilon_0 R} = k\frac{Q}{R}$$

**11.** If a body contains $n_1$ electrons and $n_2$ protons then what is the total charge on the body ?

**Ans.** $Q = q_1 + q_2 + .... + q_n$. (Additive property of charge)

$Q = (n_2 - n_1)e$

**12.** What is the total positive or negative charge present in 1 molecule of water.

**Ans.** $H_2O$ has 10 electrons (2 of hydrogen and 8 of oxygen)

Total charge = 10*e*

**13.** How does the energy of dipole change when it is rotated from unstable equilibrium to stable equilibrium in a uniform electric field.

**Ans.** Work done $= pE(\cos 180° - \cos 0°)$

$= -2pE$

*i.e.*, energy decreases.

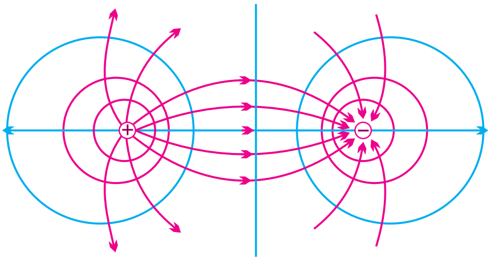
**14.** Write the ratio of electric field intensity due to a dipole at a point on the equatorial line to the field at a point on the axial line, when the points are at the same distance from the centre of dipole.

**Ans.** $E_{axial} = \dfrac{2kp}{r^3} \quad E_{equatorial} = \dfrac{kp}{r^3}$

$\therefore \quad E_{axial} = 2E_{equatorial}$

**15.** Draw equipotential surface for a dipole.

**Ans.**



**16.** An uncharged conductor A placed on an insulating stand is brought near a charged insulated conductor B. What happens to the charge and potential of B ?

**Ans.** Total charge = 0 + $q$ = $q$ remains same.

P. D. decreases due to induced charge on A.

**17.** A point charge Q is placed at point O shown in Fig. Is the potential difference $V_A - V_B$ positive, negative or zero, if Q is (i) positive (ii) negative charge.


**Ans.** $V_A - V_B > 0$ for $Q > 0$ and $V_A - V_B < 0$ for $Q < 0$

As electric field lines are in the direction of decreasing potential.

**18.** An electron and proton are released from rest in a uniform electrostatic field. Which of them will have larger acceleration ?

**Ans.** acceleration $= \dfrac{\text{force}}{\text{mass}}$, $m_p > m_e$

$a_p < a_e$

**19.** In an uniform electric field of strength E, a charged particle Q moves point A to point B in the direction of the field and back from B to A. Calculate the ratio of the work done by the electric field in taking the charge particle from A to B and from B to A.

**Ans.**
$$\frac{W_{AB}}{W_{BA}} = -1$$

$$\therefore \quad W_{AB} + W_{BA} = 0$$

$$|W_{AB}| = |-W_{BA}|$$

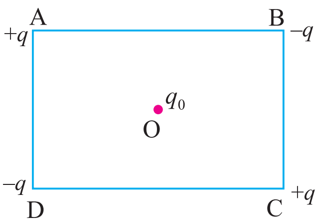
**20.** If a dipole having charge $\pm 2\mu C$ is placed inside a sphere of radius 2 m, what is the net flux linked with the sphere.

**Ans.** Net flux $= \dfrac{\text{Net charge}}{\epsilon_0} = \dfrac{+q-q}{\epsilon_0} = 0$

**21.** Four charges $+q, -q, +q, -q$ are placed as shown in the figure. What is the work done in bringing a test charge from $\infty$ to point 0.

Here, OA = OB = OC = OD

& $q_0$ = Test charge




**Ans.**
$$V_0 = \frac{kq}{AO} + \frac{kq}{OC} - \frac{kq}{OB} - \frac{kq}{OD} = 0$$

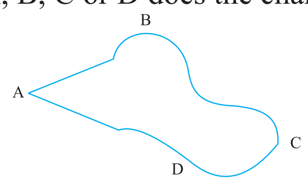
$$W = q_0 \times V_0 = 0$$

**22.** Calculate electric flux linked with a sphere of radius 1m and charge of 1C at its centre.

**Ans.** Electric flux linked with the sphere (closed surface)

$$\phi_e = \frac{q}{\epsilon_0} = \frac{1}{\epsilon_0}$$

**23.** If the metallic conductor shown in the figure is continuously charged from which of the points A, B, C or D does the charge leak first. Justify.



**Ans.** Charge leaks from A first as surface charge density (σ) at A (sharp ends) is more.

**24.** What is dielectric strength ? Write the value of dielectric strength of air.

**Ans.** Maximum electric field which can be safely applied across a dielectric before its break down is called dielectric strength.

Dielectric strength of air = $3 \times 10^6$ V/m.

**25.** Two charges – $q$ and + $q$ are located at points A (0, 0, – $a$) and B (0, 0, + $a$). How much work is done in moving a test charge from point ($b$, 0, 0) to Q (– $b$, 0, 0) ?

**Ans.** $W = \vec{F} \cdot \vec{dr} = q\vec{E} . \vec{dr} = q\ Edr \cos 90° = 0$

∴ E along equitorial line of dipole is anti-parallel to dipole moment, hence perpendicular to displacement or $W = 20 \times q_0 \times V_{equatorial} = q_0 \times 0 = 0$ J.

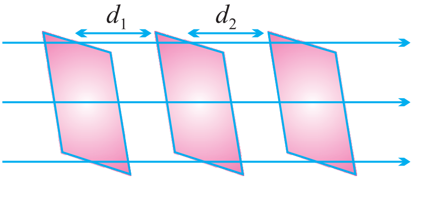
**26.** If an electron is accelerated by a Potential difference of 1 Volt, Calculate the gain in energy in Joule and electron volt.

**Ans.** Gain in Energy = eV = $1.6 \times 10^{-19} \times 1 = 1.6 \times 10^{-19}$ J

or $\Delta KE = 1e \times 1$ volt $= 1.6 \times 10^{-19}$ C $\times 1$ volt $= 1.6 \times 10^{-19}$J

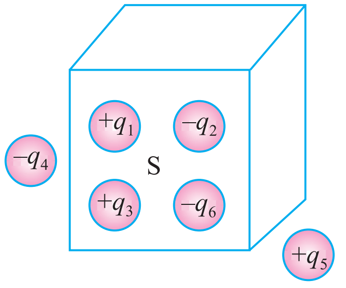
**27.** Draw schematically the equipotential surface corresponding to a field that uniformly increases in magnitude but remains in a constant (say $z$) direction.

**Ans.**




E increases therefore, equipotential surface are closer *i.e.*, $d_1 > d_2$.

**28.** Figure shows six charged lumps of plastic coin. The cross-section of a Guassian surface S is indicated. What is the net electric flux through the surface ?




**Ans.** $$\phi = \frac{+q_1}{\epsilon_0}\frac{-q_2}{\epsilon_0}\frac{+q_3}{\epsilon_0} - \frac{q_4}{\epsilon_0}.$$

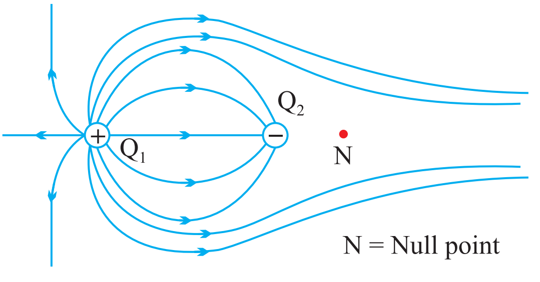
**29.** Without referring to the formula $C = \epsilon_0 A/d$. Explain why the capacitance of a parallel plate capacitor reduces on increasing the separation between the plates ?

**Ans.** $$\text{P. D.} = V = E \times d$$

'$d$' increases hence V increases.

as $C = \frac{Q}{V}$, $\therefore$ C decreases.

**30.** Draw field lines to show the position of null point for two charges $+Q_1$ and $-Q_2$ when magnitude of $Q_1 > Q_2$ and mark the position of null point.



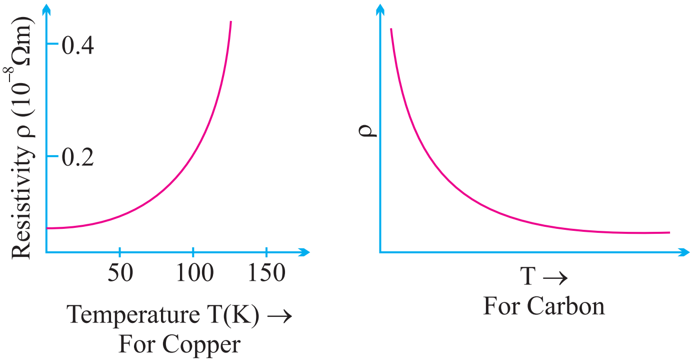

**Ans.** $|Q_1| > |Q_2|$, N is the neutral point.

**31.** How does the relaxation time of electron in the conductor change when temperature of the conductor decreases.

**Ans.** When temperature of the conductor decreases, ionic vibration in the conductor decreases so relaxation time increases.

**32.** Sketch a graph showing variation of resistivity with temperature of (i) Copper (ii) Carbon.

**Ans.**



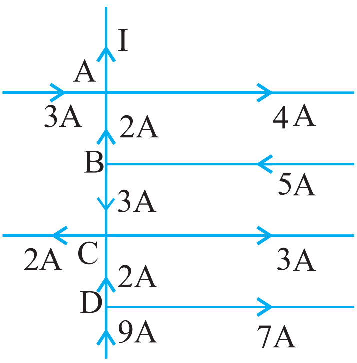

**33.** The emf of the driver cell (Auxiliary battery) in the potentiometer experiment should be greater than emf of the cell to be determined. Why ?

**Ans.** If emf of a driver cell is less, then null point will not be obtained on the potentiometer wire.

**34.** You are required to select a carbon resistor of resistance $47k\Omega \pm 10\%$ from a large collection. What should be the sequence of color bands used to code it ?

**Ans.** Yellow, Violet, Orange, Silver.

**35.** Find the value of *i* in the given circuit :




**Ans.** On applying Kirchoff current law on junction A, at junction A

$$2 + 3 = I + 4$$

so, $I = +\,1A$

**36.** Two wire one of copper and other of manganin have same resistance and equal length. Which wire is thicker ?

**Ans.** $R = \rho_c \dfrac{l_c}{A_c} = \rho_m \dfrac{l_m}{A_m} \Rightarrow \dfrac{\rho_c}{\rho_m} = \dfrac{A_c}{A_m} < 1$

$\therefore$ Manganin is thicker.

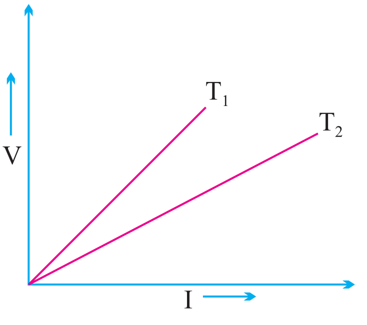
**37.** You are given three constants wires P, Q and R of length and area of cross-section (L, A), $\left(2L, \frac{A}{2}\right), \left(\frac{L}{2}, 2A\right)$ respectively. Which has highest resistance ?

**Ans.** $R_P = \rho\frac{L}{A}, \; R_Q = \frac{\rho(2L)}{\frac{A}{2}} = \frac{4\rho L}{A}$

$\Rightarrow R_R = \frac{\rho L}{4A} \Rightarrow R_Q = 4R_P, \; R_R = \frac{1}{4}R_P$

Q has the highest resistance,

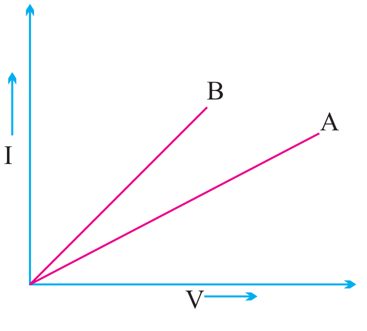
**38.** V – I graph for a metallic wire at two different temperatures $T_1$ and $T_2$ is as shown in the figure. Which of the two temperatures is higher and why ?




**Ans.** Slope of $T_1$ is large, so $T_1$ represents higher temperature as resistance increases with temperature for a conductor

$$R = \frac{V}{I} = \text{slope.}$$

**39.** Out of V – I graph for parallel and series combination of two metallic resistors, which one represents parallel combination of resistors ? Justify your answer.



**Ans.** The resistance for parallel combination in lesser than for series combination for a given set of resistors. Hence B represents parallel combination sinc $\frac{I}{V}$ is more. Hence Resistance = $\frac{V}{I}$ is less.

**40.** Why is the potentiometer preferred to a voltmeter for measuring emf of a cell ?

**Ans.** Emf measured by the potentiometer is more accurate than cell because the cell is in open circuit giving no current.

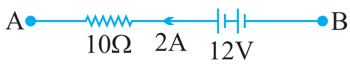
**41.** How can a given 4 wires potentiometer be made more sensitive ?

**Ans.** By connecting a resistance in series with the potentiometer wire in the primary circuit, the potential drop across the wire is reduced.

**42.** Why is copper not used for making potentiometer wires ?

**Ans.** Copper has high temperature coefficient of resistance and hence not preferred.

**43.** In the figure, what is the potential difference between A and B ?



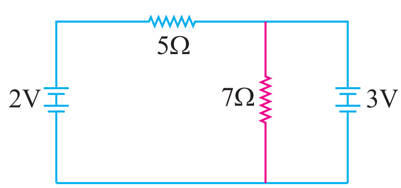

**Ans.** $V_A - V_B = -8$ volt.

**44.** A copper wire of resistance R is uniformally stretched till its length is increased to $n$ times its original length. What will be its new resistance ?

**Ans.** $$R' = n^2R$$

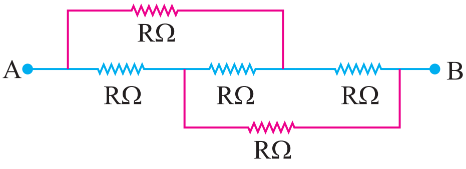
$\therefore$ $$R' = \rho\frac{nL}{A/n} = \rho n^2\frac{I}{A} = n^2R$$

**45.** Two resistance 5Ω and 7Ω are joined as shown to two batteries of emf 2V and 3V. If the 3V battery is short circuited. What will be the current through 5Ω

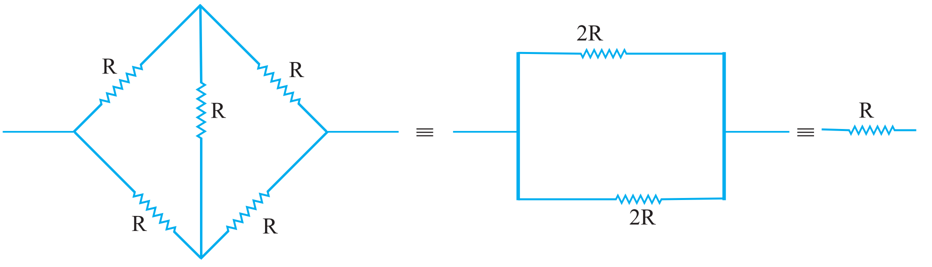



**Ans.** $I = \frac{2}{5}A.$

**46.** Calculate the equivalent resistance between points A and B in the figure given below.




**Ans.** We obtain using wheatstone bridge balencing condition.




**47.** What is the largest voltage that can be safely put across a resistor marked 196Ω, 1W ?

**Ans.** $P = \frac{V^2}{R}, V^2 = P\,R = 1 \times 196 = 196$

$$V = 14 \text{ Volt.}$$

**48.** When does the terminal voltage of a cell become (i) greater than its emf (ii) less than its emf ?

**Ans.** (i) When the cell is being charged terminal potential difference (V) becomes greater than emf (E), $V = E + Ir$

(ii) When the cell is discharged, then $V < E$

$$V = E - I\,r$$

**49.** A car battery is of 12V. Eight dry cells of 1.5 V connected in series also give 12V, but such a combination is not used to start a car. Why ?

**Ans.** Dry cell used in series will have high resistance (= 10Ω) and hence provide low current, while a car battery has low internal resistance (0. 1Ω) and hence gives high current for the same emf, needed to start the car.

**50.** Two electric lamps A and B marked 220 V, 100W and 220V, 60W respectively. Which of the two lamps has higher resistance ?

**Ans.** As $R = \frac{V^2}{P}$, 220 V, 60 W lamp has higher resistance.

**51.** Resistors of high value are made up of carbon. Why ?

**Ans.** High resistivity and low temperature Coefficient of resistance.

**52.** Draw graph showing the variation of electronic field & electronic potential with distances '*r*' due to a point change.

**53.** Net capacitance of three identical capacitors in series is 1μF. What will be their net capacitance if connected in parallel. Find the raio of energy stored in two combinations connected across the same battery.

**54.** Distinguish with the help of a suitable diagram,the difference in the behaviour of conductor and a dielectric substance placed in an external electric field. How does the polarised dielectric modifies the external field.

**55.** A parallel plate capacitor of capacitance C is charged to a potential of V volt. It is then connected across another uncharged capacitor of same capacitance .Find the ratio of initial energy of single capacitor to the final energy combination . **[Ans -2:1]**

**56.** An infinite large plane thin charged sheet has surface charge density σ. Obtain an expression for work done in carrying a point charge q from finity to a point at a distance

**57.** A proton and a alpha particle are accelerated from rest through a potential difference of 100 volt. Find (i) Their KE in eV and Joule (ii) which particle will move faster.

**[Ans: (1) 100 eV, 200 eV, 1.6 x $10^{-17}$J, 3.2x $10^{-17}$J (ii) Proton]**

**58.** An electron starting from rest takes $14\times10^{-9}$ sec to reach from one plate to other of a capacitor placed 2 cm apart. If charge to mass ratio of electron is $1.8\times10^{11}$ *CI* kg. Then find the potential difference between the plates.

**[Ans: V = 2400 Volt]**

**59.** An alpha particle of charge $3.2\times10\text{-}^{19}$ cm/sec and mass $6.8\times10^{-27}$Kg is initially moving at speed $10^7$ when it is at far distance from another fixed point charge $112\times10^{-19}$C. Find the distance of closest approach.

**[Ans: r = 9.4×10-15 m]**

**60.** If the dielectric strength of air is $3\times10^6$ *V /m*, what will be the maximum potential at the surface of a metal sphere of radius 1m.

[**Ans:** V = 3×106 Volt]

**61.** Two point charge each +3 μC are placed along the diameter of a circle of radius 15 cm. Calculate the ectric potential at the ends of perpendicular diameter [**Ans:** V = $2.52\times10^5$ Volt]

**62.** An electric dipole of dipole moment $40\times10^{-6}$C-m is enclosed by a closed surface. What is the net flux coming out of the surface? [**Ans:** zero]

**63.** Does the charge given to a metallic sphere depend on whether it is solid or hollow .Give reason.

**[Ans: Charge comes on the outer surface only, like charges repel and conductor allows flow of charge]**

**64.** A and B are two conducting spheres of the same radius, A being solid and B hollow. Both have same field on their surface. What will be the relation between the charges on the two spheres? **[Ans: Same]**

**65.** How does the electric flux due to a point charge enclosed by a spherical gaussian surface is affected ,if radius is increased

**[Ans: remains same as it does not depend upon shape and size of Gaussian surface]**

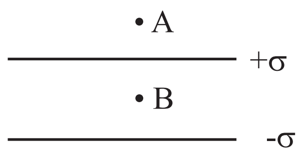
**66.** How does the Coulomb force between two point charges depend upon the dielectric constant of the intervening medium?

**[Ans: It decreases with increasing dielectric constant of medium]**

**67.** The distance of the field point, on the equatorial plane of a small electric dipole, is halved. By what factor will the electric field, due to the dipole, change? [**Ans:** As E oc $1/r^3$, 8 times]

**68.** Two plane sheets of charge densities $+\sigma$ and $-\sigma$ are kept in air as shown in figure.What are the electric field intensities at points A and B?

[Ans: zero, $\sigma/\varepsilon_0$]



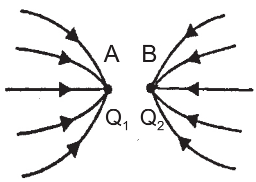

**69.** Why does the electric field inside a dielectric decrease when it is `aced in an external electric field?

**[Ans: Due to induced field is opposite direction]**

**70.** A charge Q is uniformly distributed over a ring of radius a.Obtain an expression for electric field intensity at a point on the axis of ring. show that at far point ring behaves as a point charge.

**71.** Figure shows electric lines of force due to two point charges $q_1$ and $q_2$ placed at points A and B respectively. Write the nature of charge on them.

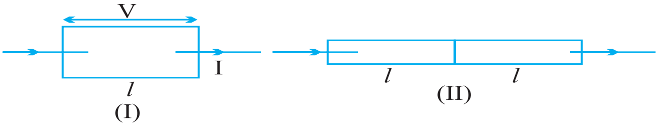
**[Ans: $Q_1$ <0, $Q_2$ < 0]**



**72.** Two points charges $q_1$ and $q_2$ are placed close to each other. What is the nature of force between the charges when $q_1 < 0, q_2 > 0$, $q_1 < 0, q_2 < 0$

**[Ans: Attractive, repulsive]**

**73.** A metal rod of square cross-section area A having length $l$ has current I flowing through it, when a potential difference of V volt is applied across its ends (figure I). Now the rod is cut parallel to its length in two Identical pieces and joined as shown in (figure-II). What potential difference must be maintained across the length $2l$ so that the current in the rod is still remains I ?




**Ans.**

$$R_1 = \rho \frac{l}{A}$$

$$R_2 = \rho \frac{2l}{A/2} = 4R_1$$

$$I = \frac{V}{R_1} = \frac{V_2}{R_2}$$

$$\frac{V}{R_1} = \frac{V_2}{4R_1}$$

$$V_2 = 4V$$

**74.** (a) Define torque acting on a dipole moment $\vec{p}$ Placed in a uniform electric field $\vec{E}$. Express it in the vector form and point out the direction along which it acts.

(b) What happens if the electric field is non-uniform ?

(c) What would happen if the external field $\vec{E}$ is increasing (i) Parallel to $\vec{p}$ (ii) anti-parallel to $\vec{p}$ ?

**75.** State the condition under which the terminal potential difference across a battery and its emf are equal.

**Ans.** When battery is in open circuit *i.e.* when no current is being drawn from the cell. $V_{open}$ = emf of cell or battery

**76.** State the condition for maximum current to be drawn from a cell.

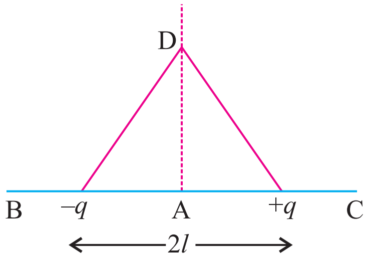
**Ans.** $I = \frac{E}{R + r}$ for I maximum R = 0 *i.e.*, for maximum current the terminals of a cell must be short circuited.

## SHORT ANSWER QUESTIONS (2 MARKS)

1. An oil drop of mass *m* carrying charge – Q is to be held stationary in the gravitational field of the earth. What is the magnitude and direction of the electrostatic field required for this purpose ? **Ans.** E = mg/Q, downward
2. Draw E and V versus *r* on the same graph for a point charge.
3. Find position around dipole at which electric potential due to dipole is zero but has non zero electric field intensity.

   **Ans.** Equitorial position, V = 0, $\vec{E} = \frac{-1}{4\pi \epsilon_0} \frac{\vec{p}}{r^3}$ (a << *r*)
4. Derive an expression for the work done in rotating an electric dipole from its equilibrium position to an angle θ with the uniform electrostatic field.
5. A electrostatic field line can not be discontinuous.Why ?
6. A thin long conductor has linear charge density of 20 μC/m. Calculate the electric field intensity at a point 5 cm from it. Draw a graph to show variation of electric field intensity with distance from the conductor.

   **Ans.** $72 \times 10^5$ N/C
7. What is the ratio of electric field intensity at a point on the equatorial line to the field at a point on axial line when the points are at the same distance from the centre of the dipole ? **Ans.** 1 : 2
8. Show that the electric field intensity at a point can be given as negative of potential gradient.
9. A charged metallic sphere A having charge $q_A$ is brought in contact with an uncharged metallic sphere of same radius and then separated by a distance *d*. What is the electrostatic force between them. **Ans.** $\frac{1}{16\pi\epsilon_0} \frac{q_A^2}{d^2}$
10. An electron and a proton travel through equal distances in the same uniform electric field E. Compare their time of travel. (Neglect gravity)
11. Two point charges – *q* and + *q* are placed 2*l* metre apart, as shown in Fig. Give the direction of electric field at points A, B, C and D, A is mid point between charges – *q* and + *q*.

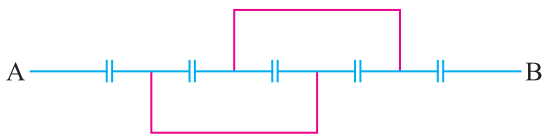



**12.** The electric potential V at any point in space is given $V = 20x^3$ volt, where $x$ is in meter. Calculate the electric intensity at point P (1, 0, 2).

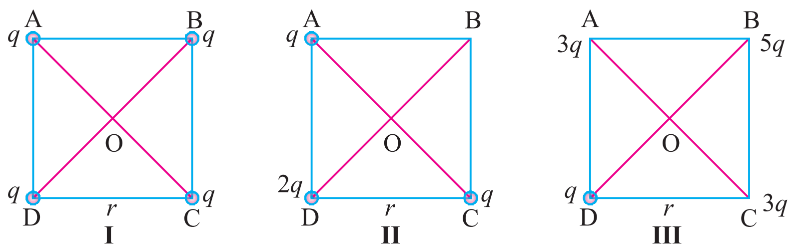
**Ans.** 60 $NC^{-1}$

**13.** Justify why two equipotential surfaces cannot intersect.

**14.** Find equivalent capacitance between A and B in the combination given below : each capacitor is of 2 μF. **Ans.** 6/7 μF




**15.** What is the electric field at O in Figures (i), (ii) and (iii), ABCD is a square of side $r$.




**Ans.** (i) Zero, (ii) $\frac{2q}{4\pi\varepsilon_0 r^2}$ along OB (iii) $\frac{4q}{4\pi\varepsilon_0}$ $r^2$ along OD

**16.** What should be the charge on a sphere of radius 4 cm, so that when it is brought in contact with another sphere of radius 2 cm carrying charge of 10 μC, there is no transfer of charge from one sphere to other ?

**Ans.** $Va = Vb$, Q = 20μC.

**17.** For an isolated parallel plate capacitor of capacitance C and potential difference V, what will be change in (i) charge on the plates (ii) potential difference across the plates (iii) electric field between the plates (iv) energy stored in the capacitor, when the distance between the plates is increased ?

**Ans.** (i) No change (ii) increases (iii) No change (iv) increases.

**18.** Does the maximum charge given to a metallic sphere of radius R depend on whether it is hollow or solid ? Give reason for your answer.

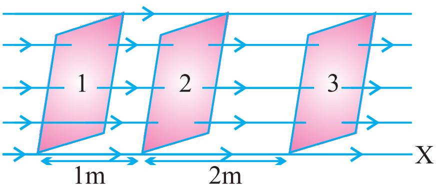
**Ans.** No, charge resides on the surface of conductor.

**19.** Two charges $Q_1$ and $Q_2$ are separated by distance *r*. Under what conditions will the electric field be zero on the line joining them (i) between the charges (ii) outside the charge?

**Ans.** (i) Charge are alike (ii) Unlike charges of unequal magnitude.

**20.** Obtain an expression for the electric field due to electric dipole at any point on the equatorial line.

**21.** The electric field component in the figure are $\vec{E}_x = 2x\hat{i}$, $\vec{E}_y = E_z = 0$. Calculate the electric flux through, (1, 2, 3) the square surfaces of side 5 m.




**22.** Calculate the work required to separate two charges 5μ*c* and – 2μ*c* placed at (– 3 cm, 0, 0) and (+ 3 cm, 0, 0) infinitely away from each other.

**Ans.** 1.5 J

**23.** What is electric field between the plates with the separation of 2 cm and (i) with air (ii) dielectric medium of dielectric constant K. Electric potential of each plate is marked in the following figure.

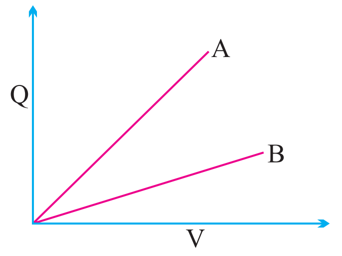
______________ 150 V

(i) ______________ – 50 V

**Ans.** $E_0 = 10^4\ NC^{-1}$, $E = \frac{10^4}{k} NC^{-1}$

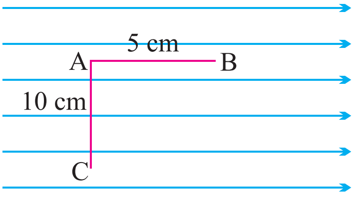
**24.** A RAM (Random access Memory) chip a storage device like parallel plate capacitor has a capacity of 55pF. If the capacitor is charged to 5.3V, how may excess electrons are on its negative plate ? **Ans.** $1.8 \times 10^9$

**25.** The figure shows the Q (charge) versus V (potential) graph for a combination of two capacitors. identify the graph representing the parallel combination.




**Ans.** A represents parallel combination

**26.** Calculate the work done in taking a charge of 1 μC in a uniform electric field of 10 N/C from B to C given AB = 5 cm along the field and AC = 10 cm perpendicular to electric field.




**Ans.** $W_{AB} = W_{BC} = 50 \times 10^{-8}$ J. $W_{AC} = 0$J

**27.** Two charges $-q$ and $+q$ are located at points A $(0, 0, -a)$ and B $(0, 0, +a)$ respectively. How much work is done in moving a test charge from point P (7, 0, 0) to Q (– 3, 0, 0) ? (zero)

**28.** The potential at a point A is – 500 V and that at another point B is + 500 V. What is the work done by external agent to take 2 units (S.I.) of negative charge from B to A. $W_{BA} = 2000$ J

**29.** How does the (i) Potential energy of mutual interaction (ii) net electrostatic P.E. of two charges change when they are placed in an external electric field.

**30.** With the help of an example, show that Farad is a very large unit of capacitance.

**31.** What is meant by dielectric polarisation ? Why does the electric field inside a dielectric decreases when it in placed in an external field ?

**32.** In charging a capacitor of capacitance C by a source of emf V, energy supplied by the sources QV and the energy stored in the capacitor is ½QV. Justify the difference.

**33.** An electric dipole of dipole moment $p$, is held perpendicular to an electric field. If the dipole is released does it have (a) only rotational motion

(b) only translatory motion (c) both translatory and rotatory motion explain?

**34.** The net charge of a system is zero. Will the electric field intensity due to this system also be zero.

**35.** A point charge Q is kept at the intersection of (i) face diagonals (ii) diagonals of a cube of side *a*. What is the electric flux linked with the cube in (i) & (ii) ?

**36.** There are two large parallel metallic plates $S_1$ and $S_2$ carrying surface charge densities $\sigma_1$ and $\sigma_2$ respectively ($\sigma_1 > \sigma_2$) placed at a distance $d$ apart in vacuum. Find the work done by the electric field in moving a point charge $q$ a distance $a$ ($a < d$) from $S_1$ and $S_2$ along a line making an angle $\pi/4$ with the normal to the plates.

**37.** Define mobility of electron in a conductor. How does electron mobility change when (i) temperature of conductor is decreased (ii) Applied potential difference is doubled at constant temperature ?

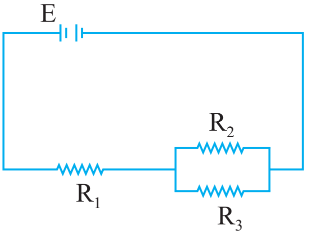
**38.** On what factor does potential gradient of a potentiometer wire depend ?

**39.** What are superconductors ? Give one of their applications.

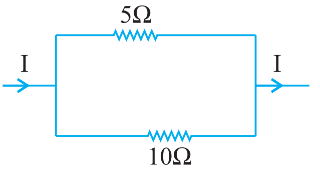
**40.** Two copper wires with their lengths in the ratio 1 : 2 and resistances in the ratio 1 : 2 are connected (i) in series (ii) in parallel with a battery. What will be the ratio of drift velocities of free electrons in two wires in (i) and (ii) ? **Ans.** (1 : 1, 2 : 1)

**41.** The current through a wire depends on time as $i = i_0 + at$ where $i_0 = 4A$ and $a = 2As^{-1}$. Find the charge crossing a section of wire in 10 seconds.

**42.** Three identical resistors $R_1$, $R_2$ and $R_3$ are connected to a battery as shown in the figure.What will be the ratio of voltages across $R_1$ and $R_2$. Support your answer with calculations. (2 : 1)




**43.** In the arrangement of resistors shown, what fraction of current I will pass through 5Ω resistor ? $\left(\frac{2I}{3}\right)$

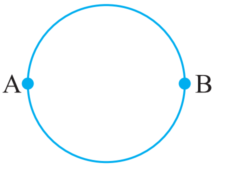



**44.** A 100W and a 200 W domestic bulbs joined in series are connected to the mains. Which bulb will glow more brightly ? Justify. (100W)

**45.** A 100W and a 200 W domestic bulbs joined in parallel are connected to the mains. Which bulb will glow more brightly ? Justify. (200W)

**46.** A battery has an emf of 12V and an internal resistance of 2Ω. Calculate the potential difference between the terminal of cell if (a) current is drawn from the battery (b) battery is charged by an external source.

**47.** A uniform wire of resistance R ohm is bent into a circular loop as shown in the figure. Compute effective resistance between diametrically opposite points A and B. **[Ans.** R/4]

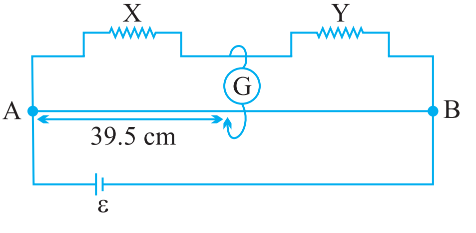



**48.** In a potentiometer arrangement, a cell of emf 1.25V gives a balance point at 35 cm length of the wire. If the cell is replaced by another cell, then the balance point shifts to 63 cm. What is the emf of the second cell ?

**[Ans.** 2.25V]

**49.** In a meter bridge, the balance point is found to be 39.5 cm from end A. The known resistance Y is 12.5Ω. Determine unknown resistance X.

**[Ans.** 8. 16Ω]




**50.** A meterbridge is in balance condition. Now if galvanometer and cell are interchanged, the galvanometer shows no deflection. Give reason.
**[Ans.** Galvanometer will show no deflection. Proportionality of the arms are retained as the galvanometer and cell are interchanged.]

**51.** If the emf of the driving cell be decreased. What will be effect on the position of zero deflection in a potentiometer.

**52.** Why should the area of cross section of the meter bridge wire be uniform ? Explain.

**53.** Given any two limitations of Ohm's law.

**54.** Which one of the two, an ammeter or a milliammeter has a higher resistance and why ?

**55.** Name two factors on which the resistivity of a given material depends ? A carbon resistor has a value of 62kΩ with a tolerance of 5%. Give the colour code for the resistor.

**56.** If the electron drift speed is so small (~ $10^{-3}$ m/s) and the electron's charge is very small, how can we still obtain a large amount of current in a conductor.

**57.** A battery of emf 2.0 volts and internal resistance 0.1Ω is being charged with a current of 5.0 A. What is the potential difference between the terminals of the battery ?


**58.** Why should the jockey be not rubbed against potentiometer wire ?

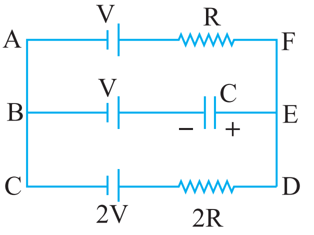
**59.** What is meant by the sensitivity of a potentiometer of any given length ?

**60.** Five identical cells, each of emf E and internal resistance *r*, are connected in series to form (a) an open (b) closed circuit. If an ideal voltmeter is connected across three cells, what will be its reading ?

[**Ans.** (a) 3E; (b) zero]

**61.** An electron in a hydrogen atom is considered to be revolving around a proton with a velocity $\frac{e^2}{n}$ in a circular orbit of radius $\frac{n^2}{me^2}$. If I is the equivalent current, express it in terms of *m, e, n*.

**62.** In the given circuit, with steady current, calculate the potential drop across the capacitor in terms of V.




**63.** A cell of e.m.f. 'E' and internal resistance '*r*' is connected across a variable resistor 'R'. Plot a graph showing the variation of terminal potential 'V' with resistance 'R'. Predict from the graph the condition under which 'V' becomes equal to 'E'.

**64.** Winding of rheostat wire are quite close to each other why do not they get short circuted ?

**Ans.** The wire has a coating of insulating oxide over it which insulate the winding from each other.

**65.** Why is it necessary to obtain the balance point in the middle of bridge wire ? Explain.

**66.** What are the possible cause of one side deflection in Galvanometer while performing potentiometer experiment ?

**Ans.** (i) Either +ve terminals of all the cells are not connected to same end of potentiometer.

or

(ii) The total potential drop across wire is less than the emf to be measured.

## SHORT ANSWER QUESTIONS (3 MARKS)

**1.** Define electrostatic potential and its unit. Obtain expression for electrostatic potential at a point P in the field due to a point charge.

**2.** Calculate the electrostatic potential energy for a system of three point charges placed at the corners of an equilateral triangle of side '*a*'.

**3.** What is polarization of charge ? With the help of a diagram show why the electric field between the plates of capacitor reduces on introducing a dielectric slab. Define dielectric constant on the basis of these fields.

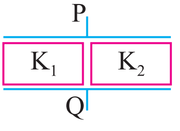
**4.** Using Gauss's theorem in electrostatics, deduce an expression for electric field intensity due to a charged spherical shell at a point (i) inside (ii) on its surface (iii) outside it. Graphically show the variation of electric field intensity with distance from the centre of shell.

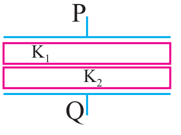
**5.** Three capacitors are connected first in series and then in parallel. Find the equivalent capacitance for each type of combination.

**6.** A charge Q is distributed over two concentric hollow sphere of radii *r* and R (R > *r*), such that their surface density of charges are equal. Find Potential at the common centre.

**7.** Derive an expression for the energy density of a parallel plate capacitor.

**8.** You are given an air filled parallel plate capacitor. Two slabs of dielectric constants $K_1$ and $K_2$ having been filled in between the two plates of the capacitor as shown in Fig. What will be the capacitance of the capacitor of initial area was A distance between plates *d* ?

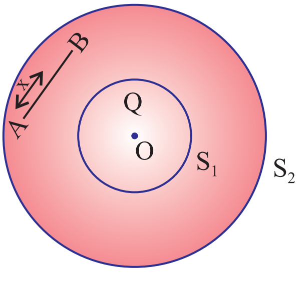



**Ans.** $C_1 = (K_1 + K_2)C_0$

$$C_2 = \frac{K_1K_2C_0}{(K_1 + K_2)}$$

**9.** In the figure shown, calculate the total flux of the electrostatic field through the sphere $S_1$ and $S_2$. The wire AB shown of length *l* has a liner charge density λ given λ = *kx* where *x* is the distance measured along the wire from end A.




**Ans.** Total charge on wire AB = $Q = \int_o^l \lambda dx = \int_o^l k\,x\,dx = \frac{1}{2}kl^2$

By Gauss's theorem.

Total flux through $S_1 = \frac{Q}{\epsilon_0}$

Total flux through $S_2 = \frac{Q + \frac{1}{2}kl^2}{\epsilon_0}$

**10.** Explain why charge given to a hollow conductor is transferred immediately to outer surface of the conductor.

**11.** Derive an expression for total work done in rotating an electric dipole through an angle $\theta$ in an uniform electric field. Hence calculate the potential energy of the dipole.

**12.** Define electric flux. Write its SI unit. An electric flux of f units passes normally through a spherical Gaussian surface of radius $r$, due to point charge placed at the centre.

(1) What is the charge enclosed by Gaussian surface ?

(2) If radius of Gaussian surface is doubled, what will be the flux through it ?

**13.** A conducting slab of thickness '$t$' is introduced between the plates of a parallel plate capacitor, separated by a distance $d$ ($t < d$). Derive an expression for the capacitance of the capacitor. What will be its capacitance when $t = d$ ?

**14.** If a dielectric slab is introduced between the plates of a parallel plate capacitor after the battery is disconnected, then how do the following quantities change.

(i) Charge

(ii) Potential

(iii) Capacitance

(iv) Energy.

**15.** What is an equipotential surface ? Write three properties Sketch equipotential surfaces of

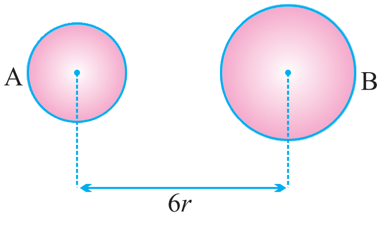
(i) Isolated point charge

(ii) Uniform electric field

(iii) Dipole

**16.** If charge Q is given to a parallel plate capacitor and E is the electric field between the plates of the capacitor the force on each plate is 1/2 QE and if charge Q is placed between the plates experiences a force equal to QE. Give reason to explain the above.

**17.** Two metal spheres A and B of radius $r$ and $2r$ whose centres are separated by a distance of $6r$ are given charge Q, are at potential $V_1$ and $V_2$. Find the ratio of $V_1/V_2$. These spheres are connected to each other with the help of a connecting wire keeping the separation unchanged, what is the amount of charge that will flow through the wire ?



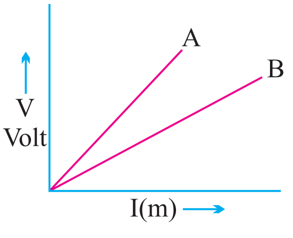

**18.** Define specific resistance. Write its SI unit. Derive an expression for resistivity of a wire in terms of its material's parameters, number density of free electrons and relaxation time.

**19.** A potential difference V is applied across a conductor of length L and diameter D. How are the electric field E and the resistance R of the conductor affected when (i) V is halved (ii) L is halved (iii) D is doubled. Justify your answer.

**20.** Define drift velocity. A conductor of length L is connected to a dc source of emf E. If the length of conductor is tripled by stretching it, keeping E constant, explain how do the following factors would vary in the conductor ?

(i) Drift speed of electrons (ii) Resistance and (iii) Resistivity

**21.** Define potential gradient. How can potential gradient of a potentiometers be determined experimentally. In the graph shown here, a plot of potential drop versus length of the potentiometer is made for two potentiometers. Which is more sensitive – A or B ?

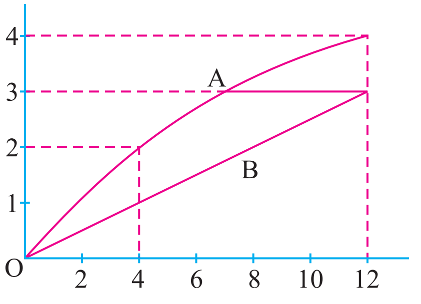


**22.** Define conductivity of a substance. Give its SI units. How does it vary with temperature for (i) Copper (ii) Silicon ?

**23.** Two cells of emf $E_1$ and $E_2$ having internal resistance $r_1$ and $r_2$ are connected in parallel. Calculate Eeq and req for the combination.

**24.** The graph A and B shows how the current varies wiht applied potential difference across a filament lamp and nichrome wire respectively. Using the graph, find the ratio of the values of the resistance of filament lamp to the nichrome wire

(i) when potential difference across them is 12 V.




(ii) when potential difference across them is 4V. Give reason for the change in ratio of resistance in (i) and (ii).

**25.** Electron drift speed is estimated to be only a few mm/s for currents in the range of few amperes ? How then is current established almost the instant a circuit is closed.

**26.** Give three differences between e.m.f. and terminal potential difference of a cell.

**27.** Define the terms resistivity and conductivity and state their S. I. units. Draw a graph showing the variation of resistivity with temperature for a typical semiconductor.

**28.** The current flowing through a conductor is 2mA at 50V and 3mA at 60V. Is it an ohmic or non-ohmic conductor ? Give reason.

**29.** Nichrome and copper wires of same length and area of cross section are connected in series, current is passed through them why does the nichrome wire get heated first ?

**30.** Under what conditions is the heat produced in an electric circuit :

(i) directly proportional

(ii) inversely proportional to the resistance of the circuit.

## LONG ANSWER QUESTIONS (5 MARKS)

**1.** Two charged capacitors are connected by a conducting wire. Calculate common potential of capacitors (ii) ratio of their charges at common potential. Show that energy is lost in this process.

**2.** Derive an expression for the strength of electric field intensity at a point on the axis of a uniformly charged circular coil of radius R carrying charge Q.

**3.** Derive an expression for potential at any point distant $r$ from the centre O of dipole making an angle $\theta$ with the dipole.

**4.** Suppose that three points are set at equal distance $r$ = 90 cm from the centre of a dipole, point A and B are on either side of the dipole on the axis (A closer to +ve charge and B closer to negative charge) point C which is on the perpendicular bisector through the line joining the charges. What would be the electric potential due to the dipole of dipole moment $3.6 \times 10^{19}$ Cm at points A, B and C ?

**5.** Derive an expression for capacitance of parallel plate capacitor with dielectric slab of thickness $t(t < d)$ between the plates separated by distance $d$. How would the following (i) energy (ii) charge, (iii) potential be affected (a) if dielectric slab is introduced with battery disconnected, (b) dielectric slab is introduced after the battery is connected.

**6.** Derive an expression for torque experienced by dipole placed in uniform electric field. Hence define electric dipole moment.

**7.** State Gauss's theorem. Derive an expression for the electric field due to a charged plane sheet. Find the potential difference between the plates of a parallel plate capacitor having surface density of charge $5 \times 10^{-8}$ $Cm^{-2}$ with the separation between plates being 4 mm.

**8.** Define current density. Give its SI unit. Whether it is vector or scalar ? How does it vary when (i) potential difference across wire increases (ii) length of wire increases (iii) temperature of wire increases (iv) Area of cross-section of wire increases justify your answer.

**9.** Using Gauss's theorem obtain an expression for electric field intensity due to a plane sheet of charge. Hence obtain expression for electric field intensity in a parallel plate capacitor.

**10.** Write any four important results regarding electro statics of conductors.

**11**. State Kirchhoffs's rules for electrical networks. Use them to explain the principle of Wheatstone bridge for determining an unknown resistance. How is it realized in actual practice in the laboratory ? Write the formula used.

**12.** Define emf and terminal potential difference of a cell. When is the terminal charging potential difference greater than emf ? Explain how emf and terminal potential difference can be compared using a potentiometer and hence determine internal resistance of the cell.

**13.** For three cells of emf $E_1$, $E_2$ and $E_3$ with internal resistance $r_1$, $r_2$, $r_3$ respectively connected in parallel, obtain an expression for net internal resistance and effective current. What would be the maximum current possible if the emf of each cell is E and internal resistance is $r$ each ?

**14.** Derive an expression for drift velocity of the electron in conductor. Hence deduce ohm's law.

**15.** State the principle of potentiometer. How can it be used to :

(i) Compare e.m.f. of two cells

(ii) Measure internal resistance of a cell ?

**16.** Explain how does the conductivity of a :

(i) Metallic conductor

(ii) Semi conductor and

(iii) Insulator varies with the rise of temperature.

**17.** Derive expression for equivalent e.m.f. and equivalent resistance of a :

(a) Series combination

(b) Parallel combination

of three cells with e.m.f. $E_1$, $E_2$, $E_3$ & internal resistances $r_1$, $r_2$, $r_3$ respectively.

**18.** Deduce the condition for balance in a Wheatstone bridge. Using the principle of Wheatstone bridge, describe the method to determine the specific resistance of a wire in the laboratory. Draw the circuit diagram and write the formula used. Write any two important precautions you would observe while performing the experiment.

## NUMERICALS

**1.** What should be the position of charge $q = 5\mu C$ for it to be in equilibrium on the line joining two charges $q_1 = -4\ \mu C$ and $q_2 = 16\ \mu C$ separated by 9 cm. Will the position change for any other value of charge $q$ ? (9 cm from – 4 μC)

**2.** Two point charges 4e and e each, at a separation $r$ in air, exert force of magnitude F. They are immersed in a medium of dielectric constant 16. What should be the separation between the charges so that the force between them remains unchanged. (1/4 the original separation)

**3.** Two capacitors of capacitance 10 μF and 20 μF are connected in series with a 6V battery. If E is the energy stored in 20 μF capacitor what will be the total energy supplied by the battery in terms of E. (6E)

**4.** Two point charges 6 μC and 2 μC are separated by 3 cm in free space. Calculate the work done in separating them to infinity. (3. 6 joule)

**5.** ABC is an equilateral triangle of side 10 cm. D is the mid point of BC charge 100 μC,– 100μC and 75 μC are placed at B, C and D respectively. What is the force experienced by a 1 μC positive charge placed at A ?

$$(90\sqrt{2} \times 10^3\ N)$$

**6.** A point charge of 2 μC is kept fixed at the origin. Another point charge of 4 μC is brought from a far point to a distance of 50 cm from origin. (a) Calculate the electrostatic potential energy of the two charge system. Another charge of 11 μC is brought to a point 100 cm from each of the two charges. What is the work done ? (a) $144 \times 10^{-3}$ J

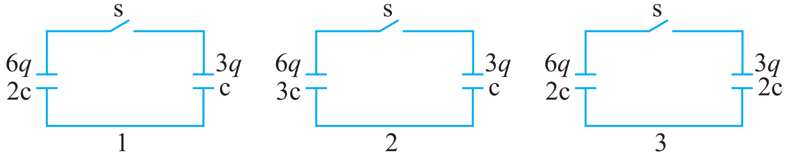
**7.** A 5 MeV α particle is projected towards a stationary nucleus of atomic number 40. Calculate distance of closest approach. $(1.1 \times 10^{-4}$ m)

8. To what potential must a insulated sphere of radius 10 cm be charged so that the surface density of charge is equal to 1 μC/m². ($1.13 \times 10^4$V)

9. A slab of material of dielectric constant K has the same area as the plates of parallel plate capacitor but its thickness is $\frac{3d}{4}$, where $d$ is separation between plates, How does the capacitance change when the slab is inserted between the plates ?

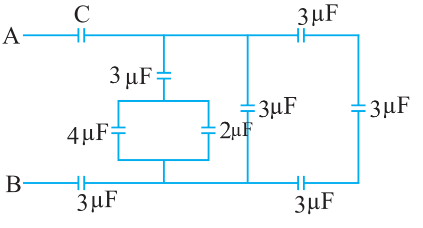
10. A point charge developes an electric field of 40 N/C and a potential difference of 10 J/C at a point. Calculate the magnitude of the charge and the distance from the point charge. ($2.9 \times 10^{-10}$ C, 25 cm)

11. Figure shows three circuits, each consisting of a switch and two capacitors initially charged as indicated. After the switch has been closed, in which circuit (if any) will the charges on the left hand capacitor (i) increase (ii) decrease (iii) remain same ?




(1 remains unchanged, 2 increases, 3 decreases).

12. For what value of C does the equivalent capacitance between A and B is 1μF in the given circuit.




All capacitance given in micro farad **Ans.** 2 μF

13. A pendulum bob of mass 80 mg and carrying charge of $3 \times 10^{-8}$ C is placed in an horizontal electric field. It comes to equilibrium position at an angle of 37° with the vertical. Calculate the intensity of electric field. ($g$ = 10m/s²) ($2 \times 10^4$ N/C)

14. Eight charged water droplets each of radius 1 mm and charge $10 \times 10^{-10}$ C coalesce to form a single drop. Calculate the potential of the bigger drop.

(3600 V)

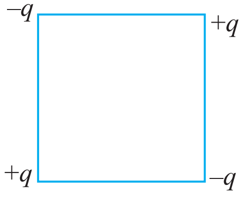
**15.** What potential difference must be applied to produce an electric field that can accelerate an electron to 1/10 of velocity of light. $(2.6 \times 10^3$ V)

**16.** A 10 μF capacitor can withstand a maximum voltage of 100 V across it, whereas another 20 μF capacitor can withstand a maximum voltage of only 25 V. What is the maximum voltage that can be put across their series combination ?

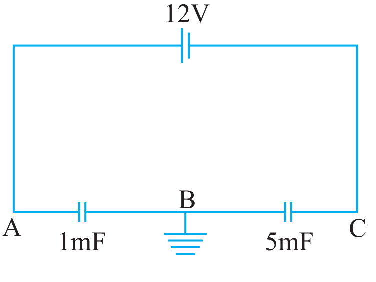
**17.** Three concentric spherical metallic shells A < B < C of radii *a, b, c* ($a < b < c$) have surface densities σ, – σ and σ respectively. Find the potential of three shells A, B and C (ii). If shells A and C are at the same potential obtain relation between *a, b, c*.

**18.** Four point charges are placed at the corners of the square of edge *a* as shown in the figure. Find the work done in disassembling the system of charges.

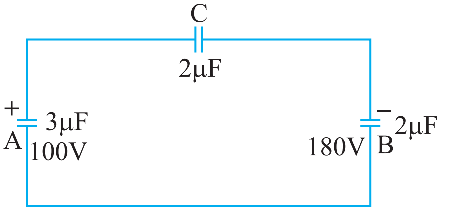
$\left[\frac{kq^2}{a}(\sqrt{2} - 4)\right]$ J



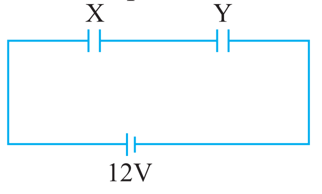

**19.** Find the potential at A and C in the following circuit :




**20.** Two capacitors A and B with capacitances 3 μF and 2 μF are charged 100 V and 180 V respectively. The capapitors are connected as shown in the diagram with the uncharged capacitor C. Calculate the (i) final charge on the three capacitors (ii) amount of electrostatic energy stored in the system before and after the completion of the circuit.



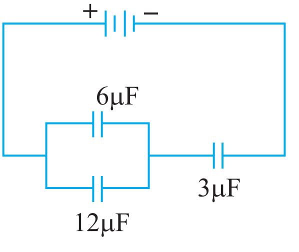

**21.** Fig. shows two parallel plate capacitors X and Y having same area of plates and same separation between them : X has air while Y has dielectric of constant 4 as medium between plates




(a) calculate capacitance of each capacitor, if equivalent capacitance of combination is 4μF (b) calculate potential difference between plate X and Y (c) what is the ratio of electrostatic energy stored in X & Y.

**Ans.** (a) 5μF, 20μF, (b) 9.6V, 2.4V (c) 4

**22.**




In the following arrangement of capacitors, the energy stored in the 6μF capacitor is E.

Find :

(i) Energy stored in 12 μF capacitors.

(ii) Energy stored in 3μF capacitor.

(iii) Total energy drawn from the battery.

**Ans.** (i) $E = \frac{1}{2}CV^2 = \frac{6}{2} \times 10^{-6}\, V^2 = 3 \times 10^{-6}\, V^2$

$$V^2 = \frac{E}{3 \times 10^{-6}}$$

Energy stored in 12μF capacitor = $\frac{1}{2}CV^2$

$$= \frac{1}{2} \times 12 \times 10^{-6} \times \frac{E}{3 \times 10^{-7}}$$

$$= 2E$$

(ii) Charge on 6μF capacitor $\left[\because E = \frac{1}{2}\frac{Q^2}{C}\right]$

$$Q_1 = \sqrt{2EC}$$

$$= 2\sqrt{3}E \times 10^{-3} C$$

Charge on 12μF capacitor

$$Q_2 = 2\sqrt{2CE}$$

$$= \sqrt{2 \times 12 \times 10^{-6} \times 2E}$$

$$= 4\sqrt{3E} \times 10^{-3} C$$

Charge on 3μF capacitor $Q = Q_1 + Q_2$

$$= 6\sqrt{3E} \times 10^{-3}$$

Energy stored in 3μF capacitor

$$= \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2} \times \frac{36 \times 3E \times 10^{-6}}{3 \times 10^{-6}}$$

$$= 18E$$

(ii) Capacitance of parallel combination = 18μF

Charge on parallel combination Q = CV

$$= 18 \times 10^{-6} V$$

$$\text{Charge on } 3\mu F = Q = 3 \times 10^{-6} V_1$$

$$18 \times 10^{-6} V = 3 \times 10^{-6} V_1$$

$$V_1 = 6V$$

Energy stored in 3μF capacitor = $\frac{1}{2}CV_1^2$

$$= \frac{1}{2} \times 3 \times 10^{-6} \times \frac{E \times 36}{3 \times 10^{-6}}$$

$$= 18E$$

(iii) Total eEnergy drawn = E + 2E + 18E = 21E

**23.** The charge passing through a conductor is a function of time and is given as $q = 2t^2 - 4t + 3$ milli coulomb. Calculate (i) current through the conductor (ii) potential difference across it at $t = 4$ second. Given resistance of conductor is 4 ohm. **Ans.** I = 12A, V = 48 V

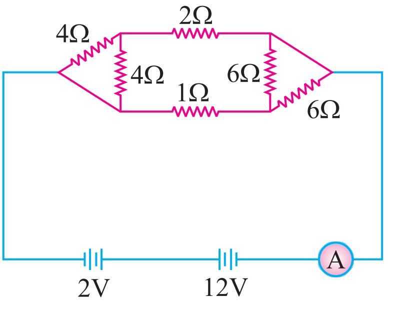
**24.** The resistance of a platinum wire at a point 0°C is 5.00 ohm and its resistance at steam point is 5.40Ω. When the wire is immersed in a hot oil bath, the resistance becomes 5.80Ω. Calculate the temperature of the oil bath and temperature coefficient of resistance of platinum.

**Ans.** *a* = 0.004°C; T = 200°C

**25.** Three identical cells, each of emf 2V and internal resistance 0.2 ohm, are connected in series to an external resistor of 7.4 ohm. Calculate the current in the circuit and the terminal potential difference across an equivalent.

**Ans.** I = 0.75; V = 5.55 V

**26.** Calculate the equivalent resistance and current shown by the ammeter in the circuit diagram given. **Ans.** R = 2Ω ; I = 5A




**27.** A storage battery of emf 12V and internal resistance of 1.5Ω is being charged by a 12V supply. How much resistance is to be put in series for charging the battery safely, by maintaining a constant charging current of 6A.

**Ans.** R = 16.5 Ω

**28.** Three cells are connected in parallel, with their like poles connected together, with wires of negligible resistance. If the emf of the cell are 2V, 1V and 4V and if their internal resistance are 4Ω, 3Ω and 2 Ω respectively, find the current through each cell. $\left[\textbf{Ans.}\ I_1 = \frac{-2}{13}A, I_2 = \frac{-7}{13}A,\ I_3 = \frac{9}{13}A\right]$

**29.** A 16 ohm resistance wire is bent to form a square. A source of emf 9 volt is connected across one of its sides. Calculate the potential difference across any one of its diagonals.

**Ans.** 1V

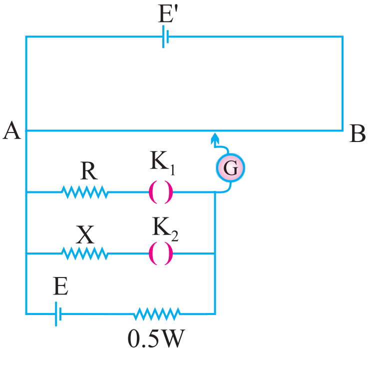
**30.** A length of uniform 'heating wire' made of nichrome has a resistance 72 Ω. At what rate is the energy dissipated if a potential difference of 120V is applied across (a) full length of wire (b) half the length of wire (wire is cut into two). Why is it not advisable to use the half length of wire ?

**Ans.** (a) 200W, (b) 400W, 400W >> 200W but since current becomes large so it is not advisable to use half the length

**31.** With a certain unknown resistance X in the left gap and a resistance of 8Ω in the right gap, null point is obtained on the metre bridge wire. On putting another 8Ω in parallel with 8Ω resistance in the right gap, the null point is found to shift by 15 cm. Find the value of X from these observations.

**Ans.** 8/3 Ω

**32.** Figure show a potentiometer circuit for comparison of two resistances. The balance point with a standard resistance R = 10Ω is found to be 160 cm. While that with the unknown resistance X is 134.4 cm. Determine the value of X. **[Ans.** 2 Ω]




**33.** In a potentiometer, a standard cell of emf 5V of negligible internal resistance maintains a steady current through Potentiometer wire of length 5m. Two primary cells of emf $E_1$ and $E_2$ are joined in series with (i) same polarity (ii) opposite polarity. The balancing point are found at length 350 cm and 50 cm in two cases respectively.

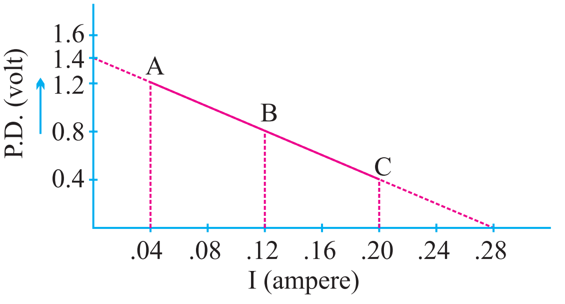
(i) Draw necessary circuit diagram

(ii) Find the value of emf $E_1$ and $E_2$ of the two cells (if $E_1 > E_2$)

**Ans.** $E_1 = 2V$, $E_2 = 1.5V$

**34.** Potential difference across terminals of a cell are measured (in volt) against different current (in ampere) flowing through the cell. A graph was drawn which was a straight line ABC. Using the data given in the graph. Determine (i) the emf. (ii) The internal resistance of the cell.

**Ans.** $r = 5\Omega$ emf = 1.4V

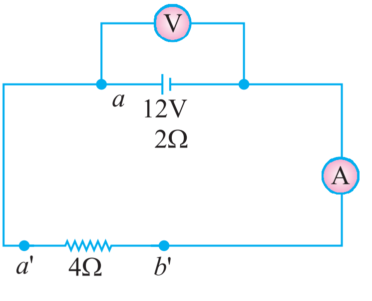



**35.** Four cells each of internal resistance 0.8Ω and emf 1.4V, *d* are connected (i) in series (ii) in parallel. The terminals of the battery are joined to the lamp of resistance 10Ω. Find the current through the lamp and each cell in both the cases.

**Ans.** $I_s = 0.424A$, $I_p = 0.137A$ current through each cell is 0.03A

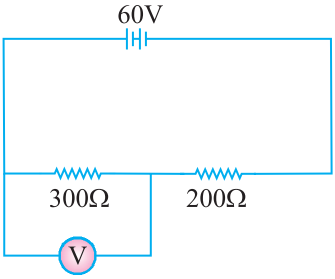
**36.** In the figure, an ammeter A and a resistor of resistance R = 4Ω have been connected to the terminals of the source to form a complete circuit. The emf of the source is 12V having an internal resistance of 2Ω. Calculate voltmeter and ammeter reading.

**Ans.** Voltmeter reading : 8V, Ammeter reading = 2A

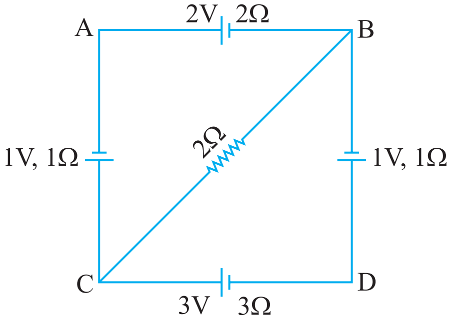



**37.** In the circuit shown, the reading of voltmeter is 20V. Calculate resistance of voltmeter. What will be the reading of voltmeter if this is put across 200Ω resistance ?

$\left[\textbf{Ans. } R_V = 150\Omega;\ V = \frac{40}{3} V\right]$

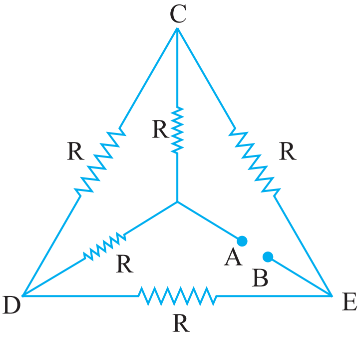



**38.** For the circuit given below, find the potential difference b/w points B and D. **Ans.** 1.46 Volts

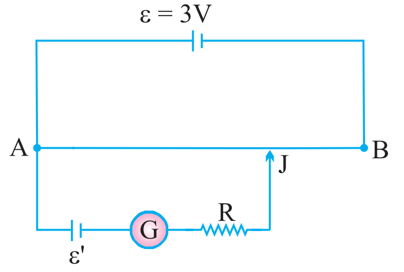



**39.** (i) Calculate Equivalent Resistance of the given electrical network *b/w* points A and B.

(ii) Also calculate the current through CD & ACB if a 10V d.c. source is connected b/w points A and B and the value of R = 2Ω.




**40.** A potentiometer wire AB of length 1m is connected to a driver cell of emf 3V as shown in figure. When a cell of emf 1.5V is used in the secondary circuit, the balance point is found to be 60 cm. On replacing this cell by a cell of unknown emf, the balance point shifts to 80 cm. :




(i) Calculate unknown emf of ε′ the cell.

(ii) Explain with reason, whether the circuit works if the driver cell is replaced with another a cell of emf IV.

(iii) Does the high resistance R, used in the secondary circuit affect the balance point ? Justify your answer.

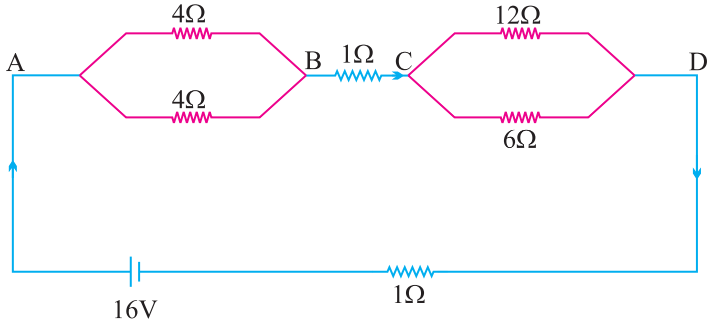
**41.** A battery of emf 10V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5A, what is the resistance of the resistor ? What is the terminal voltage of the battery when the circuit is closed ?

**42.** A network of resistance is connected to a 16V battery with internal resistance of 1Ω as shown in Fig. on next page.

(i) Compute the equivalent resistance of the network.

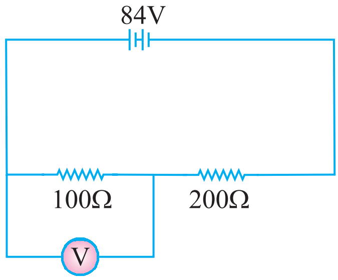
(ii) Obtain the current in each resistor.

(iii) Obtain the voltage drop $V_{AB}$, $V_{BC}$ & $V_{CD}$.

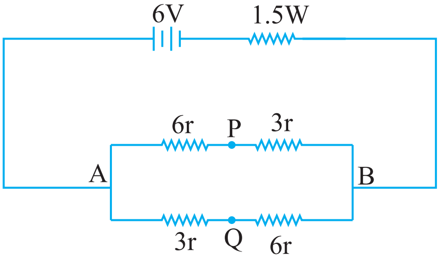



**43.** The number density of conduction electrons in a Copper Conductor estimated to be $8.5 \times 10^{28}\ m^{-3}$. How long does an electron take to drift from one end of a wire 3.0 m long to its other end ? The area of cross section of the wire is $2.0 \times 10^{-6}\ m^2$ and it is carrying a current of 3.0 A.

**44.** A voltmeter of resistance 400Ω is used to measure the potential difference across the 100Ω resistor in the circuit shown in figure. What will be the reading of voltmeter.




**45.** Find magnitude of current supplied by battery. Also find potential difference between points P and Q in the given fig. **Ans.** 1A, 1.5V

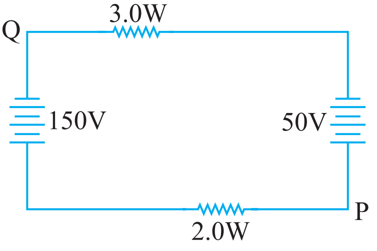



**46.** A copper wire of length 3 m and radius $r$ is nickel plated till its radius becomes $2r$. What would be the effective resistance of the wire, if specific resistance of copper and nickel are $\rho_c$ and $\rho_n$ respectively.

**[Hint :** $P_c = P_e \dfrac{I}{\pi r^2}$; $R_n = \text{In} \dfrac{I}{\pi(2r)^2 - \pi r^2}$

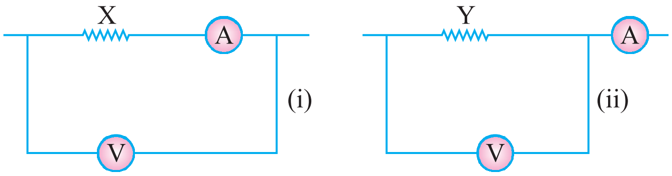
$R = \dfrac{R_C R_n}{R_C + R_n}$.  $\left[\textbf{Ans.}\ R = \dfrac{3\rho_n\rho_c}{\pi r^2 (3\rho_c + \rho_n)}\right]$

**47.** In the figure, if the potential at point P is 100V, what is the potential at point Q ?




**Ans.** – 10V

**48.** Given two resistors X and Y whose resistances are to be determined using an ammeter of resistance 0.5Ω and a voltmeter of resistance 20 kΩ. It is known that X is in the range of a few ohms, while Y is in the range of several thousand ohm. In each case, which of the two connection shown should be chosen for resistance measurement ?

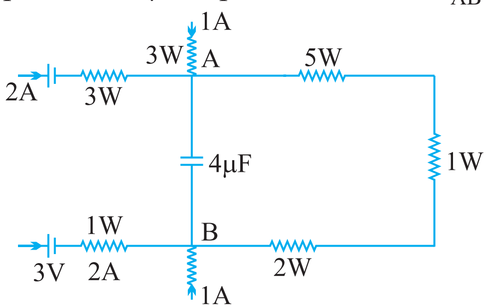



**Ans.** Small resistance : X will be preferred; large resistance : Y will be preferred

**49.** When resistance of 2Ω is connected across the terminals of a battery, the current is 0.5A. When the resistance across the terminal is 5Ω, the current is 0.25A. (i) Determine the emf of the battery (ii) What will be current drawn from the cell when it is short circuited.

**Ans.** E = 1.5 V, I = 1.5A

**50.** A part of a circuit in steady state, along with the currents flowing in the branches and the resistances, is shown in the figure. Calculate energy stored in the capacitor of 4μF capacitance. **Ans.** $V_{AB} = 20V$, $U = 8 \times 10^{-4}$ J



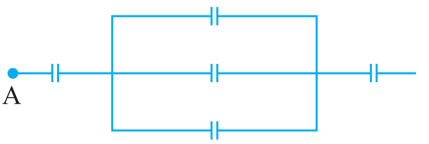

**51.** With two resistance wires in two gaps of a meter bridge, balance point was found to be 1/3m from zero end, when a 6Ω coil is connected in series with smaller of two resistances the balance point shifted to 2/3m from the same end. Find resistances of two wires. **Ans.** 2Ω, 4Ω

**52.** A voltmeter with resistance 500Ω is used to measure the emf of a cell of internal resistance 4Ω. What will be the percentage error in the reading of the voltmeter. **Ans.** 0.8%

# HINTS FOR 2 MARKS QUESTIONS

**10.** $\dfrac{t_e}{e_p} = \sqrt{\dfrac{2s\,m_e}{eE}} \Big/ \sqrt{\dfrac{2s\,m_p}{eE}} = \sqrt{\dfrac{m_e}{m_p}}$

**14.**




$$\frac{1}{Cs} = \frac{1}{2} + \frac{1}{6} + \frac{1}{2} = \frac{1}{6}$$

$$Cs = \frac{6}{7}\text{ecf}$$

**21.** $\varphi = \overline{E}.\overline{ds} = 2x\,\hat{i}.ds\,\hat{i} = 2x.ds$

$\varphi_1 = 0,\ \varphi_2 = 50\text{ Vm},\ \varphi_3 = 150\text{ Vm}$

**28.** $W_{BA} = 90\,(V_B - V_A) = 2 \times 1000 = 2000\text{ J}$

**40.** $\dfrac{R_1}{R_2} = \dfrac{l\,I_1}{A_1} \times \dfrac{A_2}{l\,I_2} \Rightarrow \dfrac{I_1 A_2}{A_1 I_2} \Rightarrow \dfrac{1}{2},\ \dfrac{I_1}{I_2} = \dfrac{1}{2} \therefore \dfrac{A_2}{A_1} = 1$

(i) in series neA, $(V_d) = neA_2(V_d)_2 \Rightarrow \dfrac{(V_d)_1}{(V_d)_2} = 1$

(ii) $i_1R_1 = i_2R_2 \Rightarrow \dfrac{(V_d)_1}{(V_d)_2} = \dfrac{2}{1}$

**43.** Current through 5Ω $= \left(\dfrac{10}{5+10}\right)I = \dfrac{2I}{3}$

**64.** Sensitivity of Wheatstone Bridge is maximum when resistance of all its four arms are nearly of same order, so the accuracy of result of the experiment will be highest, if balance point is in the middle of wire.

**32.** In the capacitor the voltage increases from O to V, hence energy stored will correspond to average which will be ½ QV. While the source is at constant emf V. So energy supplied will be QV. The difference between the two goes as heat and emf radiations.

**35.** Construct a closed system such that charge is enclosed within it. For the charge on one face, we need to have two cubes place such that charge is on the common face. According to Gauss's theorem total flux through the Gaussian surface (both cubes) is equal to $\frac{q}{2\varepsilon_0}$. Therefore the flux through one cube will be equal to $\frac{q}{2\varepsilon_0}$.

**36.** Work done $= fd \cos\theta = q\mathrm{E}d\cos\theta = \frac{q(\sigma_1 - \sigma_2)}{\varepsilon_0}\frac{a}{\sqrt{2}}$

**61.** $$\mathrm{I} = \frac{\text{Charge circulating}}{\text{Time for one revolution}} = \frac{e}{2\pi r / v}$$ $v \longrightarrow$ speed

$$= \frac{ev}{2\pi r}$$

$$= \frac{ee^2me^2}{n2\pi n^2} = \frac{me^5}{2\pi n^3}$$

**62.** In steady state the branch containing C can be omitted hence the current

$$\mathrm{I} = \frac{2\mathrm{V} - \mathrm{V}}{\mathrm{R} + 2\mathrm{R}} = \frac{\mathrm{V}}{3\mathrm{R}}$$

For loop EBCDE

$$-\mathrm{V_C} - \mathrm{V} + 2\mathrm{V} - 1\,(2\mathrm{R}) = 0$$

$\Rightarrow$ $$\mathrm{V_C} = \frac{\mathrm{V}}{3}$$

**51.** If e.m.f. decreases $\Rightarrow \frac{\mathrm{V}}{l}$ decreases $\Rightarrow$ position of zero deflection increases.

**52.** Otherwise resistance per unit length of Bridge wire be different over different length of meter Bridge.

**54.** Milliammeter. To produce large deflection due to small current we need a large number of turns we need a large number of turns in armature coil $\Rightarrow$ Resistance increases.

**55.** Temperature, Material Blue, Red, Orange, Gold

**56.** The electron number density is of the order of $10^{29}\ \mathrm{m^{-3}}$, $\Rightarrow$ the net current can be very high even if the drift spread is low.

**57.** $$\mathrm{V} = \mathrm{E} + ir$$

$$= 2 + 0.15$$

$$= 2.15\mathrm{V}$$

**58.** Affects the uniformity of the cross-section area of wire and hence changes the potential drop across wire.

**59.** A potentiometer is said to be sensitive if :

(i) It can measure very small potential differences.

(ii) For a small change in potential difference being measured it shows large change in balancing length.

## HINTS FOR NUMERICALS

**9.**
$$V = E_o\left(\frac{d}{4}\right) + \frac{E_o}{K}\left(\frac{3d}{4}\right) = E_o\, d\left(\frac{K+3}{4K}\right)$$

$$V = V_o\left(\frac{K+3}{4K}\right)$$

$$C = \frac{Q_o}{V} = \frac{4K}{K+3}\frac{Q_o}{V_o} = \frac{4K}{K+3}Co$$

**14.**
$$r = 1 \text{ mm}$$

$$\frac{4}{3}\pi R^3 = 8\cdot\frac{4}{3}\pi r^3 \Rightarrow R = 2 \text{ mm}$$

$$Q = 8q = 8 \times 10 \times 10^{-10} \text{ C}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

$$= \frac{9 \times 10^9 \times 8 \times 10^{-9}}{2 \times 10^{-3}} = 36000 \text{ Volt}$$

**21.**
$$C_x = C,\ C_y = KC = 4C$$

$$\frac{C_x C_y}{C_x + C_y} = \frac{4}{5}C = 4 \Rightarrow C = 5\mu f$$

(a) $$Ceq = C_x = 5\mu f$$
$$C_y = 20\mu f$$

(b) $$V + \frac{V}{4} = 12 \ (V_x = V,\ V_y = \frac{V}{4} \text{ as } q \text{ constant})$$

$$V = 9.6 \text{ Volt},\ V_x = 9.6 \text{ Volt},\ V_y = 2.4 \text{ Volt}$$

(c) $$\frac{U_x}{U_y} = \frac{\frac{1}{2}C_x V_x{}^2}{\frac{1}{2}C_y (V_y)^2} = 4$$

**31.** $$\frac{X}{8} = \frac{l}{100 - l} \qquad ...(1)$$

$$\frac{1}{R_p} = \frac{1}{8} + \frac{1}{8} = \frac{1}{4} \Rightarrow R_p = 4,$$

$$\frac{X}{4} = \frac{1 + 15}{100 - (1 + 15)} \qquad ...(2)$$

$\Rightarrow$ u sing (1) & (2)

$$l^2 - 85l + 1500 = 0$$

$$l = 25 \text{ cm or } l = 60 \text{ cm}$$

At $l = 60$ cm using (1) $X = \frac{8}{3}\Omega$

$l = 60$ cm using (1) $X = 12\Omega$.

**32.** $$i_x = \frac{E}{x + 0.5}, i_R = \frac{E}{10 + 0.5} = \frac{E}{10.5}$$

$$\frac{V_R}{V_x} = \frac{160}{134.4} = \frac{i_R . R}{i_x x} = \frac{10}{10.5}\frac{(x + 0.5)}{x} \Rightarrow x = 2\ \Omega.$$

## HINTS FOR 3 MARKS QUESTIONS

**16.** If E′ be the electric field due to each plate (of large dimensions) then net electric field between them

$$E = E' + E' \Rightarrow E' = E/2$$

Force on change Q at some point between the plates F = QE

Force on one plate of the capacitor due to another plate F′ = QE′ = QE/2

**17.** $$V_1 = \frac{kq}{r} + \frac{kq}{6r} = \frac{7kq}{6r}$$

$$V_2 = \frac{kq}{2r} + \frac{kq}{6r} = \frac{3kq + kq}{6r} = \frac{4kq}{6r}$$

$$\frac{V_1}{V_2} = \frac{7}{4}$$

$$V_{common} = \frac{2q}{4\pi\varepsilon_0(r + 2r)} = \frac{2q}{12\pi\varepsilon_0 r} = V'$$

Charge transferred equal to

$$q' = C_1V_1 - C_1V' = \frac{r}{k}.\frac{kq}{r} - \frac{r}{k}.\frac{k_2q}{3r}$$

$$= q - \frac{2q}{3} = \frac{q}{3}.$$

**28.** $$R_1 = \frac{V_1}{I_1} = \frac{50}{2 \times 10^{-3}} = 25{,}000\Omega$$

$$R_2 = \frac{V_2}{I_2} = \frac{60}{3 \times 10^{-3}} = 20{,}000\Omega.$$

As resistance changes with I, therefore conductor is non ohmic.

**29.** Rate of production of heat, $P = I^2R$, for given $l$, $P \times R$, $\therefore$ $\rho_{nichrome} > \rho_{cu}$
$\therefore$ $R_{Nichrome} > R_{cu}$ of same length and area of cross section.

**30.** (i) If I in circuit is constant because $H = I^2 Rt$

(ii) If V in circuit is constant because $H = \frac{V^2}{R}t$

## NUMERICALS

**17.** $$V_A = k\left[\frac{q_1}{a} + \frac{q_2}{b} + \frac{q_3}{c}\right]$$

$$= k\,4\pi a\sigma - k4\pi b\sigma + k4\pi c\sigma$$

$$= 4\pi a\sigma\,(a - b + c)$$

$$= \frac{\sigma}{\varepsilon_0}(a - b + c)$$

$$V_B = k\left[\frac{q_1}{b} + \frac{q_2}{b} + \frac{q_3}{c}\right] = k\left[\frac{4\pi a^2\sigma}{b} - 4\pi kb\sigma + 4\pi kc\sigma\right]$$

$$= \frac{\sigma}{\varepsilon_0}\left(\frac{a^2}{b} - b^2 + c^2\right)$$

$$V_C = \frac{\sigma}{\varepsilon_0 c}(a^2 - b^2 + c^2)$$

When $$V_A = V_C$$

$$\frac{\sigma}{\varepsilon_0}(a - b + c) = \frac{\sigma}{\varepsilon_0 C}(a^2 - b^2 + c^2)$$

$$ac - bc + c^2 = a^2 - b^2 + c^2$$

$$c\,(a-b) = (a-b)\,(a+b)$$

$$c = a + b$$

**19.** $$Q = CV$$

Total charge $\quad$ Q = Total capacitance in series × voltage

$$= \left(\frac{5}{6} \times 10^{-3}\right) \times 12 = 10 \times 10^{-3} \text{ coulomb}$$

$$V_{AB} = \frac{Q}{c_1} = \frac{10 \times 10^{-3}}{1 \times 10^{-3}} = 10V$$

$$V_{BC} = \frac{Q}{c_2} = \frac{10 \times 10^{-3}}{5 \times 10^{-3}} = 2V.$$

When B is earthed $V_B = 0$, $V_A = 10V$ and $V_C = -2V$.

**21.** Before dielectric is introduced.

$$E_A = \frac{1}{2}CV^2; \qquad E_B = \frac{1}{2}CV^2$$

$$E = E_A + E_B = CV^2$$

After disconnecting the battery and then introducing dielectric

$$E'_A = \frac{1}{2}(3C)V^2$$

$$E'_B = \frac{Q^2}{2C} = \frac{(CV)^2}{2 \times 3C}$$

$$= \frac{1}{3}\left(\frac{1}{2}CV^2\right),$$

$$E' = E'_A + E'_B$$

$$\frac{E'}{E} = \frac{5}{3}.$$

**33.** Pot. gradient $k = \frac{5}{5} = 1Vm^{-1}$

$$l_1 = 350 \text{ cm} = 3.5 \text{ m}$$

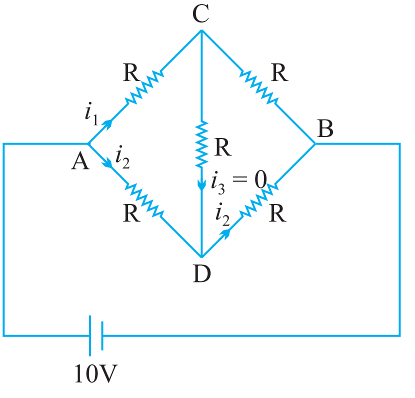
$$E_1 + E_2 = kl_1 = 3.5 \qquad ...(1)$$

$$E_1 - E_2 = 0.5 \qquad ...(2)$$

$$E_1 = 2V,\ E_2 = 1.5 \text{ Volt}$$

**39.** $$R_{AB} = 2\Omega$$

$$I_{CD} = 0,\ I_{ACB} = \frac{V}{2R} = \frac{10}{2 \times 2} = 2.5A$$




**40.** (i) $\frac{E_2}{E_1} = \frac{I_2}{I_1} \Rightarrow E_2 = \frac{I_2}{I_1}E_1 = \frac{80}{60} \times 1.5 = 2.0V$

(ii) The circuit will not work if emf of driven cell is IV,/total Voltage across AB is 1 V, which cannot balance the voltage 1.5V.

(iii) No, since at balance point no current flows through galvanometer G. *i.e.*, cell remains in open circuit.

**41.** $$E = I\,(R + r)$$

$$10 = 0.5\,(R + 3)$$

$$R = 17\Omega$$

$$V = E - Ir = 10 - 0.5 \times 3 = 8.5V$$

**42.** $$Req = 7W$$

$$I_{4\Omega} = 1A,\ I_{1\Omega} = 2A,\ I_{12\Omega} = \frac{2}{3}A,\ I_{6\Omega} = \frac{4}{3}A,$$

$$V_{AB} = 4V, V_{BC} = 2V, V_{CD} = 8V$$

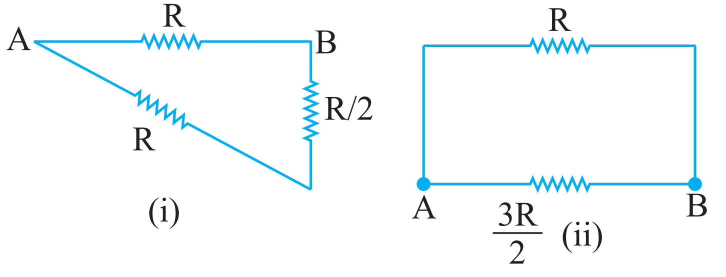
**43.** $$I = enAV_d = \frac{l}{t}$$

$$t = \frac{en\,Al}{1} = 2.7 \times 10^4 \text{ s}$$

**44.** $$I = \frac{84}{\left(\frac{100 \times 400}{100 + 400}\right) + 200} = \frac{84}{280} = 0.3A$$

P.d. across voltmeter & 100Ω combination

$$= 0.3 \times \frac{100 \times 400}{100 + 400} = 24V.$$




When, $I << r$,

**45.** $$R_{AB} = 4.5\Omega$$

$$i = \frac{E}{R_{AB} + 1.5} = \frac{6}{6} = 1A.$$

$$i_{AP} = i_{AQ} = 0.5A, V_{AP} = 3 \Rightarrow V_p = 3 \text{ Volt}$$

$$V_{AQ} = 1.5\ V_Q = 4.5 \text{ Volt}$$

$$V_Q - V_P = 1.5 \text{ Volt}$$

**51.** For two resistor P and Q

$$\frac{P}{Q} = \frac{I}{100 - I} = \frac{\frac{1}{3}}{1 - \frac{1}{3}} = \frac{1}{2} \qquad \text{...(i)}$$

$$Q = 2P, P < Q$$

Now, $P' = P + 6$, $I' = 2/3$

$$\frac{P^1}{Q} = \frac{I'}{(100 - I')} = \frac{\frac{2}{3}}{\frac{1}{3}} = \frac{2}{1}$$

$$\frac{P + 6}{Q} = \frac{2}{1} \qquad \text{...(ii)}$$

On solving (i) & (ii), $P = 2\Omega$, $Q = 4\Omega$.