Drift current.

$$\mu = \frac{v_d}{E} \quad \text{---(i)} \Rightarrow v_d = \mu E \quad \text{--- (3)}$$

μ = mobility , J = current density = $\frac{I}{A}$

v_d = drift velocity.

E = applied electric field.

$$I = neAv_d$$

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

$$J = nev_d \quad \text{--- (2)}$$

from eq (2) & (3).

current density.

$$\boxed{J = ne\mu E} \quad \text{--- (4)}$$

now →

$$\Rightarrow R = \frac{\overset{E \cdot d}{V}}{\underset{J \cdot A = I}{I}} \Rightarrow \frac{Ed}{J \cdot A} \quad \text{--- (5)}$$

$$\Rightarrow \frac{RA}{d} = \frac{E}{J} \qquad \left\{ \text{we know } \frac{RA}{l} = \rho \right\}$$

$$\Rightarrow \rho = \frac{E}{J}$$

$$\Rightarrow \underset{\text{conductivity}}{\sigma} = \frac{J}{E} \Rightarrow \sigma = \frac{ne\mu \cancel{E}}{\cancel{E}}$$

$\left\{ \sigma = \frac{1}{\rho} \right\}$

$$\boxed{\sigma = ne\mu} \quad \text{--- (5)}$$

$n \rightarrow$ no. of e^- /unit volume
$p \rightarrow$ no. of holes /unit volume } number density

→ for electron → (using eq. 5)

$$\boxed{J_n = e n \mu_n E} \longrightarrow (6)$$

$$\boxed{\sigma_n = e n \mu_e} \longrightarrow (7)$$

→ for p holes

$$\boxed{J_p = e p \mu_p E} \longrightarrow (8)$$

$$\boxed{\sigma_p = e p \mu_p} \longrightarrow (9)$$

→ now
total current density → eq. (6) + eq. (8)

$$\boxed{J_T = e\,(n\mu_e + p\mu_p)\,E} \longrightarrow (10)$$

total conductivity → eq (7) + eq. (9)

$$\boxed{\sigma_T = e\,(n\mu_e + p\mu_p)} \longrightarrow (11)$$

or

$$\boxed{\sigma = e n_i\,(\mu_e + \mu_p)} \longleftarrow (12)$$

Note:- for intrinsic semiconductor.

$$\boxed{n \cdot p = n_i^2}$$

○ Diffusion current :- (page no. 28 - reference data).

generally the ~~[illegible]~~ ← ficks law ⇒ $f = -D\frac{dn}{dx}$ and $\boxed{J = -qf}$

$J_n \propto \frac{dn}{dx}$ for n-type ——— (i)

$J_p \propto \frac{dp}{dx}$ for p-type ——— (ii).

diffusion current density → $\propto$ → concentration gradient.

○ → $J_n = -(-e D_n) \cdot \frac{dn}{dx}$

$J_n = e D_n \frac{dn}{dx}$ ——— (iii).

* as current flow in opposited direction charge flow

** → just to represent negative charge in n-type

○ $J_p = -(e D_p) \cdot \frac{dp}{dx}$

$J_p = -e D_p \frac{dp}{dx}$ ——— (iv)

Here, D_n, D_p are diffusion coefficients (a purportionality factor).

→ overall diffusion (J) = Drift current + diffusion current
density

i.e $\boxed{J_T = J_n + J_p}$

→ for electrons (or n-type)

$$\boxed{J_{nT} = e n \mu_n E + e D_n \frac{dn}{dx}} \quad \text{—— (A)}$$

→ for holes (or P-type)

$$\boxed{J_{pT} = e p \mu_p E - e D_p \frac{dp}{dx}} \quad \text{—— (B)}$$

→ at eqb. condition → there is not net flow
flow of ~~electr~~ current so
J_{nT} or $J_{pt} = 0$.

from eq. (B)

$$\Rightarrow e P \mu_p E - e D_p \frac{dp}{dx} = 0$$

$$\Rightarrow \cancel{e} P \mu_p E = \cancel{e} D_p \frac{dp}{dx} \Rightarrow$$

$$E_x = \frac{D_p}{\mu_p} \cdot \frac{1}{p} \cdot \frac{dp}{dx} \quad \text{— (C)}$$

we know that.

$$\text{work done} = \overset{\text{p.diff.}}{qV} = \overset{\text{energy}}{E_i}$$

$$\frac{dV}{dx} \cdot q = \frac{dE_i}{dx}$$

$$\boxed{E(x) = \frac{1}{q} \frac{dE_i}{dx}} \quad \text{— (D)}$$

→ at equillibrium E_f (fermi level) doesn't vary with x so, $\frac{dE_f}{dx} = 0$

using eq. (D) & (C)

$$\frac{1}{q} \frac{dE_i}{dx} = \frac{D_p}{\mu_p} \frac{1}{p} \cdot \frac{dp}{dx} \quad \text{— (E)}$$

we know that

$$\Rightarrow \quad p_0 = n_i \, e^{(E_i - E_f)/kT}$$

$$\Rightarrow \quad \frac{dp}{dx} = \underbrace{n_i \, e^{(E_i - E_f)/kT}}_{p} \cdot \frac{1}{kT} \cdot \frac{dE_i}{dx}$$

$$\frac{dp}{dx} = \frac{p}{kT} \cdot \frac{dE_i}{dx} \quad \text{— (F)}$$

from eq. (g) and (e)

$$\frac{1}{q}\frac{dE_i}{dx} = \frac{D_p}{\mu_p}\cdot\frac{1}{\cancel{kp}}\cdot\frac{\cancel{p}}{kT}\cdot\frac{\cancel{dE_i}}{\cancel{dx}}$$

$$\boxed{\frac{D_p}{\mu_p} = \frac{kT}{q}}$$

$\Downarrow$

this is Einstein relation.

→ **Effective mass :-**

$$E = \frac{h}{\lambda} = \frac{2\pi}{\lambda}\times\frac{h}{2\pi} = \hbar\frac{2\pi}{\lambda}$$

$$\boxed{E = k\hbar} \quad \text{—(A)} \qquad \text{as } k = \frac{2\pi}{\lambda}$$

wave number

→ from debroglie wavelength we have.

$$\frac{h}{p} = \lambda \quad \text{or} \quad \frac{h}{\lambda} = \sqrt{2m\,K.E.}$$

$\frac{h}{p} = \lambda$

$\frac{h}{mv} = \lambda$

$\frac{h}{\lambda} = mv$

$\frac{h}{\lambda} = m v \cdot v$

$\downarrow$

now $\frac{h}{\lambda} = p \Rightarrow \boxed{p = mv}$

$K.E = \frac{1}{2}mv^2$

$= \frac{1}{2}\,m\cdot\frac{p}{m}\cdot\frac{p}{m}$

$K.E. = \frac{p^2}{2m}$

or $K.E = \frac{1}{2}mv^2 \times \frac{m}{m}$

$K.E = \frac{p^2}{2m}$

$\Rightarrow p = \sqrt{2m\cdot K.E}$

$$\boxed{\frac{h}{\lambda} = \sqrt{2m\cdot K.E}}$$

$\Downarrow$

$$K.E = \frac{h^2}{\lambda^2} \qquad p^2 = 2m\cdot K.E \Rightarrow p = \sqrt{2m\,K.E}$$

Number density :- no. of charge carrier per unit volume.

for e^- / n-type / for conduction band.

$$n = \int_{E_c}^{+\infty} S(E) \cdot f(E) \cdot dE$$

$$n_e = N_c \, e^{-(E_c - E_f)/KT}$$

for holes/p-type / valance band.

$$n_h = N_v \, e^{-(E_f - E_v)/KT}.$$

↑ effective density of state in valance band.

$$n_i^2 = n_e \cdot n_h = N_c \cdot N_v \cdot e^{-E_g/KT}$$

Unit 2 - Summary.

① Diode- current Equation

$$\rightarrow I = I_S \left(e^{\frac{V_D}{\eta V_T}} - 1 \right)$$

→ V_D = voltage across diode

→ η = 1 for Ge, 2 for Si } Ideality factor.

→ V_T = voltage equivalent for temperature

⇒ $\frac{KT}{q}$ { K = boltzman's constant } { T = absolute temperature in K° }

→ I = diode current

② forbidden energy gap ⇒ energy difference b/w V.B and C.B.

③ Half wave rectifier

	Half wave rectifier	full-wave rectifier
① average D.C current	$= I_m/\pi$	$\frac{I_m}{\pi} \times 2$
② R.M.S load current	$= I_m/2$	$I_m/\sqrt{2}$
③ form factor $= \frac{\text{R.M.S value}}{\text{DC value}}$	$= 1.57$	1.11
④ efficiency $= \frac{\text{output DC}}{\text{Input AC}}$	$= 40.6\%$	81.2%
⑤ DC output voltage	$= \frac{V_m}{\pi}$	$(V_m/\pi) \times 2$
⑥ ripple factor $= \frac{\text{R.M.S of AC output}}{\text{Avg. value of output}}$	↑	↓

$\sqrt{\left(\frac{V_m}{V_{DC}}\right)^2 - 1}$