Aayush Koirala

021-304

EEM

TUTORIAL

Date
Page

1. Physical significance of wave function

* The probability that a particle will be found at given place in space at a given instant of time is characterized by function $\psi(x, y, z, t)$ is called wave function

* By knowing the value of ψ we can locate the positions and instantaneous displacement of fast moving particle.

2. probability distribution func.

$$|\psi|^2 = \psi^* \psi$$

where ψ^* is complex conjugate of ψ

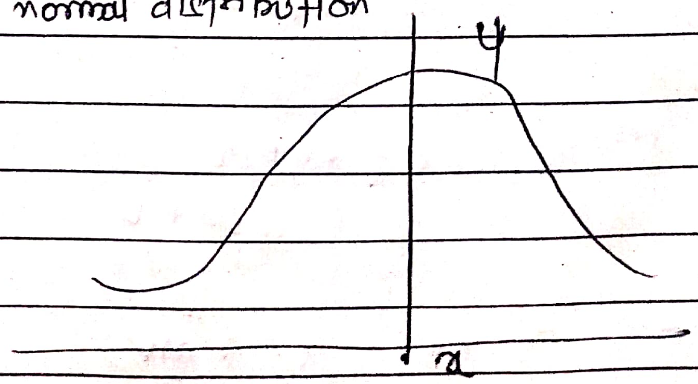
$$p = \int_{x_1}^{x_2} \psi^* \psi \, dx$$

Prob- of finding particle at normalization cond?

$$\int_{-\infty}^{\infty} \psi^* \psi \, dx = 1$$

$$= \int_{0} \psi^* \psi \, dx = 1$$

it obeys normal distribution



Aayush Koirala

021-304

3. Time independent SWE

we have,

$$\psi(x,t) = Ae^{-i/\hbar (Et-px)}$$

diff wrt x,

$$\frac{d\psi}{dx} = A\left(\frac{-i}{\hbar}\right)(-P)e^{-i/\hbar (Et-px)}$$

$$\frac{d\psi}{dx} = \left(\frac{i}{\hbar}\right)(-P)e^{-i/\hbar (Et-px)}$$

$$\frac{d\psi}{dx} = \left(\frac{ip}{\hbar}\right)\psi$$

again, diff wrt x,

$$\frac{d^2\psi}{dx^2} = \frac{-p^2}{\hbar^2}\psi$$

$$p^2\psi^2 = \frac{p^2}{\hbar^2}\psi$$

$$p^2\psi = \frac{p^2}{\hbar^2}\psi$$

$$p^2\psi = -\hbar^2\frac{d^2\psi}{dx^2}$$

consider a particle having mass 'm' and speed 'v' in potential 'V'

total energy = $E = KE + PE$

$$E = \frac{1}{2}mv^2 + V$$

$$E = \frac{p^2}{2m} + V. \quad (\because p = mv)$$

Aayush koirala
021-204

multiplying both side by ψ

$$E\psi = \frac{p^2}{2m}\psi + V\psi$$

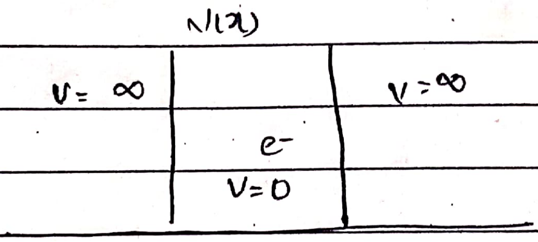
or, $$(E-V)\psi = \frac{p^2 \psi^2}{2m}$$

using eqn (1)

$$(E-V)\psi = \frac{h^2}{2m} \frac{d^2\psi}{dx^2}$$

$$\boxed{\frac{d^2\psi}{dx^2} + \frac{2m}{h^2}(E-V)\psi = 0}$$

3. Energy level inside the potential gradient well:



$$V(x) = \begin{cases} 0, & 0 < x < l \\ \infty, & x \leq 0,\ x \geq l \end{cases}$$

Time independent SWE : $\frac{d^2\psi}{dx^2} + \frac{2m}{h^2}(E-V)\psi = 0$

when $V = 0$

$$\frac{d^2\psi}{dx^2} + k^2\psi = 0 \quad \text{--- (1)}$$

where $k^2 = \frac{2mE}{h^2}$

Aayush Koirala

KCE-204

ψ = Arbitrary function

using boundary condition

i) $\psi = 0$ at $x = 0$

ii) $\psi = 0$ at $x = l$

$\because A \neq 0$

$kl = n\pi$ — (3)

so, (2) becomes

$$\psi = A\sin\left(\frac{n\pi x}{l}\right)$$

$$\psi_n(x) = A\sin\left(\frac{n\pi x}{l}\right)$$

So

$k^2 l^2 = n^2 \pi^2$

$$E_n = \frac{\pi^2 n^2 \hbar^2}{2ml^2}, \quad n = 0, 1, 2, 3$$

this shows energy of particle is quantized

$\hbar = \frac{h}{2\pi}$ $\quad E_n = \frac{\pi^2 n^2 h^2}{(2\pi)^2 \times 2ml^2}$

$= \frac{n^2 h^2}{8ml^2}$

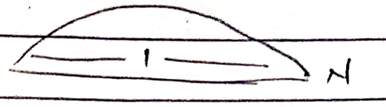
Ayush Koirala

021-304

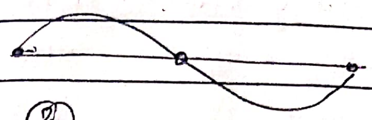
Date

Page

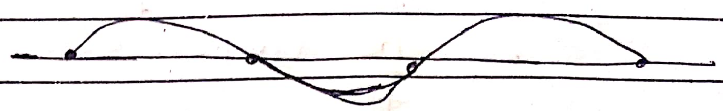
3. Energy level in copper



① $\lambda/2 = l$



② $\frac{2\lambda}{2} = l$



③

$\frac{3\lambda}{2} = l$

consider a copper metal of length l There are free that have KE and consequently the wave associated with it

let λ be the wave length of wave

from ①

$$\lambda = 2L \text{ ——— } ①$$

From ②

$$\lambda = \frac{2l}{2} \text{ ——— } ②$$

From ③ $\frac{3\lambda}{2} = l$

$$\lambda = \frac{2l}{3}$$

For $\frac{n\lambda}{2} = l$

$$\therefore \lambda = \frac{2l}{n}$$

in series,

$$\lambda = \frac{2l}{l}, \frac{2l}{2}, \frac{2l}{3} \text{ - - - } \frac{2l}{n-1}, \frac{2l}{n}$$

then,

$$\text{wave no } (k) = \frac{2\pi}{\lambda}$$

$$k_1 = \frac{2\pi}{\frac{2l}{1}} = 1 \cdot \frac{\pi}{L}$$

$$k_2 = \frac{2\pi}{\frac{2l}{2}} = \frac{2\pi}{L}$$

Aayush koirala

021-204

$\therefore k = \frac{2\pi}{L}, \frac{2\pi}{L}, \frac{3\pi}{L} \ldots \frac{n\pi}{L}$

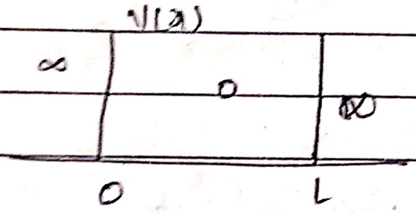
n^{th} energy level $= \frac{\hbar^2 k^2}{2m}$

$= \frac{\hbar^2 \times \pi^2 n^2}{2mL^2}$

$= \frac{\frac{n^2}{4\pi^2} \times n^2 h^2}{2ml^2}$

$$\boxed{E_n = \frac{n^2 h^2}{8ml^2}}$$

4. Infinite 1D potential well,



$V(x) = \begin{cases} 0 \; ; & 0 < x < l \\ \infty \; ; & 0 \geq x \text{ OR } x \geq L \end{cases}$

Time independent SWE:

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{2m}{\hbar^2}(E - V)\psi = 0$$

inside well, $V = 0$

$$\frac{\partial^2 \psi}{\partial x^2} + k^2 \psi = 0 \text{ —— } (1)$$

Aayush Koirala
021-804

where $k = \sqrt{\frac{2mE}{\hbar^2}}$

General soln of eqn (1) is

$$\psi = A\sin kx + B\cos kx \quad \text{——— (2)}$$

at $x = 0$, $\psi(x) = 0$

$0 = 0 + B\cos k0$

$\therefore B = 0$

eqn (2) becomes $\psi = A\sin kx$ ——— (3)

at $x = l$, $\psi(L) = 0$

$0 = A\sin kL$

$\sin L = \sin 0$

or, $kL = n\pi$

$k = \frac{n\pi}{L}$

~~sq~~

$k^2 = \frac{n^2\pi^2}{L^2}$

or, $\frac{2mE}{\hbar^2} = \frac{n^2 h^2}{L^2}$

$\therefore E_n = \frac{n^2h^2}{8ml^2}$ is reqd eqn of energy for

$n = 0, 1, 2, 3 \dots$

This shows energy is quantized

so eqn (3) becomes,

$$\psi = A\sin\left(\frac{n\pi}{L}\right) = x$$

Aayush koirala
021-304

using box normalization condn

$$\int_0 |\psi^2| = 1$$

$$\int_0^l A^2 \sin^2 \left(\frac{n\pi}{L}\right) x \, dx = 1$$

or, $\frac{A^2}{2} \int_0^l \left(1 - \cos\frac{2n\pi x}{L}\right) dx = 1$

or, $\frac{A^2}{2} \int_0^l dx - \frac{A^2}{2} \int_0^l \cos\frac{2n\pi x}{2} dx = 1$

or, $\frac{A^2}{2} * (\alpha - 0) = 1$

or, $LA^2 = 2$

or, $A^2 = 2/L$

$\therefore A = \pm \frac{\sqrt{2}}{L}$

$$\psi = \pm \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi}{L}\right) x$$

The 1st three eigen function ψ_2, ψ_1, ψ_0 together with the probaility densities $|\psi_2|^2, |\psi_1|^2, |\psi_0|^2$.

Aayush Koirala
021-304

6.

Hisenberg Uncertanity principle

If Δx and Δp are uncertanity in position & momentum of an electron during simultaneously measurement along x, then uncertanity principle states that their product must be greater or equal than $\hbar$.

i.e $\Delta x \; \Delta p \geq \hbar$

similarly

$$\Delta E \cdot \frac{\Delta t}{2} \geq \hbar$$

Here energy and time pairs that follows uncertanity principles callee cannonical conjugate pairs.

Eg:

consider an electron in 1-D Infinite potential well having t extending $x = 0$ to $x = L$ so uncertanity in position is equal to width 'l' of well. The momentum is

$$p_x = \hbar k \; (+ve) \; axis$$

$$= \hbar k \; (-ve) \; axis$$

$$\Delta p_x = \frac{2\hbar k}{L}$$

where $n = 1$ and $kL = n$ (ground state)

$$\therefore \Delta p_x = \frac{2\hbar \pi}{L}$$

Aayush Koirala
021-304

Date
Page

(5) Finite potential barrier

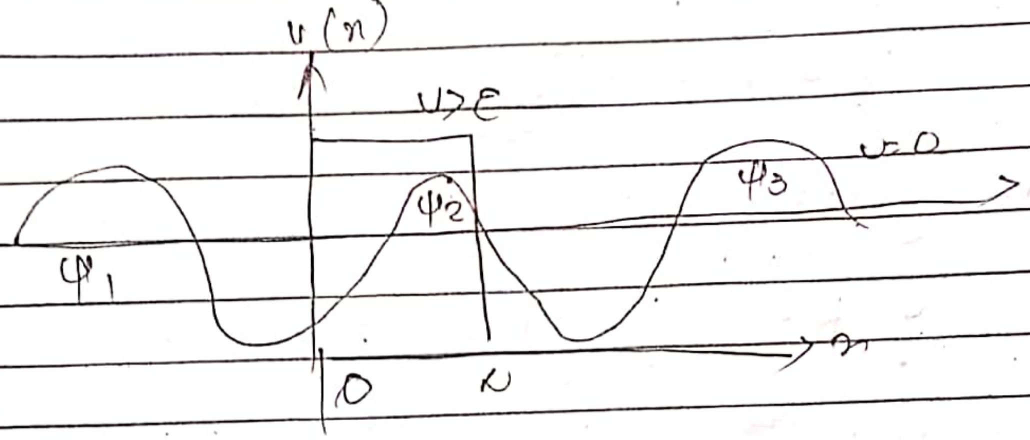


fig :- Potential barrier

$$V(x) = \begin{cases} 0 & \text{for } x<0 \ \& \ x>l \\ V & \text{for } 0<x<l \end{cases}$$

Consider a barrier of potential 'V' having width 'l'. A moving particle of energy $E<V$ is moving along x-axis & strikes the pot^n box of height V
Classically the particle return back after striking the box. Since $E<V$ but according to Qm there is small possibility of transmission of very small amount through box by penetration and this effect is called tunneling effect

The time independent SWE for region I is

$$\psi_1 = \frac{\partial^2 \psi_1}{\partial x^2} + \frac{2m}{\hbar^2}(E-0) = 0$$

Aayush Koirala
021-304

or, $\frac{\partial^2 \psi_1}{\partial x^2} + k_1^2 \psi = 0$

where $k_1 = \sqrt{\frac{2mE}{\hbar^2}}$

The general sol^n of eq^n (1) is

$\psi_1 = Ae^{ik_1x} + Be^{-ik_2x}$

(2) For region II

$\psi_2 = \frac{\partial^2 \psi_2}{\partial x^2} - \frac{2m}{\hbar^2}(U-E)\cdot\psi_2 = 0$

$\frac{\partial^2 \psi_2}{\partial x^2} - k_2^2 \psi_2 = 0$ —— (ii)

where $k_2 = \sqrt{\frac{2m(U-E)}{\hbar^2}}$

The general sol^n of eq^n (ii) is

$\psi_2 = Ce^{+k_2x} + De^{-k_2x}$

(3) For region III

$\frac{\partial^2 \psi_3}{\partial x^2} + k^2 \psi = 0$ same as (1)

where $k_3 = \sqrt{\frac{2mE}{\hbar^2}}$ —— (iii)

The general sol^n of eq^n (iii) is

$\psi_3 = Fe^{ik_3x} + Ge^{ik_3x}$

$\psi_3 = Fe^{ik_1x} + Ge^{-ik_1x}$

Aayush koirala
021-304

Date
Page

where
A → amplitude of incident wave in 1
B → amplitude of ~~transmitted~~ reflected wave in 1
F → amplitude of transmitted in 3
G → " " reflected " "
C → " " penetrated wave in 2
D → " " reflected wave in 2

transmission coff (T) $= \left|\frac{F}{A}\right|^2$

$$T = \frac{16E(U-E)}{U^2} e^{-2k_2 L}$$

6) Define fermi energy & degenerate states. What is probability that an electron having energy less than fermi energy will occupy an energy level at absolute zero temperature? What is probability for higher energies at any temp rather than absolute zero?

ans 'Degenerate State'
Two or more energy state are said to be degenerate if they give same energy upon measure.
we have

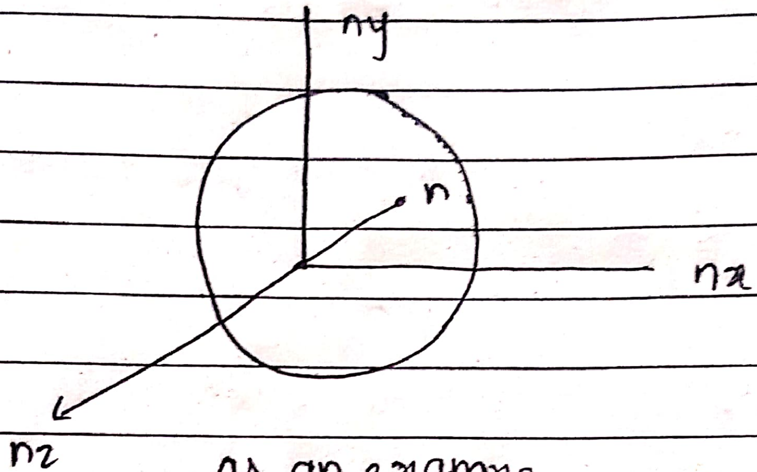
$$E = \frac{n^2 h^2}{8mL^2}$$

Aayum Koirala
021-304

For 3-D

$E = E_x + E_y + E_z$

$n^2 = n_x^2 + n_y^2 + n_z^2$



as an example

$$E = \frac{(n_x^2 + n_y^2 + n_z^2)\, h^2}{8ml^2}$$

① $(n_{x_1}, n_{y_1}, n_{z_1}) = (2,1,1)$

$$E_1 = \frac{6h^2}{8ml^2}$$

② $(n_x, n_y, n_z) = (1,2,1)$

$$E_2 = \frac{6h^2}{8ml^2}$$

③ $(1,1,2)$

$$E_3 = \frac{6h^2}{8ml^2}$$

Aayush Koirala
021-304

Numericals:

1. Soln

$l = 0.2mm$ wide
$= 0.2 \times 10^{-3} m$

we know,

$E = \frac{n^2 h^2}{8 m l^2}$ for, e^-; $m = 9.1 \times 10^{-31}$

$= \frac{n^2 \times (6.62 \times 10^{-34})^2}{8 \times (9.1 \times 10^{-31}) \times (0.2 \times 10^{-3})^2}$

for

$n = 1$

$E_1 = 1.50 \times 10^{-30} J$

for $n = 5$

$E_5 = 3.76 \times 10^{-29} J$

also

$E_5 - E_1 = 2.61 \times 10^{-29} J$.

Aayush Koirala
021-304

Q. Soln

wavelength(λ) = 980 nm
= 980×10^{-9} m

$v = ?$

We know,

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

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

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

or, $$v = \frac{h}{m\lambda}$$

or, $$v = \frac{6.62 \times 10^{-34}}{9.1 \times 10^{-31} \times 980 \times 10^{-9}}$$

$\therefore$ Velocity (v) = 742.3 m/s

Aayush Koirala
021-304

3. Soln.

Width of well(L) = 8.5nm
$= 8.5 \times 10^{-9}$ m

$E_1 = ?$
$E_4 - E_1 = ?$

$$E = \frac{n^2h^2}{8mL^2}$$

$$= \frac{n^2 (6.62 \times 10^{-34})^2}{8 \times (9.1 \times 10^{-31})(8.5 \times 10^{-9})^2}$$

for

n=1

$E_1 = 8.33 \times 10^{-22}$ J

n = 4

$E_4 = 1.33 \times 10^{-20}$ J

$E_4 - E_1 = 1.24 \times 10^{-20}$ J

also,

we know,

$E_1 = hf$

$$f_1 = \frac{E_1}{h} = \frac{8.33 \times 10^{-22}}{6.62 \times 10^{-34}}$$

$f_1 = 1.25 \times 10^{12}$

$\omega_1 = 2\pi f_1 = 7.90 \times 10^{12}$.

Aayush Koirala
021-304

again

$$E_4 - E_1 = \frac{hc}{\lambda}$$

or, $1.24 \times 10^{-20} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{\lambda}$

$\lambda = 1.6 \times 10^3 m$

4 soln.

From F-D distribution

$$F(E) = \frac{1}{1+e^{\frac{E-E_F}{KT}}}$$

or, $30\% = \frac{1}{1+e^{\frac{0.75 \times 10^{-19} \times 1.6}{kT}}}$

or, $0.3 \left(1+e^{\frac{0.75 \times 10^{-19} \times 1.6}{KT}}\right) = 1$

or, $1 + e^{\frac{1.2 \times 10^{-19}}{kT}} = 10/3$

or, $e^{\frac{1.2 \times 10^{-19}}{kT}} = 7/3$

or, $\frac{8691.55}{T} = \ln\left(\frac{7}{3}\right)$

Aayush Koirala

021-304

Date

Page

9. $T = 10257.96K$

5. <u>soln.</u>

$L = 0.1 \times 10^{-9} m$

$\Delta P = ?$ (momentum uncertainity)

$\Delta E = ?$ (Kinetic uncertainity)

we know,

$$\Delta P \geq \frac{h}{2\pi}$$

$$\Delta P = \frac{6.62 \times 10^{-34}}{2 \times \pi \times 0.1 \times 10^{-9}}$$

$$\Delta P = 1.05 \times 10^{-24} \text{ kg m/s}$$

OR,

$$\Delta KE = \frac{\Delta P^2}{2m}$$

$$= \frac{1.11 \times 10^{-48}}{2.91 \times 10^{-31}}$$

$$= 6.090 \times 10^{-19} J$$

Aayush Koirala

021-304

6. Soln.

$$y = A\sin 2\pi \left(Et - x/\lambda\right)$$

$$y = A\sin \frac{1}{\hbar}\left(Et - px\right) \quad \text{——— (1)}$$

$$= A\cos\left(\frac{Et - px}{\hbar}\right) * \frac{-p}{\hbar}$$

$$\therefore \frac{\partial y}{\partial x} = A\frac{p}{\hbar}\cos\left(\frac{Et - px}{\hbar}\right)$$

again diff,

$$\frac{\partial^2 y}{\partial x^2} = \frac{p^2}{\hbar^2} A\sin\left(\frac{Et - px}{\hbar}\right)$$

$$\frac{\partial^2 y}{\partial x^2} = \left(\frac{-p}{\hbar}\right)^2 y$$

$$\frac{\partial^2 y}{\partial x^2} + \left(\frac{p}{\hbar}\right)^2 y = 0$$

$$E = \frac{p^2}{2m} + V$$

$$Ey = \frac{p^2 \psi}{2m} + Vy$$

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{2m}{\hbar^2}(E - V)y = 0$$

Aayush Koirala
021-304

Date
Page

7. Soln.

$$\Delta x \cdot \Delta p \geq \frac{h}{2\pi}$$

$$\Delta x \geq \frac{h}{2\pi \times m \Delta v}$$

$$= \frac{6.62 \times 10^{-34}}{2\pi \times 9.1 \times 10^{-31} \times 2 \times 10^{6}}$$

$$= 5.78 \times 10^{-11} m$$

8. Soln.

$$\psi_n = \left(\frac{2}{L}\right)^{1/2} \sin \frac{n\pi}{2} x$$

To find expected value of pos

$$x = \int_0^L \psi^* \psi \, dx$$

$$= \frac{2}{L} \int_0^L x \left[\sin^2 \left(\frac{n\pi}{L}\right) x \, dx\right.$$

$$= 2 \times \frac{2}{L} \times \int_0^L x \left(1 - \frac{\cos 2n\pi}{L} x\right) dx$$

Aayush Koirala
021-304

$$= \frac{1}{L} \times \int_0^L x\,dx$$

$$= \frac{1}{L} \times \left[\frac{x^2}{2}\right]_0^L$$

$$= \frac{1}{L} \times \frac{L^2}{2}$$

$$= \frac{L}{2}$$

expected value of momentum.

$$\langle p \rangle = \int_0^L \psi \times p\psi\,dx$$

$$\hat{p} = \frac{\hbar}{L} \frac{\partial \psi}{\partial x}$$

$$p\psi = \frac{\hbar}{1} \frac{\partial \psi}{\partial x}$$

$$= i\hbar \frac{\partial \psi}{\partial x}$$

Now,

$$\int_0^L \psi \times \left[-\hbar i \frac{d\psi}{dx}\right] dx$$

Aayush koirala
021- 304

$$= \hbar i \times \int_0^L \left(\frac{2}{L}\right)^{1/2} \sin\frac{n\pi}{L} x \times d \left(\frac{2}{L}\right)^{1/2} \sin\frac{n\pi x}{L}$$

$$= i\hbar \times \frac{2}{L} \times \int_0^L \sin\frac{n\pi x}{L} \times \cos\frac{n\pi x}{L} \times \frac{n\pi}{L} dx$$

$$= \frac{i\hbar n\pi}{L^2} \times \int_0^L \sin\frac{2n\pi x}{L} dx$$

$$= \frac{i\hbar n\pi}{L^2} \left[\frac{\cos\frac{2n\pi x}{L}}{\frac{2n\pi}{L}} \right]_0^L$$

$$= \frac{-i\hbar n\pi}{L^2} \times \frac{L}{2n\pi} \times \left[(-1)^{2n} - 1\right]$$

$$= 0$$

$\therefore \langle p \rangle = 0$

021 · 304
Aayush koirala

9 Soln

$\lambda = 10^{-10} m$

$M_n = 1.67 \times 10^{-27}$

$KE = ?$

we know,

$KE = 1/2 mv^2$

$= \frac{1}{2} \times m \times \frac{h^2}{m^2 \lambda^2}$

$= \frac{h^2}{2m\lambda}$

$= \frac{(6.67 \times 10^{-34})^2}{2 \times 1.67 \times 10^{-27} \times (10^{-10})^2}$

$= 1.31 \times 10^{-20} J$

$= \frac{1.31 \times 10^{-20}}{1.60 \times 10^{-19}} eV$

$= 0.083 eV.$

Aayush Koirala
021-304

Date
Page

10. Soln

$l = 0.1 \times 10^{-8} m$

$E_n = \frac{n^2 h^2}{8 m l^2}$

$= \frac{n^2 \times (6.62 \times 10^{-34})^2}{8 \times 9.1 \times 10^{-31} \times (0.1 \times 10^{-9})^2}$

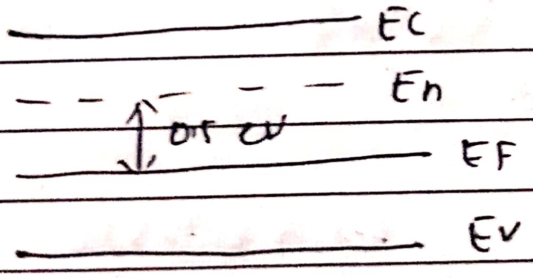
For, $n = 1$

$E_1 = 6.01 \times 10^{-18} J$

for $n = 5$

$E_5 = 1.80 \times 10^{-16}$

11. Soln



($\mu = 450 \, cm^2 \, V^{-1} s^{-1}$ at 300K

Here fermi-level is below intrinsic Fermi level
∴ given material tye p type

Aayush Koirala
021-304

∴ holes con is given by

$$P = Nve^{-(E_F - E)/KT}$$ $\left[\begin{array}{l} m_c^* = 1.08\,me \\ m_n^* = 0.56\,me \end{array}\right]$

$$N_0 = \frac{2(2\pi \times m_n^* \cdot KT)^{3/2}}{h^2}$$

$$= \frac{2^*(2\pi(0.56 \times 9.1 \times 10^{-16}) \times 1.38 \times 10^{-23} \times 300h)^{3/2}}{(6.62 \times 10^{-34})^2}$$

$= 1.05 \times 10^{25} m^{-3}$

similarly,

$N_c = 2.8 \times 10^{20} cm^{-3}$

The intrinsic con?

$$N_i = \sqrt{N_c N_v} * e^{-\left[\frac{E_g}{2KT}\right]}$$

$\boxed{= 1.45 \times 10^{16}}$

$$P = n_i \times e^{\frac{E_i - E_F}{2KT}}$$

$$= 1.45 \times 10^{16} \times e^{\frac{0.5 \times 10^{-19} \times 1.6}{2 \times 1.38 \times 10^{-23} \times 300}}$$

$= 2.825 \times 10^4 \, m^{-3}.$

Aayush koirala

021-304

Date ____
Page ____

2. soln.

$np = ni^2$

$n = \frac{ni^2}{P}$

$= \frac{(1.45 \times 10^{10})^2}{2.\cancel{85} \times 10^{24}}$

$= 4.64 \times 10^{6} m^{-3}$

$n <<< p$ so the conductivity

$\sigma = Pe\,\mu_a$

$= 2.84 \times 10^{24} \times 1.6 \times 10^{-13} \times 450 \times 10^{-4}$

$= 20340 \Omega^{-1} m^{-1}$

3. soln

$n = ni \times e^{\left(\frac{Ec - Efi}{KT}\right)}$

$N = Nd - Nb = 1.45 \times 10^{16} \times e^{\frac{0.1 \times 1.6 \times 10^{-19}}{1.38 \times 10^{-23} \times 300}}$

$= 5.46 \times 10^{17} m^{-3}$

Aayush Koirala
021-209.

13. Soln

$$FD = \frac{1}{1+e^{\frac{E-EF}{KT}}}$$

For, T=0K, E >>>> EF

$$FD = \frac{1}{1+e^{+ve/\infty}}$$

$$= \frac{1}{1+\infty}$$

FD = 0 (probability)

Hence it is verified.

14. Soln

built in potential

$n_i = 1.145 \times 10^{16} m^{-3}$.

given,

$N_0 = 10^{16} cm^3$

$N_d = 107\ cm^{-3}$

$N_i = 45 \times 1010\ cm^{-3}$

$$V_0 = \frac{KT}{e} \ln \frac{N_0 N_d}{n_i^2}$$

Aayush Koirala

021 - 304

$$= 26 \times 10^{-3} \times \ln \frac{10^{17} \times 10^{16}}{(1.45 \times 10^{10})^2}$$ [at 300K $\frac{KT}{e} = 26mV$]

$= 0.756\ V$

17. $\underline{soln.}$

$T = 0K$

density of copper $(\rho) = 8.96 gm/cm^3$

atomic mass $(m) = 63.5 gm/mole$

$N_a = 6.22 \times 10^{23}/mole$

fermi energy $(E_F) = ?$

$$E_F = \frac{h^2}{4\pi^2 \times 2m_e} (3\pi^2 \times n)^{2/3}$$

$$n = \frac{\rho N}{m^+} = \frac{8.96 \times 6.022 \times 10^{23}}{63.5}$$

$= 8.5 \times 10^{23}\ /cm^3$

$= 8.5 \times 10^{28}\ /m^3$

$$E_F = \frac{(6.62 \times 10^{-34})^2}{4\pi^2 \times 2 \times 1.6 \times 10^{-19}} (3\pi^2 \times 8.5 \times 10^{28})^{2/3}$$

$= 1.128 \times 10^{-18} J$

Date
Page

Aayush koirala
021-304

18 Soln

$T = 8000k$
$\mu_e = 1300 cm^2 v^{-1} s^{-}$

using einesteines relation

$\frac{D_e}{\mu_e} = \frac{KT}{e}$ at 300K

or, $D_e = (26 \times 10^{-3}) \times \mu_e$

$D_e = (26 \times 10^{-3}) \times 1300$

$= 33.7 cm^2 s^{-1}$

20. Soln.

$T = 20°C = 293K$
resistance $(\rho) = 0.69 \times 10^{-8} \Omega^{-1} m$

density of free electron $(n) = 8.5 \times 10^{28}$

$m^* = 1.01 m_e$
$= 1.01 \times 9.1 \times 10^{-31}$
$= 9.191 \times 10^{-31}$ kg

Aayush Koirala

021-204

conductivity (σ) $= ne\mu$

$= \frac{ne^2\tau}{m}$

$\rho = \frac{m}{ne^2\tau}$

$\tau = \frac{m}{ne^2\rho}$

$= \frac{9.191 \times 10^{-31}}{(1.6 \times 10^{-19})^2 \times 8.5 \times 10^{28} \times 0.09 \times 10^{-13}}$

$= 6.12 \times 10^{-14}$

Q1 Soln

$\lambda = 980$ nm

$= 980 \times 10^{-9}$ m

$v = ?$

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

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

$v = \frac{h}{m\lambda} = \frac{6.62 \times 10^{-34}}{9.1 \times 10^{-31} \times 980 \times 10^{-9}}$

$= 742.31$ m/s

Date
Page

Aayush Koirala
021-304

23. Soln

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

$= \frac{h}{mv}$

$= \frac{6.62 \times 10^{-34}}{1.67 \times 10^{-27} \times 2900}$

$= 2.08 \times 10^{-10} m$

19. Soln.

relative permittivity $(\epsilon_r) = 2.3$

$\epsilon_0 = 8.85 \times 10^{12}$

(n-side) $N_d = 10^{17} cm^{-3}$

(p-side) $N_a = 10^{16} cm^{-3}$

$n_i = 1.45 \times 10^{10} cm^{-3}$

Now,

$V_0 = \frac{KT}{e} \cdot \ln \frac{N_a \cdot N_d}{(n_i)^2}$

$= 26 \times 10^{-3} \times \ln \frac{10^{17} \times 10^{16}}{(1.45 \times 10)^2}$

$= 0.75 eV.$

Aayush Koirala
021-304

junction width (w) :

$$= \sqrt{\frac{2\epsilon m V_0}{e}\left(\frac{1}{m_r} + \frac{1}{N_d}\right)}$$

$$= \sqrt{\frac{2 \times \epsilon_r \times \epsilon_0 V_0}{e}\left(\frac{1}{10^{10}} + \frac{1}{10^{12}}\right)}$$

$$= \sqrt{\frac{2 \cdot 23 \times 8.855 \times 10^{-12} \times 0.758}{1.6 \times 10^{-19}}\left(\frac{1}{10^{6}} + \frac{1}{10^{17}}\right)}$$

$= 145\ \mu m$.

Q6. Soln.

doped with arsenic (pentavalent)
to calculate conductivity
we can we doner ion only since
$N_d << n_i$ and $p << n$ the electron
dript mobility at $N_d = 10^{17}\ cm^{-3}$

i.e $\mu_e = 850 cm^3 V^{-1} s^{-1}$ at 300K

the reqd conductivity at 300K,

$\sigma = n e \mu_e$

$= 10^{17} \times 1.6 \times 10^{-19} \times 800$

$= 12.85\ m/cm$

Aayush Koirala
021-304

similarly

$\mu_e = 1200 cm^3 V^{-1} s^{-1}$ at 400K

$\sigma = n e \mu_e$

$= 6.725$ m/cm

27 soln.

Hole con. is given by

$n = Na - Nd$
$= 10^{17} - 10^{16}$
$= 9 \times 10^{16} cm^{-3}$

$\therefore e^{-1}$ concn $= \dfrac{(1.45 \times)^2}{1 \times 10^{-16}}$

$= 2336.11 cm^{-3}$