SAP ID - 60004200132
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Engineering Physics.

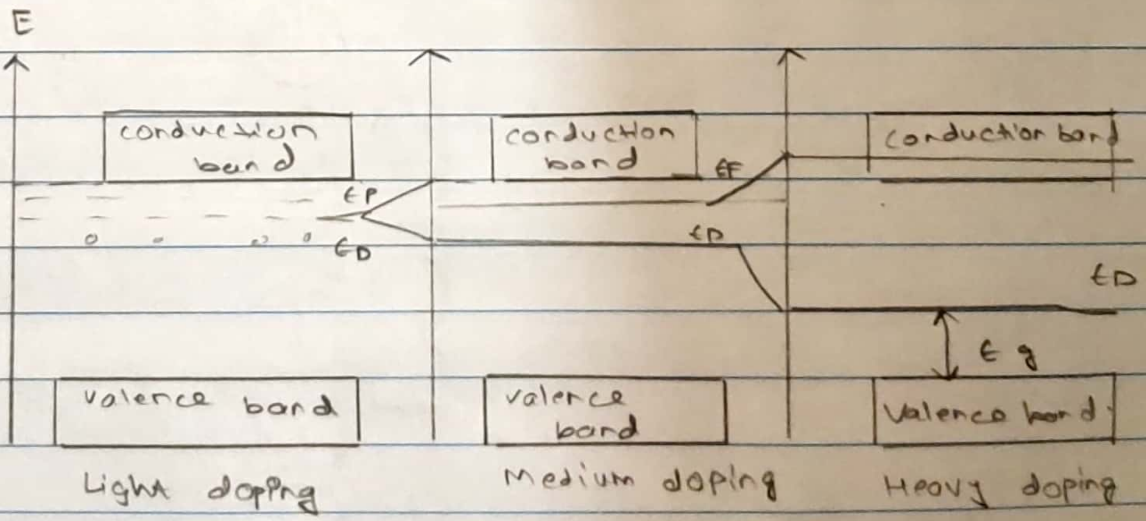
Q. 1 a)

→ i) Effect of dopant concentration on position of fermi level of n time semiconductor.

(a) When impurity concenteration is low, the impurity level is introduced in forbidden gap. When doping concenteration is increased, the impurity atoms interact with each other, impurity level splits and formation of impurity band starts.

(b) With increasing doping concenterations, the band widens and overslap with conduction band. Band gap of semiconductor reduces along with shifting of fermi level.

(c) In n-type, fermi level shifts upwards and enter in conduction band.



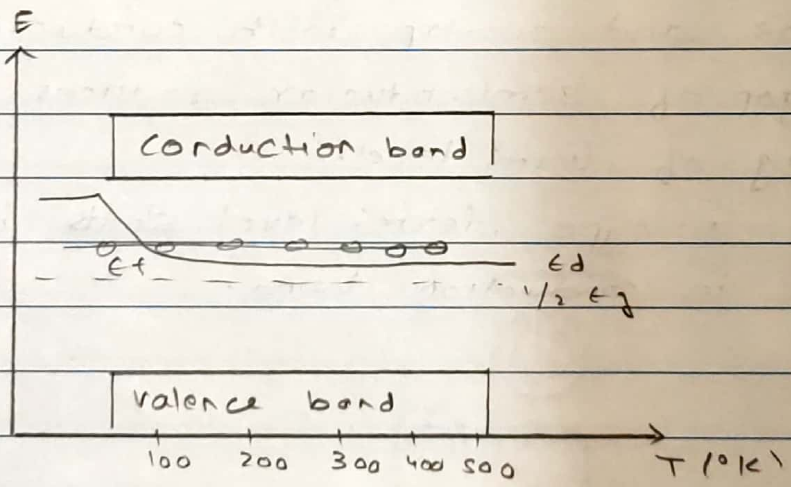
ii) Effect of temperature.

(a) At very low temperature, n-type the fermi level lies between the conduction band and donor energy level.

(b) As temperature increases, electrons from the valence band move to conduction band leaving behind holes in conduction band.

(c) Hence, fermi level shifts towards the centre of energy gap i.e. the intrinsic fermi level but never merges with it.

(d)



1.b) Given: $a = 1.5\,\text{Å}$, $b = 2\,\text{Å}$, $c = 2\,\text{Å}$

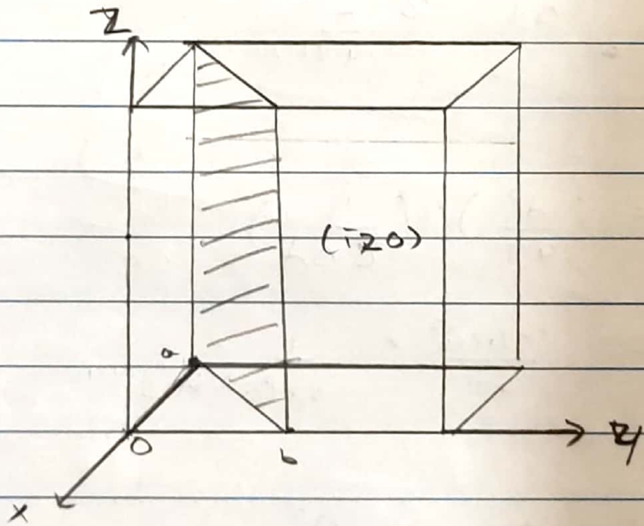
Intercepts, $m = -1.5\,\text{Å}$, $n = 1\,\text{Å}$, $p = \infty$

∴ Intercepts in terms of lattice parameter,

$$\frac{m}{a}, \frac{n}{b}, \frac{p}{c} = \frac{-1.5}{1.5}, \frac{1}{2}, \frac{\infty}{2}$$

∴ Reciprocal: $-1, 2, 0$

∴ Miller indices of plane are $(\bar{1}, 2, 0)$



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Q. 2 a) Derive Schrodinger time independent wave equation

→ i) The general differential equation of a matter wave travelling in x-direction is given by

$$\frac{\partial^2 \psi}{\partial x^2} = \frac{1}{u^2}\frac{\partial^2 \psi}{\partial t^2} \quad \text{— (i)}$$

where ψ is wave function
u = phase velocity.

The general solution of above equation is of the form

$$\psi = \psi_0 e^{i(kx-\omega t)} \quad \text{— (2)}$$

where ψ_0 = a constant.

2) Differentiating the equation partially wrt to t,

$$\frac{\partial \psi}{\partial t} = (-i\omega)\psi_0 e^{i(kx-\omega t)} \quad \text{— (3)}$$

3) Differentiating the eq (2) partially wrt t,

$$\frac{\partial^2 \psi}{\partial t^2} = (-i\omega)^2 \psi_0 e^{i(kx-\omega t)}$$

$$= -\omega^2 \psi_0 e^{i(kx-\omega t)}$$

$$= -\omega^2 \psi_0 \quad \text{— (4)}$$

Substituting in equation (i) we get,

$$\frac{\partial^2 \psi}{\partial x^2} = \frac{-\omega^2}{u^2}\psi$$

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iv) But $\omega = 2\pi \cdot \nu = \frac{2\pi u}{\lambda}$, where ν = frequency

$$\therefore \frac{\omega}{u} = \frac{2\pi}{\lambda}$$

$$\therefore \frac{\omega^2}{u^2} = \frac{4\pi^2}{\lambda^2} \quad — (5)$$

v) By de-Broglie hypothesis,

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

$\therefore$ Substituting value of λ in eq (5)

$$\therefore \frac{\omega^2}{u^2} = \frac{4\pi^2 p^2}{h^2} \quad — (6)$$

vi) Total energy = Kinetic energy + Potential energy

$$\therefore TE = \frac{1}{2}mv^2 + P.E$$

$$= \frac{1}{2}\frac{m^2v^2}{m} + PE$$

$$= \frac{p^2}{2m} + PE \quad \ldots (p = mv)$$

$$\therefore p^2 = 2m(TE - PE)$$

vii) Substituting in equation (6),

$$\frac{\omega^2}{u^2} = \frac{8\pi^2 m}{h^2}(TE - PE)$$

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viii) Substituting in eq (4),

$$\frac{\partial^2 \psi}{\partial x^2} = \frac{-8\pi^2 m}{h^2}(TE - PE) \cdot \psi$$

$$\therefore \frac{\partial^2 \psi}{\partial x^2} + \frac{8\pi^2 m}{h^2}(TE - PE)\psi = 0$$

The above equation is used when PE is constant in time but varies in space.

$\therefore$ Replacing the above equation by total derivative,

$$\frac{d^2 \psi}{\partial x^2} + \frac{8\pi^2 m}{h^2}(TE - PE)\psi = 0$$

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Q. 2b) Given : $d = 3\,\mathring{A} = 3 \times 10^{-10}\ m$

$m = 1.675 \times 10^{-27}\ kg$

$\therefore KE = \frac{1}{2} mv^2 \quad ; \quad d = \frac{h}{mv}$

$$\therefore KE = \frac{h^2}{2md^2}$$

$$= \frac{(6.63 \times 10^{-34})^2}{2 \times 1.675 \times 10^{-27} \times (3 \times 10^{-10})^2}$$

$$\therefore \boxed{KE = 1.456 \times 10^{-21}\ J}$$

NOW,

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

$$\therefore v = \frac{h}{md}$$

$$= \frac{6.63 \times 10^{-34}}{3 \times 10^{-10} \times 1.675 \times 10^{-27}}$$

$$\therefore \boxed{V = 1318.61\ m/s}$$

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Q.3 (a)

→ i) A carbon nanotube is a cylindrical rolled up sheet of graphene, which is single layer of graphete atoms arranged in hexagonal pattern. Each nanotube is a single molecule composed of millions of atoms.

ii) Applications of carbon nanotubes are:

(a) Energy storage graphite, carbonaceous materials and carbon fibre electrodes are commonly used in fuel cells, batteries and electromagnetic applications.

(b) Hydrogen storage: The advantage of hydrogen as energy source is that its combution product is water.

(c) Electrochemical supercapacitors: Supercapacitors have a high capacitance and potentially applicable in electronic device. They are comprised of two electrodes seperated by a ionic insulating material.

(d) Field emitting device: If a solid is subjected to a sufficiently high electric field, electrons tunnel through the surface potential barrier of the solid.

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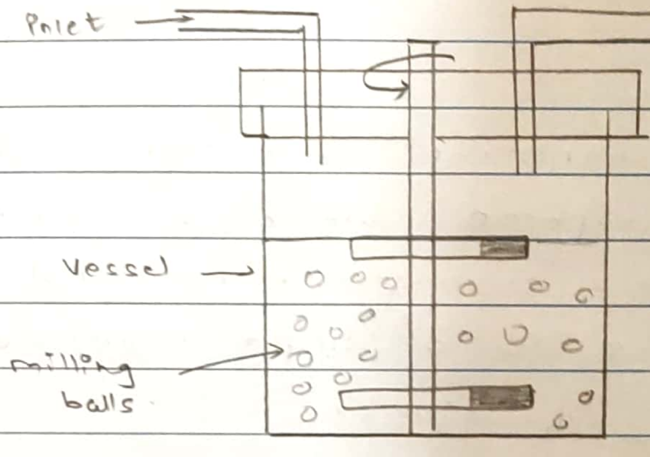
3 b)

→ ④



i) High energy ball milling is a top-down approach technique.

ii) Coarse grained materials are crushed in rotating drums by hard steel and tungsten carbide balls.

3) The grain size in powder samples are reduced to nanometer range by mechanical deformation produced by ball milling process.

4) magnetic and catalytic non-polar ticles are usually produced by this method.

5) The main advantage of top-down approach is high production rates of nano-powders.

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Q.5 a)

→ i) The production of potential difference across on electrical conductor when a magnetic field is applied in a direction ~~perpendicular~~ perpendicular to that of flow current.

2) Let V_H = Hall voltage.

$\therefore E_H$ = Electric Intensity = $\frac{V_H}{d}$

Under equilibrium, forces on the charge carrier q due to the electric field and magnetic field will be equal.

$$\therefore q \cdot E_H = qVB$$

$$\therefore E_H = VB$$

$$\therefore \frac{V_H}{d} = VB \quad \text{or} \quad \boxed{V_H = VBd}$$

We know that, $I = nqaV$

$$\therefore V = \frac{1}{nqa}$$

Putting this in equation, we get

$V_H = \frac{IBd}{nqa}$. Further as $a = w \times d$

$$\therefore V_H = \frac{IB}{nqw}$$

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we also know that current density, $J = \frac{I}{a}$

$\therefore$ Substituting in above expression,

$$V_H = \frac{IBd}{nqa} = \frac{BJd}{nq}$$

$\therefore$ $\boxed{V_H = Bvd = \frac{IB}{nqw} = \frac{BJd}{nq}}$ is the required expression for hall voltage.

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Q. 5 b)

→ We know that

$$E = \frac{hc}{\lambda} \quad -(1)$$

and, $$\Delta E \cdot \Delta t \geq \frac{h}{4\pi} \quad -(2)$$

where, $$\Delta E = \frac{hc \cdot \Delta\lambda}{\lambda^2} \quad -(3)$$

from eq. (i), (2) and (3)

$$\frac{hc\Delta\lambda}{\lambda^2} \cdot \Delta t \approx \frac{h}{4\pi}$$

$$\therefore \Delta t = \left(\frac{\lambda^2}{4\pi}\right) \cdot \left(\frac{1}{c\Delta\lambda}\right)$$

$$\Delta t \simeq \frac{(646\,nm)^2}{4\pi} \times \frac{1}{3\times10^8 \times 10^{-14}}$$

$$\simeq \frac{(646\times10^{-9})^2}{4\pi} \times \frac{1}{3\times10^8 \times 10^{-14}}$$

$$\simeq 11069.65 \times 10^{-12}$$

$$\therefore \boxed{\Delta t \simeq 11\times10^{-9}\ s.}$$

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Engineering Physics - 1

Q.4 a) What is fringe width? Derive the expression for fringe width of wedge shaped film.

→ 1) The distance between two consecutive bright or dark fringes is called the fringe width. The fringe formed at the centre of the fringe pattern is called central bright fringe.

2) For the wedge-shaped film, we have for n^{th} maximum,

$$2\mu t \cos(r+\theta) = (2n-1)\frac{\lambda}{2}$$

For normal incidence and air film,

$$r = 0 \quad \text{and} \quad \mu = 1$$

$$\therefore 2t\cos\theta = (2n-1)\frac{\lambda}{2} \quad \text{—— (1)}$$

where, t is thickness.

The n^{th} bright band is produced at a distance x_n from the edge of the wedge.

$$t = x_n \tan\theta \quad \text{—— (2)}$$

Substituting for t in eq (1),

$$2x_n \tan\theta \cos\theta = (2n-1)\frac{\lambda}{2}$$

$$\therefore 2x_n \sin\theta = (2n-1)\frac{\lambda}{2} \quad \text{—— (3)}$$

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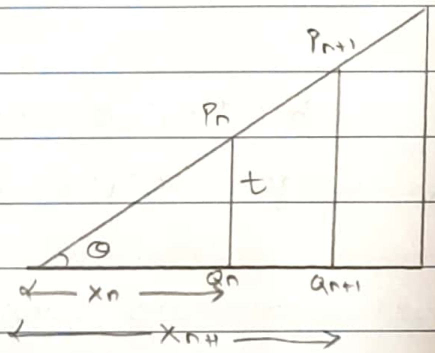

Let $(n+1)^{th}$ maximum be obtained at a distance x_{n+1} from the thin edge.

$$\therefore \quad 2x_{n+1}\sin\theta = (2(n+1)-1)\frac{\lambda}{2}$$

$$\therefore \quad 2x_{n+1}\sin\theta = (2n+1)\frac{\lambda}{2} \quad - \quad (4)$$

$\therefore$ From eq.(3) and eq.(4),

$$2(x_{n+1}-x_n)\sin\theta = \lambda$$

$\therefore$ The spacing between two consecutive bright band is

$$\beta = x_{n+1} - x_n = \frac{\lambda}{2\sin\theta}$$

$\sin\theta \to \theta$ if θ is small and measured in radians.

$$\therefore \quad \beta = \frac{\lambda}{2\theta}$$

For a medium of refractive index μ, $\beta = \frac{\lambda}{2\mu\theta}$

$$\therefore \quad \boxed{\beta = \frac{\lambda}{2\mu\theta}}$$