CMR INSTITUTE OF TECHNOLOGY

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Internal Assesment Test - II

Sub:	Engineering Physics							Code:	15PHY22
Date:	09/ 5 / 2017	Duration:	90 mins	Max Marks:	50	Sem:	II	Branch:	All
Answer Any **FIVE FULL** Questions									

Note: Value of Constants: $h = 6.625\times10^{-34}$ Js, $c = 3\times10^{8}$ m/s, $k = 1.38\times10^{-23}$ J/K

Q. No.		Question	Marks	OBE CO	OBE RBT
1	(a)	Derive an expression for electrical conductivity in an intrinsic semiconductor. State and explain law of mass action for semiconductors.	[6]	CO3	L3
	(b)	Distinguish between Type I and Type II superconductors.	[4]	CO3	L2
2	(a)	Obtain an expression for energy density of radiation under thermal equilibrium in terms of Einstein's coefficients.	[6]	CO4	L3
	(b)	Explain the method of recording hologram and reconstruction of image in Holography.	[4]	CO4	L1
3	(a)	Describe the construction of CO_2 laser and explain its working with the help of energy level diagram.	[7]	CO4	L2
	(b)	The ratio of population of two energy levels is 1.6×10^{-30}. Find the wavelength of light emitted by spontaneous emission at 330 K.	[3]	CO4	L3
4	(a)	What is numerical aperture? Obtain an expression for numerical aperture and arrive at the condition for propagation of signal in an optical fiber.	[7]	CO4	L3
	(b)	The attenuation in an optical-fiber is 5.5 dB/km. What fraction of its initial intensity remains after 6 km?	[3]	CO4	L3
5	(a)	Explain in brief the seven crystal systems with neat diagrams.	[7]	CO5	L2
	(b)	Sketch the following planes in a cubic unit cell. (2 0 0), (1 1 0) & $(1\bar{1}0)$	[3]	CO5	L2
6	(a)	Describe the construction and working of Bragg's X-ray spectrometer and explain how it is used for the determination of inter-planar spacing.	[6]	CO5	L3
	(b)	Copper has fcc structure and its atomic radius is 0.1278 nm. Calculate the inter-planar spacing for (111) plane.	[4]	CO5	L3
7	(a)	Explain the crystal structure of diamond with the help of a neat diagram.	[5]	CO5	L2
	(b)	Define atomic packing factor (APF) and calculate the APF for BCC and FCC structures.	[5]	CO5	L2

ENGG PHYSICS IAT-2

SCHEME OF EVALUATION

1. a.[3]

Conductivity of Intrinsic semiconductors:

Current density J = n e V_d

For a semiconductor, J = n_e e V_d (e) + n_h e V_d (h) ....(1) .[1]

But drift velocity V_d = μE=μ.J/σ

Using (1), σ = n_e e μ_e + n_h e μ_h

In an intrinsic semiconductor, number of holes is equal to number of electrons.

, $\sigma_{int} = n_e e[\mu_e + \mu_{hole}]$.[2]

n_e is the electron concentartion

n_p is the hole concentration

μ_e is the mobility of electrons

μ_h is the mobility of holes

Law of mass action: .[3]

The product of electron and hole concentration is constant at any given temperature independent of Fermi energy & type of doping.This principle is used to calculate hole and electron densities.

$$n_e n_h = 4\left(\frac{kT}{2\pi h^2}\right)^3 (m_e^* m_h^*)^{\frac{3}{2}} e^{-\frac{E_g}{kT}} = a \text{ constant}$$

Electron concentration $n_e = 2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{\frac{3}{2}} e^{-\left(\frac{E_c - E_F}{kT}\right)}$.[1]

Hole concentration $n_h = 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{\frac{3}{2}} e^{-\left(\frac{E_F - E_{VF}}{kT}\right)}$.[1]

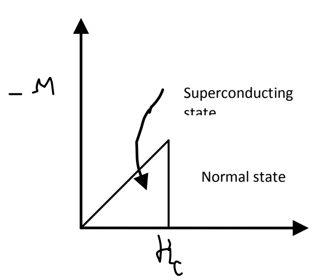
For Intrinsic semiconductor $n_e = n_h = n_i$

hence

$$n_i^2 = n_e n_h = 4\left(\frac{kT}{2\pi h^2}\right)^3 (m_e^* m_h^*)^{\frac{3}{2}} e^{-\frac{E_g}{kT}} = a \text{ constant}$$.[1]

1.b. .[4]

Type 1 Superconductors: .[2]

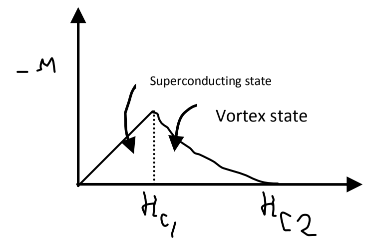


These are pure superconductors.When kept in magnetic field, initially they continue to exhibit superconductivity and the negative magnetic moment increases. At critical magnetic field there is a sharp transition to normal state due to the penetration of magnetic flux lines. The transition is sharp.

These possess low critical magnetic fields. Their critical temperatures also low.They are generally pure metals.

Ex: Al, Pb

Type 2 superconductor: .[2]



These are generally alloys.

When kept in magnetic field, initially they continue to exhibit superconductivity and the negative magnetic moment increases. At lower critical magnetic field H_{C1}, the flux lines start penetrating .As the magnetic field is increased, the super conductivity coexists with magnetic field and this phase is known as mixed state(vortex state). At higher critical magnetic field H_{C2}, the penetration is complete and the material transforms to normal state. They possess higher critical magnetic fields. Their critical temperatures are high.

Ex: Nb_3Ge, $YBa_2Cu_3O_7$

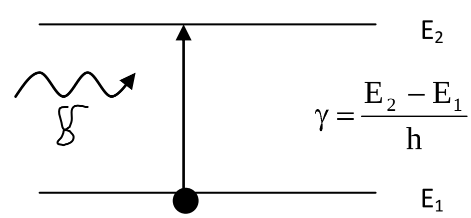
2.a

Expression for energy density: .[6]

Induced absorption: .[2]

It is a process in which an atom at a lower level absorbs a photon to get excited to the higher level.

Let E_1 and E_2 be the energy levels in an atom and N_1 and N_2 be the number density in these levels respectively. Let U_γ be the energy density of the radiation incident.



Rate of absorption is proportional to the number of atoms in lower state and also on the energy density U_γ.

Rate of absorption = B_{12} N_1 U_γ

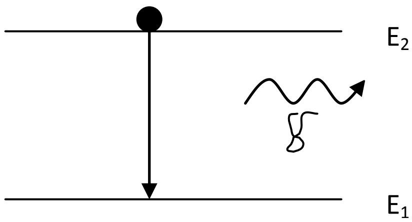
Here B_{12} is a constant known as Einsteins coefficient of spontaneous absorption.

Spontaneous emission:

It is a process in which ,atoms at the higher level voluntarily get excited emitting a photon. The rate of spontaneous emission representing the number of such deexcitations is proportional to number of atoms in the excited state.

Rate of spontaneous absorption = A_{21} N_2

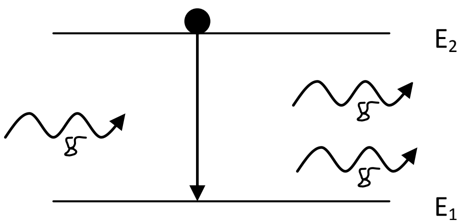
Here B_{12} is a constant known as Einsteins coefficient of spontaneous emission.



$$\gamma = \frac{E_2 - E_1}{h}$$

Stimulated emission:

In this process, an atom at the excited state gets deexcited in the presence of a photon of same energy as that of difference between the two states.



$$\gamma = \frac{E_2 - E_1}{h}$$

The number of stimulated emissions is proportional to the number of atoms in higher state and also on the energy density U_{γ}.

Rate of stimulated emission = $B_{21}\, N_2\, U_{\gamma}$

Here B_{21} is the constant known as Einsteins coefficient of stimulated emission.

At thermal equilibrium,

Rate of absorption = Rate of spontaneous emission + Rate of stimulated emission

$B_{12}\, N_1\, U_{\gamma} \;=\; A_{21}\, N_2 \;+\; B_{21}\, N_2\, U_{\gamma}$.[2]

$$U_{\gamma} = \frac{A_{21} N_2}{B_{12} N_1 - B_{21} N_2}$$

Rearranging this, we get

$$U_{\gamma} = \frac{A_{21}}{B_{21}} \left[\frac{1}{\frac{B_{12} N_1}{B_{21} N_2} - 1} \right]$$

By Boltzmans law , $\frac{N_1}{N_2} = e^{\frac{h\gamma}{kT}}$

Hence

$$U_{\gamma} = \frac{A_{21}}{B_{21}} \left[\frac{1}{\frac{B_{12}}{B_{21}} e^{\frac{h\gamma}{kT}} - 1} \right]$$.[2]

From Planck's radiation law,

$$U_{\gamma} = \frac{8\pi h \gamma^3}{c^3} \left[\frac{1}{e^{\left[\frac{h\gamma}{kT}\right]} - 1} \right]$$

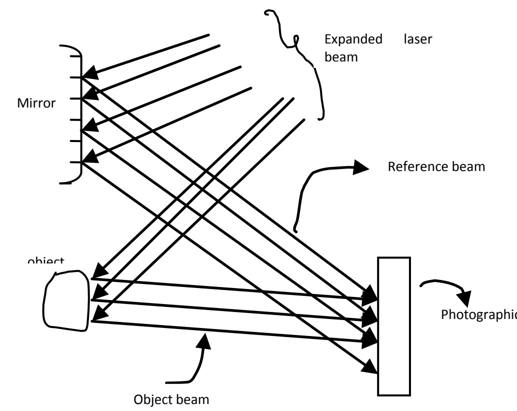
Comparing these expressions, we get

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h \gamma^3}{c^3} \quad \text{and} \quad \frac{B_{12}}{B_{21}} = 1$$

$$\therefore U_{\gamma} = \frac{A}{B} \left[\frac{1}{e^{\frac{h\gamma}{kT}} - 1} \right]$$

2.b. .[4]

Recording of the image of an object :

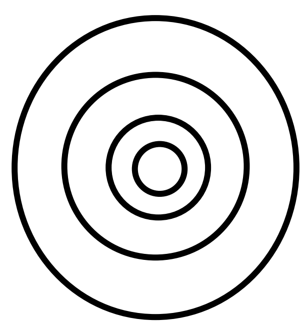


The given object , mirror and photographic plates are arranged as shown in the figure .An expanded laser beam is directed on this arrangement in which a part of the beam is incident on the mirror and the rest falls on the object.

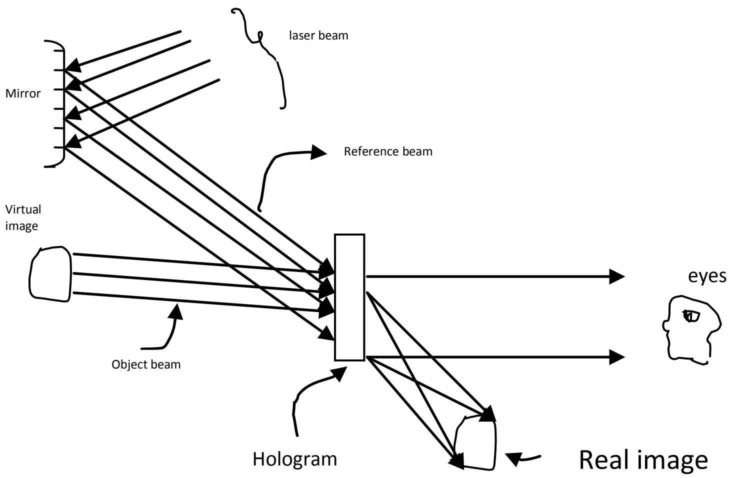
The photographic plate is placed such that it receives the reflected beam (reference beam) and light scattered from the object (object beam).

Due to the interference between plane wavefronts of reference beam and spherical wavefronts of object beam , an interference pattern is formed on the photographic plate. This will be called as a hologram. .[2]

Hologram :



Reconstruction of the image:



The image of the object is reconstructed by passing the reference beam from the same laser through the hologram ,which is oriented with respect to the reference beam .The reference beam is diffracted and two images of the object , real image and virtual image are seen. .[2]

3.a. .[7]

CO_2 LASER

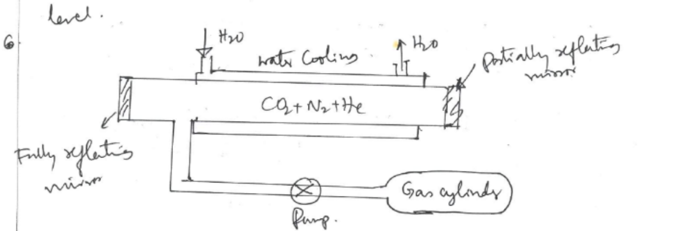
It belongs to the category of gas lasers with 4 level lasing system.

Active medium: Mixture of CO_2, N_2 & He in the ratio 1 : 2 : 8

Nitrogen is used as Molecular Nitrogen absorbs energy more efficiently from electric discharge than CO_2 does.

Construction :

1. A glass plasma tube of 10-15mm diameter with an integral water cooling jacket.
2. Partially reflecting and fully reflecting mirrors are mounted on the ends of the tube.
3. A coaxial water jacket around the plasma tube serves to remove heat through the tube walls.
4. optical pumping is achieved by electric discharge caused by applying a P.D of over 1000V.
5. Helium gas conducts away heat generated and also catalyses collisional deexcitation of CO_2 molecules from lower laser level.
6.



Working :

① CO_2 is a linear molecule and has three fundamental modes of vibration : Symmetric Stretching, bending and asymmetric stretching, represented as (001), (100) & (020) with corresponding energy states E_1, E_2, E_3 ----.

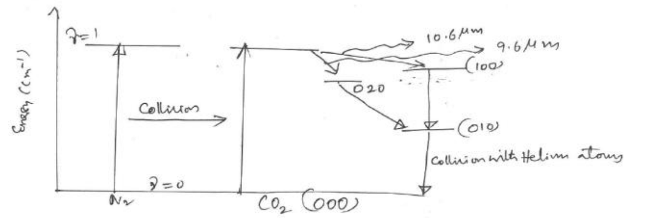
② The energy level 001 corresponding to asymmetric stretching is the upper lasing level. The energy levels (100), (020) are the lower lasing states.

③ During electric discharge, electrons released due to ionization excite N_2 molecules to the first vibrational level which is close to upper lasing level of CO_2.

④ N_2 molecules undergo collisions with CO_2 molecules and cause their excitation leading to population inversion.

⑤ Lasing action usually takes place due to transitions from 001 to 100, (001) to (020) corresponding to a wavelength $\lambda_1 = 10.6\mu m$ and $9.6\mu m$ respectively.

⑥ The CO_2 molecules deexcite to ground state through collisions with Helium atoms.



.[2+2+3]

3.b .[3]

$$\frac{N_2}{N_1} = \frac{1}{e^{(\frac{hc}{\lambda kT})}} = 1.6x10^{-30}$$

Substitute for T = 330k, we get

λ =636nm

4.a. .[7]

Sine of angle of acceptance is known as Numerical aperture. .[1]

Expression for condition for propagation :

Consider a light ray falling in to the optical fibre at an angle of incidence θ_0 equal to acceptance angle. Let n_0 be the refractive index of the surrounding medium .

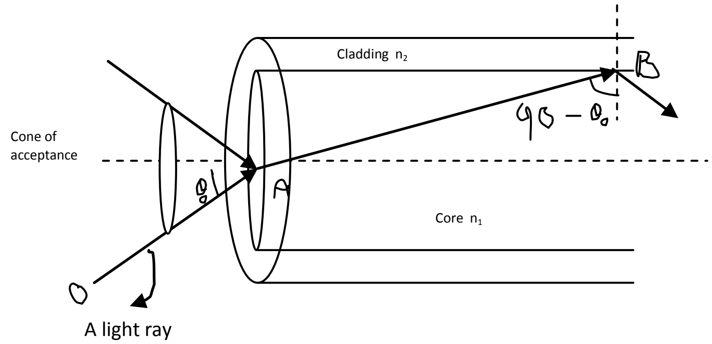
Let n_1 be the refractive index of the core.

Let n_2 be the refractive index of the cladding.

From Snell's Law:

For the ray OA $n_0 \sin\theta_0 = n_1 \sin\theta_1$

$$= n_1(1-\cos^2\theta_1)^{\frac{1}{2}} \quad ....(1)$$.[2]



For the ray AB

$$n_1 \sin(90 - \theta_1) = n_2 \sin 90$$

[here the angle of incidence is $(90 - \theta_1)$ for which angle of refraction is 90^0].

$$n_1 \cos\theta_1 = n_2 \quad .[2]$$

Substituing for $\cos\theta_1$ in equation (1)

$$n_0 \sin\theta_0 = n_1 \sqrt{1 - \frac{n_2^2}{n_1^2}}$$

$$\sin\theta_0 = \frac{\sqrt{n_1^2 - n_2^2}}{n_0} \quad .[2]$$

If the medium surrounding the fibre is air then $n_0 = 1$,

Numerical aperture = $\sin\theta_0 = \sqrt{n_1^2 - n_2^2}$

The total internal reflection will take place only if the angle of incidence $\theta_i < \theta_0$

$$\therefore \sin\theta_i < \sin\theta_0$$

$$\sin\theta_i < \sqrt{n_1^2 - n_2^2}$$

This is the condition for propagation.

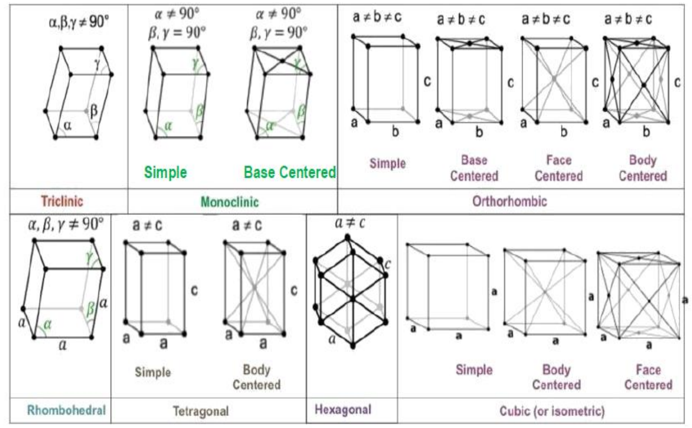
4.b. .[3]

Attenuation constant $\alpha = \frac{10}{z}\log\left(\frac{P_{in}}{P_{out}}\right) dB/km$

Here z =6km , α=5.5dB/km

$$\left(\frac{P_{in}}{P_{out}}\right) = 5.011 \times 10^{-4}$$

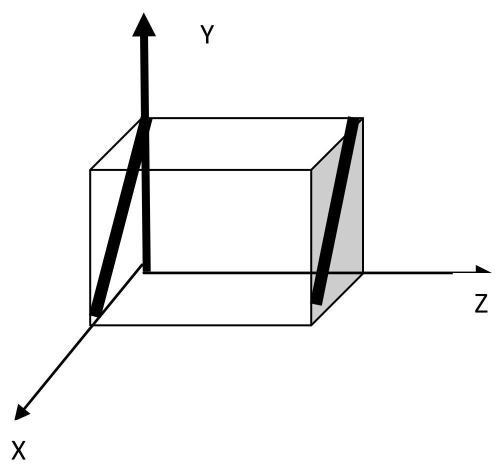
5.a. .[7]



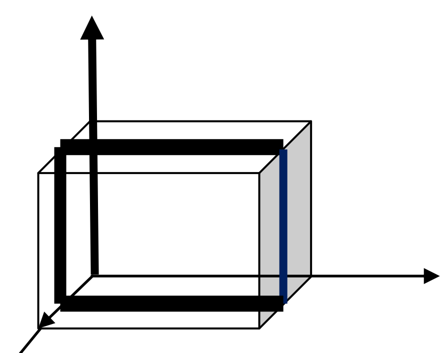
Crystal systems	Type and No. of Bravais lattices		Unit cell axes	Interfacial angles	Example
Cubic	Simple Body centered Face centered	3	a=b=c	$\alpha=\beta=\gamma=90^0$	Au,Cu, NaCl
Tetragonal	Simple Body centered	2	a=b≠c	$\alpha=\beta=\gamma=90^0$	SnO_2, TiO_2
Orthorhombic	Simple Body centered Face centered Base ceneterd	4	a≠b≠c	$\alpha=\beta=\gamma=90^0$	K_2SO_4, $BaSO_4$
Monoclinic	Simple Base centered	2	a≠b≠c	$\alpha=\gamma=90^0\neq\beta$	Na_3AlF_6, $CaSO_4.2H_2O$
Triclinic	Simple	1	a≠b≠c	$\alpha\neq\beta\neq\gamma\neq90^0$	$K_2Cr_2O_7$, $CuSO_4.5H_2O$
Trigonal or Rhombohedral	Simple	1	a=b=c	$\alpha=\beta=\gamma\neq90^0$	As, Sb, Bi
Hexagonal	Simple	1	a=b≠c	$\alpha=\beta=900, \gamma=120^0$	Zn, Mg, Graphite

5.b.[3]

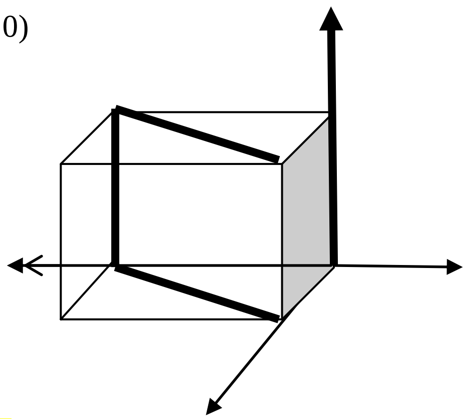
(110)



(200)



$(1\bar{1}0)$



6.a.[6]

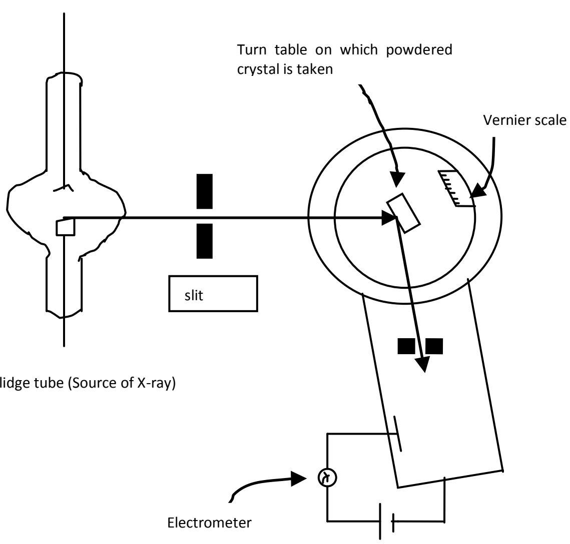
X-ray diffraction spectrometer:

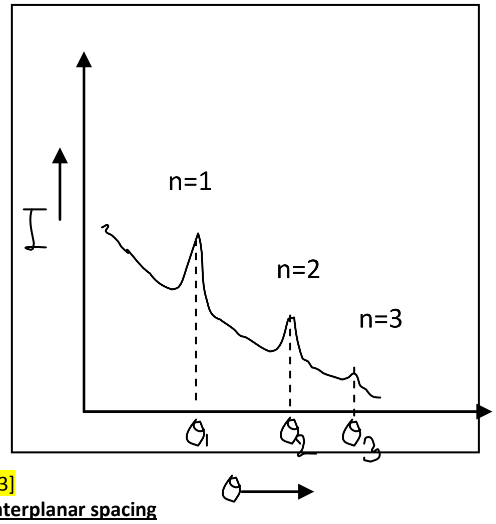
Apparatus: A source of X-ray, slits, crystal mounted on a circular turn table spectrometer with vernier scale.

Construction: X –ray beam after reflection from the crystal enters the ionization chamber mounted on a mechanical arm which can turn co axially with the turn table .This ionization chamber is coupled with the turn table so that if the turn table rotates through an angle ‘θ’, the ionization chamber rotates through ‘2θ’.The ionization current produced by X-rays is recorded by the electrometer

Working: The ionization current is measured for different values of glancing angle ‘θ’. A plot is then obtained between ‘θ’ and ionization current .For certain values of ‘θ’, the intensity of Ionization current increases abruptly.

Whenever the crystal receives X-rays at an angle of incidence satisfying Bragg’s law $2d\sin\theta = n\lambda$,constructive interference takes place and maximum intensity occurs .The rise in current occurs more than once as ‘θ’ is varied because the law is satisfied for various values of ‘n’ i.e., $2d\sin\theta = 1\lambda, 2\lambda, 3\lambda$ etc. .[3]





.[3]

Interplanar spacing

$d_{100}:d_{110}:d_{111}$	1:1/√2:1:√3	SC
$d_{100}:d_{110}:d_{111}$	1:2/√2:1:√3	BCC
$d_{100}:d_{110}:d_{111}$	1:1/√2:2:√3	FCC

6.b. .[4]

$$d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}$$

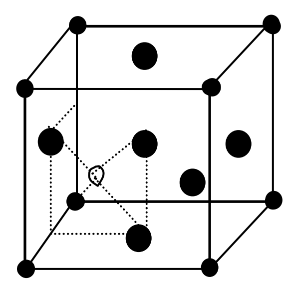
Given r =0.1278nm .[2]

For FCC, lattice constant a = $2\sqrt{2}\mathrm{r}$

(h k l) =(1 1 1)

d=2.09 x10^{-10}m.[2]

7.b. Structure of Diamond: .[5]



.[2]

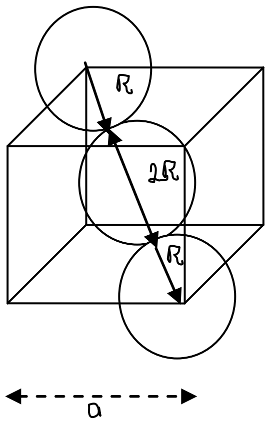
Diamond structure consists of two inter penetrating face centered cubic lattices. Each carbon atom is surrounded by 4 other carbon atoms situated at the corners of a regular tetrahedron. The unit cell for this structure is an FCC with a basis made up of two carbon atoms associated with each lattice site .The positions of two basis atoms are(0 0 0)and $(\frac{1}{4}\frac{1}{4}\frac{1}{4})$. .[2]

Packing factor = 0.34
Number of atoms per unit cell = 8 .[1]

7.b. **Packing factor:** .[5]

It is the ratio of total volume occupied by the atoms in the unit cell to the total volume of the unit cell. .[1]

For BCC structure: BCC: .[2]



Number of atoms per unit cell = 2

$\therefore$ Volume of two atoms = $2.\ \frac{4}{3}\Pi R^3$

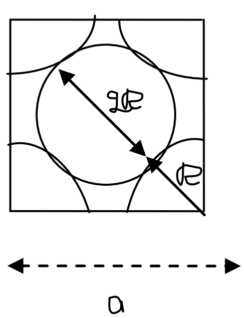
Volume of the unit cell = a^3

For BCC, $a = \frac{4R}{\sqrt{3}}$

$\therefore$ Volume of the unit cell = $\frac{64R^3}{3\sqrt{3}}$

Packing factor = 0.68

For FCC structure: .[2]



Number of atoms per unit cell = 4

Volume occupied by four atoms = $4 \times \frac{4}{3}\Pi R^3$

For FCC, a = $R.2\sqrt{2}$

Volume of the unit cell = $a^3 = 16\sqrt{2}\ R^3$

Packing factor = $(16/3)\ \Pi\ R^3 / 16\sqrt{2}\ R^3 = 0.74$