Blue Print (As per PU Board)

Topic	1 mark questions	2 marks questions	3 marks questions	5 marks questions	Total Marks
Current Electricity	1	1	–	1	8

One mark questions

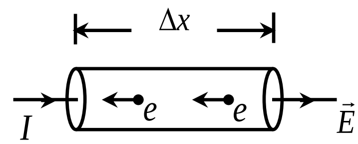
1. **Name the charge carriers in a metallic conductor.**
   Answer: Free electrons.
2. **Mention the SI unit of electric current.**
   Answer: ampere (A)
3. **How many electrons flow per second through a conductor carrying a current of $1\mathrm{A}$?**
   Answer: 6.25×10^{18} electrons|s

Two marks questions

4. **Derive an expression for the acceleration of an electron in a current carrying conductor.**
   Answer: An electron in a current carrying conductor moves under the action of an external applied electric field of intensity E . The electron experiences a force $\vec{F}=-e\vec{E}$ in a direction opposite to that of the field. (1 mark)
   Now $\vec{F}=m\vec{a}$
   $\vec{a}=-\frac{e\vec{E}}{m}$
   The electron gets accelerated in a direction opposite to that of the field. (1 mark)
5. **Derive an expression for drift velocity of electrons in terms of relaxation time**.
   Answer: When an external electric field is applied on a current carrying conductor, the free electrons drift in a direction opposite to that of the electric field. They collide with the vibrating atoms. The time in between two successive collisions is called relaxation time. (1 mark)
   Let v_d = Drift velocity;
   τ = Relaxation time
   a = Acceleration produced by the external electric field $\vec{E}$
   $V_d = u + a\tau \qquad (\because u=0)$
   $\therefore \tau = \frac{v_d}{a}$
   But $\vec{a}=\frac{-e\vec{E}}{m}$ where e = charge of the electron
   m = mass of the electron. (1 mark)
6. **Obtain an expression for the mobility of electron (μ) in terms of relaxation time (τ).**
   Answer: Mobility $=\mu=\frac{|v_d|}{E}$ (1 mark)
   But $v_d = aT = \frac{eE}{m}\tau$
   $\therefore \mu = \frac{\left(\frac{eE}{m}\right)\tau}{E}$
   $\therefore \mu = \frac{e\tau}{m}$ (1 mark)

Three marks questions

7. **Derive an expression for current passing through a conductor in terms of free electron density and drift velocity.**
OR
Show that $I = Anev_d$ where the symbols have their usual significance.



Answer: Consider a small portion of a conductor of length Δx .Let a potential difference V be applied across the ends of the conductor. This produces an electric field inside the conductor on account of which the electrons drift in a direction opposite to that of the current. Let n be the free electron density of the material of the conductor. It is the number of free electrons per unit volume of the conductor.
(1 mark)

Volume of the portion of the conductor considered
$= A\Delta x$ (Volume=area of cross-section $\times$ length)
Number of free electrons present in this volume $= A\Delta x.n$
Charge due to these free electrons $= (A\Delta x\, n)e$
Let the time taken by these electrons to drift across the length Δx be Δt .

Now current $= \dfrac{\text{charge}}{\text{time}}$ (1 mark)

$$I = \frac{(A\Delta x.n)e}{\Delta t}$$

$$= Ane\left[\frac{\Delta x}{\Delta t}\right]$$

But $\dfrac{\Delta x}{\Delta t} = v_d$ = Drift velocity of electrons.

$\therefore I = Anev_d$ (1 mark)

8. **Derive the equivalent form of Ohm's law $\vec{J} = \sigma\vec{E}$ or $\vec{J} = \dfrac{\vec{E}}{\rho}$ where the symbols have their usual meaning.**

Answer: Let V = Voltage applied across a conductor
R = Resistance of the conductor
I = Current passing through the conductor
$V = IR$ [By ohm's law] (1 mark)

Now $R = \dfrac{\rho L}{A}$

Where ρ = Resistivity of the material of the conductor
L = Length of the conductor
A = Area of cross section of the conductor

$$\therefore V = \frac{I\rho L}{A}$$

$$\frac{V}{L} = \frac{I\rho}{A}$$

But $\dfrac{V}{L} = E$ = Intensity of electric field produced by the conductor. (1 mark)

$$\therefore E = \frac{I\rho}{A}$$

The current density of a conductor is defined as the ratio of current to the cross-sectional area of the conductor.

$\frac{I}{A} = J$

But $\rho = \frac{1}{\sigma}$ where σ is the electrical conductivity of the conductor.

$\therefore E = \frac{J}{\sigma}$ Or $J = \sigma E$ (1 mark)

This is the equivalent form of ohm's law in terms of current density.

Vectorially $\vec{J} = \sigma \vec{E}$.

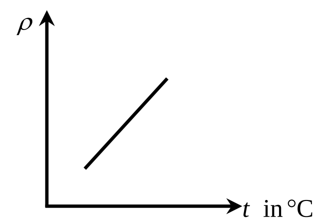
9. Explain the variation of resistivity with temperature.

Answer: The resistivity of the material of a conductor varies with the temperature of the conductor.

$\rho = \frac{m}{ne^2 \tau}$ (1 mark)

As temperature increases, the relaxation time τ decreases. Hence the resistivity ρ increases with temperature. Let ρ_t and ρ_0 denote the resistivity of the material of a conductor at temperature $t°C$ and $0°C$ respectively. Then

$\rho_t = \rho_0 (1 + \alpha t)$ (1 mark)



α is a constant called the temperature coefficient of resistivity of the material.

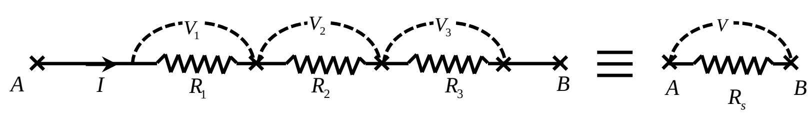
$\propto = \frac{\rho_t - \rho_0}{\rho_0 t}$

The variation of resistivity with temperature as shown in the figure. (1 mark)

Five marks questions

10. Derive an expression for the effective resistance of three resistances connected in series.

Answer:



(1 mark)

Consider three resistances R_1, R_2 and R_3 to be connected in series between two points A and B in a circuit. Let I be the current passing from A to B. The same current flows through all the resistances since they are connected in series. But the potential differences are different. Let V_1, V_2 and V_3 denote the p.d's across R_1, R_2 and R_3

$V_1 = IR_1$

$V_2 = IR_2$

$V_3 = IR_3$ (1 mark)

Let V denote the p.d across the combination and R_s the effective or equivalent resistance of the combination.

Then $V = IR_s$ (1 mark)

Now $V = V_1 + V_2 + V_3$ (1 mark)

$\therefore IR_s = IR_1 + IR_2 + IR_3$

$IR_s = I(R_1 + R_2 + R_3)$

$\therefore R_s = R_1 + R_2 + R_3$. (1 mark)

11. Derive an expression for the effective resistance of three resistances connected in parallel.

Answer: Consider three resistances R_1, R_2 and R_3 to be connected in parallel. Let V denote the p.d across the combination. The same p.d is maintained across each resistance. Let a current I be passed into the combination.

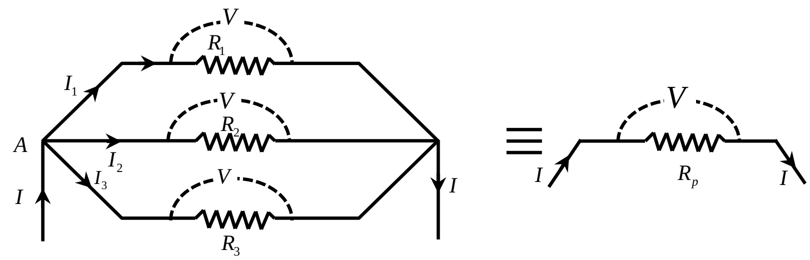


fig (1 mark)

It branches off into I_1, I_2 and I_3 amperes passing through R_1, R_2 and R_3 respectively. (1 mark)

p.d across $R_1 = V = I_1R_1$

$\therefore I_1 = \frac{V}{R_1}$

p.d across $R_2 = V = I_2R_2$

$\therefore I_2 = \frac{V}{R_2}$

p.d across $R_3 = V = I_3R_3$

$\therefore I_3 = \frac{V}{R_3}$ (1 mark)

Let R_p denote the effective or equivalent resistance of R_1, R_2 and R_3 connected in parallel. When the same current is passed into the combination, the p.d across the combination will be

$V = IR_p$

$\therefore I = \frac{V}{R_p}$

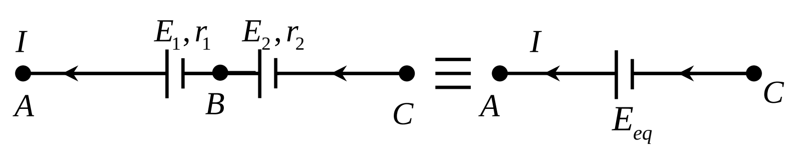
But $I = I_1 + I_2 + I_3$ (1 mark)

$\therefore \frac{V}{R_p} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

$\therefore \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$. (1 mark)

12. Derive an expression for the equivalent emf and equivalent internal resistance of two non-identical cells connected in series.

Answer:



(1 mark)

Consider two cells of emf's E_1 and E_2 having internal resistances r_1 and r_2 respectively. The cells are connected in series.

Let V_A, V_B and V_C be the potential at A, B and C respectively.

p.d across A and B is

$V_{AB} = V_A - V_B = E_1 - Ir_1$

p.d across B and C is

$V_{BC} = V_B - V_C = E_2 - Ir_2$ (1 mark)

p.d across A and C is

$V_{AC} = [V_A - V_B] + [V_B - V_C]$

$V_{AC} = [E_1 - Ir_1] + [E_2 - Ir_2]$

$V_{AC} = (E_1 + E_2) - I(r_1 + r_2)$ (1 mark)

$V_{AC} = E_{eq} - Ir_{eq}$

$\therefore\ E_{eq} - I\, r_{eq} = (E_1 + E_2) - I(r_1 + r_2)$ (1 mark)

$\therefore E_{eq} = (E_1 + E_2)$

$r_{eq} = (r_1 + r_2)$ (1 mark)