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List of Formulas — Electronics devices.

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1. Electric field $\mathcal{E}_x = \dfrac{\text{Voltage}}{\text{distance}} = \dfrac{V}{cm}$

2. Mobility $\mu = \dfrac{v_d}{\mathcal{E}}$ $\quad \dfrac{\text{velocity}}{\text{Electric field}} \cdot \dfrac{\frac{cm}{sec}}{\frac{V}{cm}}$

$$\mu_m = \frac{cm^2}{V\,sec}$$

3. $J = n q\, v_{drift}$

4. $v_{drift} = \dfrac{q\mathcal{E}}{m_n^*} t$, m_n^* = effective mass of electrons

5. $J = \sigma \mathcal{E}$, $\mu_n = \dfrac{v_{drift}}{\mathcal{E}} = \dfrac{q\,t}{m_n^*}$
$\sigma = q n \mu_n$

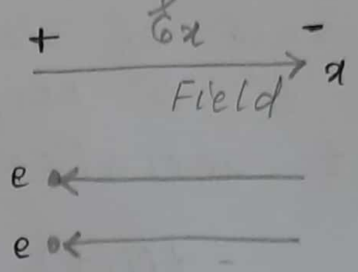
6. Newtons Law:
The rate of change of momentum of a body is porportional to Force, applied to it.

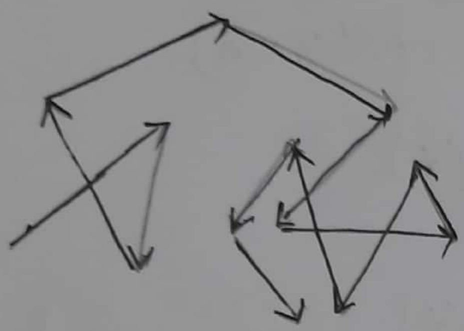
7. $\text{Force} = q\,\mathcal{E}_x$, $I = \dfrac{dQ}{dt} \cdot \dfrac{\text{coloumb}}{\text{sec}}$

Conductivity and Mobility

1. Drift of carriers in an Electric field.

→ The net movement of electrons or holes due to an electric field is called drift current.





$V_x = -\mu_n \mathcal{E}_x$.
V_x = drift velocity
$\mathcal{E}_x$ = Electric field
μ_n = Mobility

1. If an Electric field $\mathcal{E}_x$ is applied in x-direction, The electrons experiences a net force $F = -q\mathcal{E}_x$ from the field.

2. The group of electrons will have a net average velocity in the x-direction. The mean velocity is called <u>drift velocity</u>.

3. If P_x is the total momentum of the group of 'n'-electrons/cm^3 the ~~accelerating~~ accelerating force due to electric-field is

$$\boxed{\left.\frac{dP_x}{dt}\right|_{field} = -nq\mathcal{E}_x} \quad \text{— (1)}$$

$$\frac{dP_x}{dt} = -nq\mathcal{E}_x \quad \text{--- (1)}$$

Let a group of N_0 electrons at time $t = 0$ be considered.

Let $N(t)$ be the number of electrons have not undergone collision by time t.

The rate of decrease in $N(t)$ at any time 't' is porportional to the number left unscattered (no collision)

$$-\frac{dN(t)}{dt} \propto N(t)$$

$$-\frac{dN(t)}{dt} = \frac{N(t)}{\bar{t}} \quad \text{--- (2)}$$

$\bar{t} \rightarrow$ proportionality constant.

(2) solved is exponential function

$$N(t) = N_0 e^{-t/\bar{t}} \quad \text{--- (3)}$$

$\bar{t} \rightarrow$ mean time between collision or mean free time.

The probability of collision for an electron in any time interval $dt = \frac{dt}{\bar{t}}$.

$\therefore$ The differential change in momentum due to collision in time dt ie.

$$dP_x = -P_x \frac{dt}{\bar{t}} \quad \text{--- (4)}$$

The rate of change of P_x due to the ② decelerating effect of collision is

$$\frac{dP_x}{dt} = -\frac{P_x}{\bar{t}} \quad — (5)$$

The sum of accerleration ① & deacceralation ⑤ must be zero for steady state

$$① + ⑤ = 0$$

$$-nq\mathcal{E}_x - \frac{P_x}{\bar{t}} = 0$$

The average momentum per electron is

$$\langle P_x \rangle = \frac{P_x}{n} = -q\mathcal{E}_x\bar{t} \longrightarrow (6)$$

$\langle\ \rangle \longrightarrow$ average over entire group of electrons.

⑥ indicates that electrons have on velocity in negative x-direction given by

$$\langle V_x \rangle = \frac{\langle P_x \rangle}{m_n^*} = \frac{-q\bar{t}\mathcal{E}_x}{m_n^*} \quad — (7)$$

$$\boxed{\langle V_x \rangle = \frac{-q\bar{t}\mathcal{E}_x}{m_n^*}}$$

drift velocity of avg electron in response to the electric-field

The current density due to electrons drift is the number of electrons crossing unit area per unit time. $\langle n \langle V_x \rangle \rangle$ multiple by charge (q)

$$J_x = -q\,n\langle V_x \rangle$$

$$\frac{amp}{cm^2} = \frac{coulomb}{electrone} \cdot \frac{electron}{cm^3} \cdot \frac{cm}{sec}$$

$$J_x = -q\,n\frac{(-q\,\bar{t}\,\mathcal{E}_x)}{m_n^*} \quad \text{From eqn } 7$$

$$J_x = \frac{q^2 n}{m_n^*}\,\bar{t}\,\mathcal{E}_x \quad — \quad 8$$

From ohm's Law, current density is proportional to the Electric field

$$J_x = \sigma\,\mathcal{E}_x \rightarrow 9$$

compare 8 & 9

$$\boxed{\sigma = \frac{q^2 n\,\bar{t}}{m_n^*}} \quad — \quad 9$$

The conductivity 'σ' can be written

$\sigma\,(\Omega/cm)$

$$\sigma = q\,n\,\mu_n \quad — \quad 10$$

compare (9) & (10)

$$\mu_n = \frac{q\bar{t}}{m_n^*} \quad — (11)$$

$\mu_n \rightarrow$ electron Mobility

$\mu_n \rightarrow$ describes the ease with which electron drift in the material.

$$\text{Mobility } \mu_n = \frac{\text{average velocity}}{\text{Electric field}}$$

$$\mu_n = -\frac{\langle v_x \rangle}{\mathcal{E}_x} \quad cm^2/V\,sec$$

The current density can be written in ~~of~~ terms of Mobility

$J = \sigma \mathcal{E}_x \longrightarrow$ from (9)

$\sigma = qn\mu_n \longrightarrow$ from (10)

we get $\therefore \boxed{J = qn\mu_n\mathcal{E}_x}$

If both electrons and holes participate

$$\boxed{J_x = q(n\mu_n + p\mu_p)\mathcal{E}_x}$$

$$J_x = \sigma\mathcal{E}_x$$

$$\boxed{\sigma = q[n\mu_n + p\mu_p]}$$

σ = conductivity

The resistance of the semiconductor bar. is given by.

$$R = \frac{\rho L}{w \cdot t}$$

$$= \frac{L}{w \cdot t} \cdot \rho$$

w: width
t = thickness
L = Length.
ρ = resistivity

$$R = \frac{L}{w \cdot t} \cdot \frac{1}{\sigma}$$

ρ = resistivity

$$\boxed{\rho = \frac{1}{\sigma} \quad \Omega\text{-cm}}$$