①

Carrier concentration.

$$n = \int Z(E)\,dE \; F(E).$$

$$= \int \frac{4\pi}{h^3}(2m)^{3/2} E^{1/2}\,dE \times \frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)}$$

$$= \frac{4\pi}{h^3}(2m)^{3/2} \int_{\text{Energy band}} E^{1/2} \frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)}$$

where 'T' is absolute temperature.

Density of electrons in conduction band.
(Intrinsic Semiconduct

$$n = \int_{E_C}^{\infty} Z(E)\,dE \; F(E).$$

$$Z(E)\,dE = \frac{4\pi}{h^3}(2m)^{3/2} E^{1/2}\,dE.$$

$$m = m_e^* \quad \text{and} \quad E^{1/2} = (E - E_C)^{1/2}$$

$$\therefore n = \int_{E_C}^{\infty} \frac{4\pi}{h^3}(2m_e^*)^{3/2}(E - E_C)^{1/2}\,dE \; F(E)$$

$$F(E) = \frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)}.$$

②

$$E_F = \frac{E_C + E_V}{2} \quad \text{(For itrinsic)}$$

$$\therefore F(E) = \left[1 + \exp\left(\frac{E - E_F}{KT}\right)\right]^{-1}$$

If $E - E_F >> KT$

$$F(E) = \exp^{-\left(\frac{E - E_F}{KT}\right)} = \exp\left(\frac{E_F - E}{KT}\right)$$

$$\therefore n = \int_{E_C}^{\infty} \frac{4\pi}{h^3} (2m_e^*)^{3/2} (E - E_C)^{1/2} \exp\left(\frac{E_F - E}{KT}\right) dE$$

$$= \frac{4\pi}{h^3} (2m_e^*)^{3/2} \int_{E_C}^{\infty} (E - E_C)^{1/2} \exp\left(\frac{E_F - E}{KT}\right) dE.$$

$$n = \frac{4\pi}{h^3} (2m_e^*)^{3/2} \exp\left(\frac{E_F}{KT}\right) \int_{E_C}^{\infty} (E - E_C)^{1/2} \exp\left(\frac{-E}{KT}\right) d$$

To solve the above one

Let $E - E_C = x$

$E = x + E_C$

$dE = dx.$

$$\therefore n = \frac{4\pi}{h^3} (2m_e^*)^{3/2} \exp\left(\frac{E_F - E_C}{KT}\right) \int_0^{\infty} x^{1/2} \exp\left(\frac{-x}{KT}\right) dx$$

③

Using γ- function

$$\int_0^\infty x^{1/2} \exp\left(\frac{-x}{KT}\right) dx = (KT)^{3/2} \frac{\pi^{1/2}}{2}$$

$$\therefore n = \frac{4\pi}{h^3} (2m_e^*)^{3/2} \left(\exp \frac{E_F - E_C}{KT}\right) (KT)^{3/2} \frac{\pi^{1/2}}{2}$$

∴ The number of electrons per unit Volume of the material is given by

$$\boxed{n = 2\left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/2} \exp\left(\frac{E_F - E_C}{KT}\right)}$$

Calculation of density of holes.

$$P = \int_{-\infty}^{E_V} Z(E)\, dE \,[1 - F(E)]$$

$$\boxed{\therefore P = 2\left(\frac{2\pi m_h^* KT}{h^2}\right)^{3/2} \exp\left(\frac{E_V - E_F}{KT}\right)}$$