PHYSICS

Module 1

* Wien's displ. law

$$\lambda_m T = 2.898 \times 10^{-3} mK$$

$$U_\lambda d\lambda = C_1 \lambda^{-5} e^{-(C_2/\lambda T)} \cdot d\lambda.$$

* Rayleigh-Jean's law

$$U_\lambda d\lambda = 8\pi k_B T \cdot \lambda^{-4}$$

* $E = nh\nu$ $\qquad$ $E = mc^2$

h = planck's const. $= 6.626 \times 10^{-34}$ Js

$$\nu = \frac{\Delta E}{h} = \frac{(E_2 - E_1)}{h}$$

* planck's law

$$U_\lambda d\lambda = \frac{8\pi hc}{\lambda^5}\left[\frac{1}{(e^{h\nu/k_B T} - 1)}\right] d\lambda$$

* $$\Delta\lambda = (\lambda' - \lambda) = \frac{h}{mc}(1 - \cos\phi)$$

ϕ = glancing angle $\qquad$ c = speed of light

m = mass of e^-

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

$\therefore p = mv$

p = momentum

$p = mc$

* $c = \lambda\nu$

$$\nu = \frac{E}{h}$$

* $$KE = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$

* $\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$

$\Delta L \cdot \Delta \theta \geq \frac{h}{4\pi}$

$\Delta E \cdot \Delta t \geq \frac{h}{4\pi}$

* $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$ m_0 = rest mass of body

* $|\Psi|^2 = \Psi \cdot \Psi^*$

* $\omega = 2\pi \nu$ $v = \nu \lambda$

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

* $\frac{d^2\Psi}{dx^2} + \frac{8\pi^2 m}{h^2}(E - V)\Psi = 0$ → One dimensional Schröndinger wave eqn.

* Energy eigen value →

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

* Normalised wave fn. → $\Psi_n = \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi}{a}\right) x$

* $p = \sqrt{2mE}$

Module 2

* $V_{avg.} = V'_{avg.} \, e^{-t/\tau_r}$ → decay process eqn.

τ_r = relaxation time

* drift velocity (ϑ_d) : $\vartheta_d = \frac{eE\tau}{m}$

* $F_r = \frac{m\vartheta_d}{\tau}$ $F_d = -eE$

F_r = resistive force F_d = driving force

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* Mean collision time (τ)

$$\tau = \frac{\lambda}{v} \qquad v_{th} >> v_d$$

$$v = v_{th} + v_d \qquad \therefore v \simeq v_{th}$$

* E = electric field = $\frac{V}{L}$

* $I = nev_d A$

$$\sigma = \frac{1}{R} \times \frac{l}{A} \qquad \sigma = \text{conductivity}$$

$$\rho = \frac{RA}{l} \qquad \rho = \text{resistivity}$$

$J = \frac{I}{A}$ = current density

* $$\sigma = \frac{J}{E} = \frac{ne^2\tau}{m}$$

* Mobility $(\mu) = \frac{v_d}{E} = \frac{e\tau}{m}$

* $T_F = \frac{E_F}{k_B}$ $\qquad$ T_F = fermi temp.
E_F = fermi energy

k_B = Boltzmann Const. $= 1.38 \times 10^{-23}$

* Fermi factor

$$f(E) = \frac{1}{1 + e^{(E-E_F)/k_BT}}$$

$f(E)$ = probability of an $\bar{e}$ occupying state of E.

* $$\sigma = \frac{ne^2\lambda_F}{m^* v_F} = \frac{ne^2\tau_F}{m^*}$$

* $g(E)\,dE$ = density of states

$$g(E)\cdot dE = \frac{4\pi}{h^3}(2m^*)^{3/2}\sqrt{E}\,dE$$

for E = energy diff.

* ~~$J = ne v_{de} + pe v_{dh}$~~

$$J = ne\mu_e E + pe\mu_h E$$

For intrinsic SC (semi. cond.)

$$J = n_i E(e\mu_e + p\mu_h)$$

* Conc. of e^- in intr. SC

$$n = N_c e^{-(E_c - E_F)/k_BT}$$

where, $N_c = 2\left[\frac{2\pi m_e^* k_BT}{h^2}\right]^{3/2}$

conc. of h^+ in intr. SC

$$p = N_v e^{-(E_F - E_v)/k_BT}$$

where $N_v = 2\left[\frac{2\pi m_h^* k_BT}{h^2}\right]^{3/2}$

* Law of mass action $\rightarrow$

$$np = N_v e^{-(E_F - E_v)/k_BT} \cdot N_c e^{-(E_c - E_F)/k_BT}$$

for intr. SC, $n = p = n_i$

$$np = n_i^2$$

* $E_F = \frac{E_c + E_v}{2} = \frac{E_g}{2}$ $\quad \because E_g = E_c + E_v$

* Hall coeff. $\rightarrow$ $R_H = \frac{E_H}{JB} = \underbrace{\frac{1}{pe}}_{\text{for } h^+} = \underbrace{\frac{1}{ne}}_{\text{for } e^-}$

* Hall voltage (V_H)

$$V_H = \frac{R_H I B w}{wt} = \frac{R_H I B}{t}$$

w = width of SC $A = wt$.
t = thickness of SC $J = I/A$.

Module 3

* LASER ⟹ Light Amplification by Stimulated Emission of Radiation.

* Requisites of a laser system →
  i) Source of pumping energy
  ii) Active medium
  iii) An optical cavity or resonator. / laser cavity

* Basic principles
  i) Induced absorption
  ii) Spontaneous Emission
  iii) Stimulated Emission

* Conditions for laser action
  i) Population inversion
  ii) Metastable state

* $$\frac{N_2}{N_1} = e^{-(E_2-E_1)/k_BT}$$

* Energy density at equilibrium →

$$U_\nu = \frac{A}{B}\left[\frac{1}{e^{h\nu/k_BT}-1}\right]$$

where, $\frac{A}{B} = \frac{8\pi h \nu^3}{c^3}$

* $N \times \Delta E = P$

no. of photons emitted × energy diff. = power o/p.

* $\frac{n_2}{n_1} = \sin\theta_c$

n_1 & n_2 = RI of med. 1 & med. 2

θ_c = critical angle

* $\sin\theta = \sqrt{n_1^2 - n_2^2}$ ⟹ θ = acceptance angle

$\sqrt{n_1^2 - n_2^2}$ = numerical aperture (NA)

* Δ = fractional index change

$$\Delta = \frac{(n_1 - n_2)}{n_1}$$

n_1 = RI of core n_2 = RI of cladding

$$NA = n_1\sqrt{2\Delta}$$

* net attenuation

$$\alpha = -\frac{10}{L}\log_{10}\left(\frac{P_{out}}{P_{in}}\right) \quad \cdots \text{dB/Km}$$

α = attenuation coeff.

L = length of fiber P_{out} = o/p power

P_{in} = i/p power

* Mode of propagation

$$V = \frac{\pi d\sqrt{n_1^2 - n_2^2}}{\lambda} = \frac{\pi d(NA)}{\lambda}$$

d = core diameter

λ = wavelength of propagating light
for $V >> 1$ no. of modes $= \frac{V^2}{2}$

Module 4

* Electronic polarizability $\alpha_e = \frac{\varepsilon_r(\varepsilon_r - 1)}{N}$

* Electronic polarization, $P_e = N\mu_e$
  N = no. of atoms per m^3

* orientation polarizability $\alpha_o = \mu^2 / 3k_BT$

  " polarization $P_o = N\mu^2 E / 3k_BT$

* Total P $(\alpha) = \alpha_e + \alpha_i + \alpha_o$

* one dimensional internal field expression,

$$\cancel{E_i = \frac{E}{1 - \frac{1.2\alpha_e}{\pi\varepsilon_0 d^3}}} \qquad E_i = E + \frac{1.2\alpha_e E_i}{\pi\varepsilon_0 d^3}$$

in 3D $\longrightarrow$ $E_i = E + (\gamma/\varepsilon_0) P$
P = polarization
γ = proportionality const. $\gamma = 1/3$ for cube

* Clausius - Mossotti relation

$$\frac{\varepsilon_r - 1}{\varepsilon_r + 2} = \frac{N\alpha_e}{3\varepsilon_0}$$

* General form of Miller index (h, k, l)

* inter planar distance (d)

$$d = \frac{a}{\sqrt{h^2+k^2+l^2}} \quad \text{for } a=b=c$$

if $a \neq b \neq c$ then,

$$d = \frac{1}{\sqrt{\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}}}$$

* Atomic packing factor : (η)

$$\eta = \frac{n \times V_a}{V_u}$$

V_u = vol. of unit cell $\quad$ n = no. of atoms
V_a = vol. of atom

* For Simple cubic
  $CN = 6$
  $\eta = 0.52$
  $Z = n = 1$
  $a = 2R$

For body centered cubic (BCC)
  $CN = 8$
  $\eta = 0.68$
  $n = 2$
  $a = 4R/\sqrt{3}$

For face centered cubic (FCC)
  $CN = 12$ $\quad$ $n = 4$
  $\eta = 0.74$ $\quad$ $a = 4R/\sqrt{2}$

* Density = $\frac{\text{mass}}{\text{vol.}}$

$$\rho = \frac{M}{V} = \frac{nA}{N_A V_u}$$

N_A = avagadro's no. $= 6.022 \times 10^{23}$

* Lattice + Basis = crystal structure

* To find miller indices
  i) Intercepts are to be found
  ii) Take reciprocal of intercepts
  iii) Reduce to the smallest integers
  iv) Express in terms of (h, k, l)

* Bragg's law ⇒ $n\lambda = 2d\sin\theta$ → Bragg's eqn.