USN

Internal Assessment Test 3 – March 2022

Sub:	Engineering Physics Theory				Sub Code:	21PHY12	Branch:	CS/IS/CIV/MECH
Date:	28/03/2022	Duration:	90 min's	Max Marks: 50	Sem/Sec:	I Sem / A, B, C, D, E, F and G		OBE

Answer any FIVE FULL Questions

Given: $c = 3 \times 10^8$ m/s; $h = 6.625 \times 10^{-34}$Js; $k = 1.38 \times 10^{-23}$ J/K; $m_e = 9.1 \times 10^{-31}$kg; $e = 1.6 \times 10^{-19}$C

		MARKS	CO	RBT
1 (a)	Obtain the expression for energy density using Einstein's A and B Coefficients and hence show that $B_{12}=B_{21}$.	[07]	CO1	L3
(b)	Calculate the number of photons emitted per pulse of duration 1 microsecond given the power output of LASER is 3 mW and the wavelength of laser is 632.8 nm.	[03]	CO1	L3
2 (a)	With the help of neat diagrams explain the construction and working of CO_2 laser.	[07]	CO1	L3
(b)	The ratio of population of two energy levels out of which upper one corresponds to a metastable state is 1.059x 10^{-30}. Find the wavelength of light emitted at 330 K.	[03]	CO1	L3
3 (a)	Derive the expression for numerical aperture of an optical fiber and hence obtain the condition for propagation.	[07]	CO1	L3
(b)	Estimate the attenuation in an optical fiber of length 500m when a light signal of power 100mW emerges out of fiber with a power 90Mw.	[03]	CO1	L3
4 (a)	Define Modes of Propagation. Distinguish between the various types of optical fibers.	[07]	CO1	L4
(b)	Explain how laser find application in eye surgery	[03]	CO1	L2

PTO

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PTO

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(b)	Describe in brief the ionic and orientational polarization mechanisms.	[4]	CO2	L2
6 (a)	Define nano-material and classify the nano-materials based on the dimensional constraints. .	[7]	CO1	L3
(b)	X-rays are diffracted in the first order from a crystal with d spacing 2.8×10^{-10} m at a glancing angle 60 °. Calculate the wavelength of X-rays.	[3]	CO1	L3
7 (a)	Describe the construction and working of Scanning Electron Microscope with the help of a neat diagram.	[7]	CO1	L4
(b)	Explain the principle and any two applications of Atomic Force Microscope. .	[3]	CO1	L2
8 (a)	With neat diagram, explain the principle, construction and working of X-ray Diffractometer	[7]	CO1	L3
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IAT-3 PHYSICS SCHEME

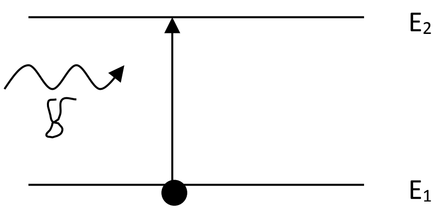
1.A

Expression for energy density:

Induced absorption:

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 N1 and N_2 be the number density in these levels respectively. Let U_γ be the energy density of the radiation incident..



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

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

Rate of absorption = $B_{12}\ N_1 U_\gamma$

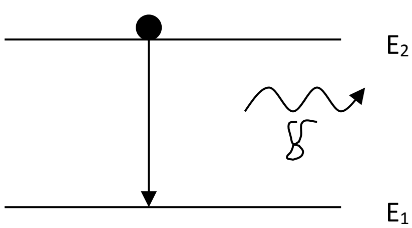
Here B_{12} is a constant known as Einsteins coefficient of spontaneous absorption.

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 = $A_{21}\ N_2$

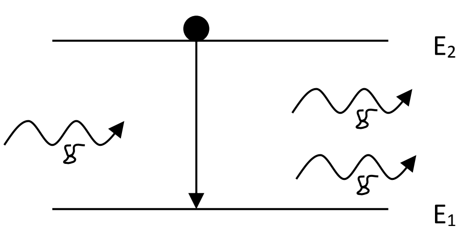
Here B_{12} is a constant known as Einsteins coefficient of spontaneous emission.



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

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.

(3 Marks)

At thermal equilibrium,

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

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

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

Rearranging this, we get

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

From Boltzmanslaw , $\frac{N_1}{N_2} = e^{\frac{h\gamma}{kT}}$

Hence

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

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

$\frac{A_{21}}{B_{21}} = \frac{8\pi h\gamma^3}{c^3}$ and $\frac{B_{12}}{B_{21}} = 1$ (4 marks)

1.B (Formula -1mark, Substitution- 1mark, Answer- 1 mark)

$$Power = \frac{E}{t} = \frac{nhc}{t\lambda}$$

$$n = \frac{P \times t \times \lambda}{hc} = \frac{0.003 \times 1x10^{-6} x632.8x10^{-9}}{6.62x10^{-34} x3x10^{8}} = 9.5x10^{9}$$

2A **Carbon dioxide laser**

Construction (3 marks)

1.Active medium – Mixture of CO_2, N_2 and He in the ratio 1:2:8. Nitrogen absorbs energy from the pumping source efficiently.Helium gas conducts away the heat and also catalyses collisional deexcitation of CO_2 molecules.

2.The discharge tube consists of a glass tube of 10-15mm diameter with a coaxial water cooling jacket.

3.Partially reflecting and fully reflecting mirrors are mounted at the ends of the tube.

4.Optical pumping is achieved by electric discharge caused by applying potential difference of over 1000V.

Working: (4 Marks)

1.CO_2 is a linear molecule and has three modes of vibration –Symmetric stretching (100), Asymmetric stretching (001) and bending (010).

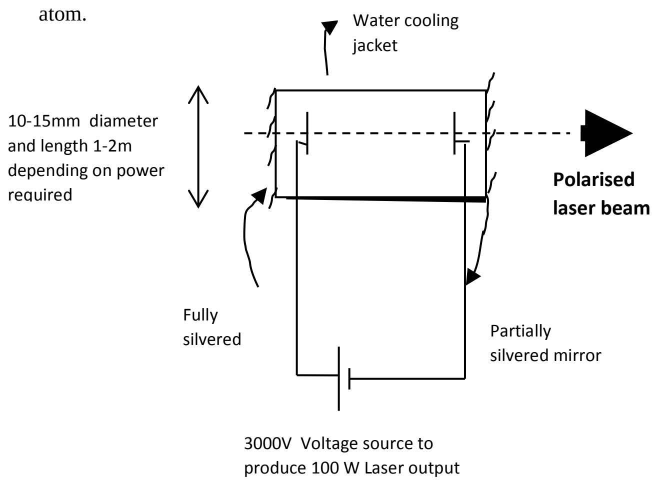
2. Asymmetric stretching (001) is the upper laser level which is a metastable state. (100) and (020) are the lower lasing states

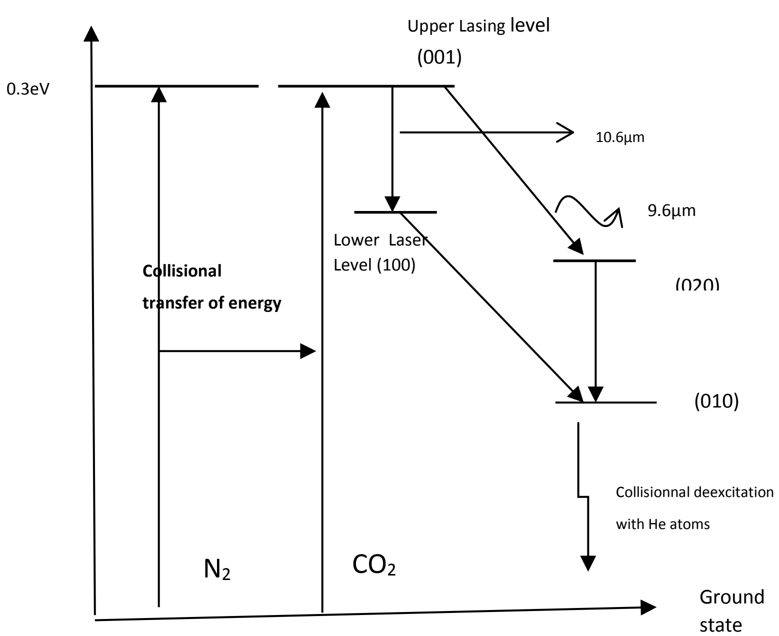
3.During electric discharge, the electrons released due to ionisation excite N_2 molecules to its first vibrational level which is close to upper lasing level of CO_2.

4.N_2 molecules undergo collisions with CO_2 molecules and excite them to (001). This results in population inversion.

5.Lasing transition occurs between (001) and (100) emitting at 10.6µm and (001) to (020) emitting at 9.6µm

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





2B (Formula -1mark, Substitution- 1mark, Answer- 1 mark)

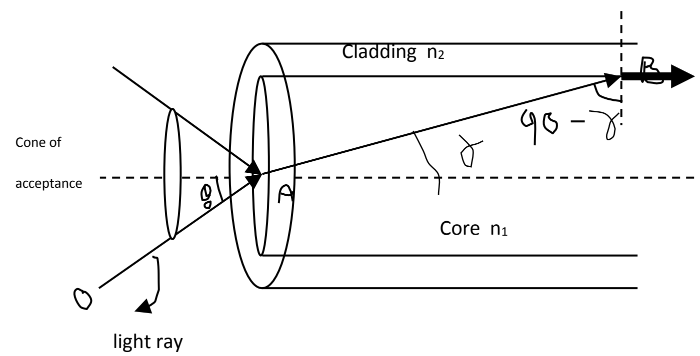
$$\frac{N_{ex}}{N_{gr}} = e^{-\frac{hc}{\lambda kT}}$$

$$1.059x10^{-30} = \frac{1}{e^{\frac{hc}{\lambda kT}}}$$

$$\lambda = 633x10^{-9}\,m$$

3A

Expression for condition for propagation :
(1 mark)



From Snell's Law: **(5 marks)**

For the ray OA $\quad n_0 \sin\theta_0 = n_1 \sin r = n_1\left(\sqrt{1-\cos^2 r}\right)$

………… (1)

For the ray AB

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

$$n_1 \cos r = n_2$$

$$\cos r = \frac{n_2}{n_1}$$

[here the angle of incidence is (90 - θ_1) for which angle of refraction is 90^0].

Substituting for cosr in equation (1)

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

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

If the medium surrounding the fiber 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 $\theta_i < \theta_0$ **(1 mark)**

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

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

This is the condition for propagation.

3B (Formula -1mark, Substitution- 1mark, Answer- 1 mark)

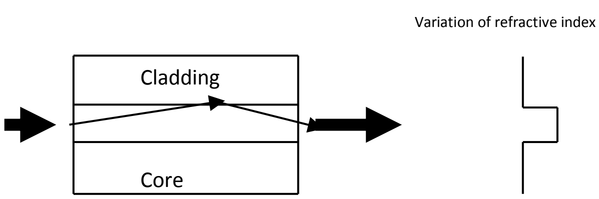
$$\alpha = \frac{10}{L}\log\left(\frac{P_{in}}{P_O}\right) = \frac{10}{0.5km}\log\left(\frac{100}{90}\right) = 0.91dB/km$$

7.b. **Mode:** It represents a specific electric field and magnetic field pattern propagating along specific path. Only a certain discrete number of modes are capable of propagating along the fiber. These are the electromagnetic waves that satisfy the homogeneous wave equation and the boundary conditions. **(1 mark)**

Types:

1. Single mode fiber: **(2 marks)**

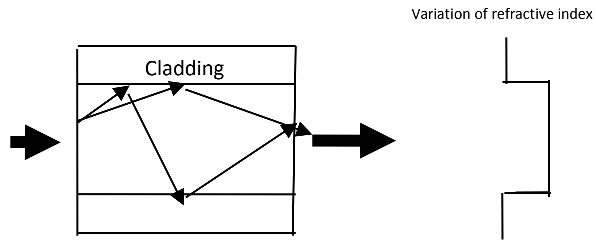
Core diameter is around 5-10 µm. The core is narrow and hence it can guide just a single mode.



- No modal dispersion
- Difference between n_1& n_2 is less.Critical angle is high. Low numerical aperture.
- Low Attenuation -0.35db/km
- Bandwidth -100GHz
- Preferred for short range

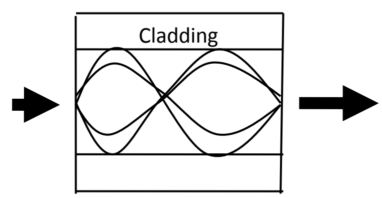
Step index multimode fibre : **(2 marks)**

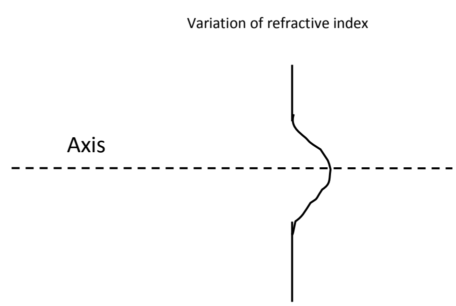
- Here the diameter of core is larger so that large number of rays can propagate. Core diameter is around 50. µm.
- High modal dispersion
- Difference between n_1& n_2 is high. Low Critical angle. Large numerical aperture.
- Losses high
- Bandwidth -500MHz
- Allows several modes to propagate
- Preferred for Long range



Graded index multimode fiber: **(2 marks)**

In this type, the refractive index decreases in the radially outward direction from the axis and becomes equal to that of the cladding at the interface. Modes travelling close to the axis move slower where as the modes close to the cladding move faster.As a result the delay between the modes is reduced. This reduces modal dispersion.





- Low modal dispersion
- High data carrying capacity.
- High cost
- Many modes propagate
- Bandwidth -10GHz

4B

Laser *in situ* keratomileusis (LASIK)

In recent years, a number of possible surgical procedures in ophthalmology has offered prospective patients an alternative to wear spectacles or contact lenses. Laser is used to modify the shape of the cornea and correct myopia, hyperopia, astigmatism, and presbyopia. Introduction of the excimer laser to reshape the cornea has resulted in remarkable developments in the correction of these refractive errors. Combined with other advanced ophthalmic instruments, laser refractive eye surgery has resulted in a substantial increase in the safety, efficacy, and predictability of surgical outcomes. **(2 marks)**

Laser *in situ* keratomileusis (LASIK) surgery can correct refractive errors and for elimination of myopic refractive errors.

The preoperative myopic sphere was − 3.50 ± 1.70 D and postoperative was −0.20 ± 0.4D **(1 mark)**

5A

CLAUSIUS – MOSOTTI RELATION:

This expression relates dielectric constant of an insulator (ε) to the polarization of individual atoms(α) comprising it.

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

where N is the number of atoms per unit volume

α is the polrisability of the atom

ε_r is the relative permittivity of the medium

ε_o is the permittivity of free space.

Proof:

If there are N atoms per unit volume,the electric dipole moment per unit volume –known as polarization is given by

$$P = N\alpha E_i$$

By the definition of polarization P, it can be shown that

$$P = \varepsilon_0 E_a(\varepsilon_r - 1) = N\alpha E_i$$

$$\varepsilon_0\varepsilon_r E_a - \varepsilon_0 E_a = N\alpha E_i$$

$$\varepsilon_r = 1 + \frac{N\alpha E_i}{\varepsilon_0 E_a} \quad \text{......................(1)}$$ **(2 marks)**

The internal field at an atom in a cubic structure(γ =1/3) is of the form

$$E_i = E_a + \frac{p}{3\varepsilon_0} = E_a + \frac{N\alpha E_i}{3\varepsilon_0}$$

$$\frac{E_i}{E_a} = \frac{1}{\left[1 - \left(\frac{N\alpha}{3\varepsilon_0}\right)\right]}$$

Substituting for $\frac{E_i}{E_a}$ in equation (1)

$$\varepsilon_r = 1 + \frac{N\alpha}{\varepsilon_0}\left[\frac{1}{\left(1 - \frac{N\alpha}{3\varepsilon_0}\right)}\right] = \frac{\varepsilon_0\left[1 - \frac{N\alpha}{3\varepsilon_0}\right] + \frac{N\alpha\varepsilon_0}{\varepsilon_0}}{\varepsilon_0\left[1 - \frac{N\alpha}{3\varepsilon_0}\right]} = \frac{1 + \frac{2}{3}\left(\frac{N\alpha}{\varepsilon_0}\right)}{1 - \frac{1}{3}\left[\frac{N\alpha}{\varepsilon_0}\right]}$$

$$\left[\frac{\varepsilon_r - 1}{\varepsilon_r + 2}\right] = \frac{\dfrac{1 + (2/3)\frac{N\varepsilon}{\varepsilon_0}}{1 - (1/3)\frac{N\alpha}{\varepsilon_0}} - 1}{\dfrac{1 - (2/3)\frac{N\alpha}{\varepsilon_0}}{1 - (1/3)\frac{N\alpha}{\varepsilon_0}} + 2} = \frac{N\alpha}{3\varepsilon_0}$$ **(4 marks)**

5B

Ionic polarization: (2 marks)

This is exhibited by ionic compounds.

When ionic compounds are kept in an electric field, displacement of positive and negative ions occurs developing a dipole moment.

Ionic polarizability $\alpha_i = \frac{\varepsilon_o(\varepsilon_r - 1)}{N_i} \approx 0.1\alpha_e$

Orientation polarization: (2 marks)

Polar molecules exhibit this mechanism.

When polar molecules are kept in an electric field, already existing dipoles tend to align in the direction of applied electric field .This increases the dipole moment.

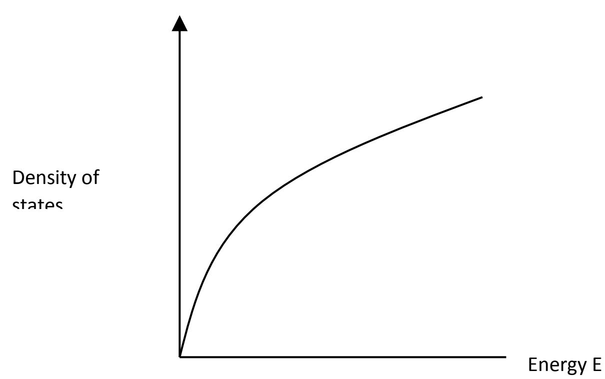
Orientation polarization $\alpha_o = \frac{\mu^2}{kT}$

6A **(1 mark)**

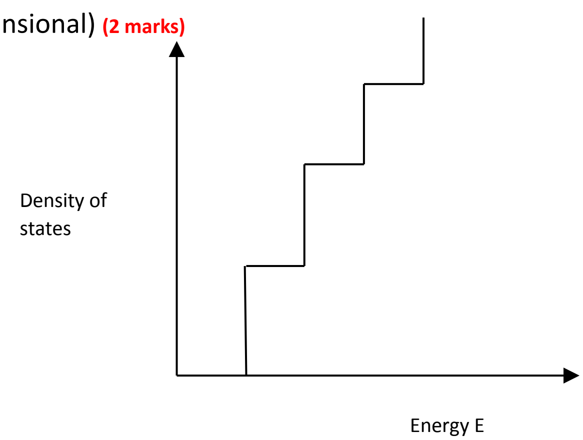
Nano materials possess dimensions of 0.1 to 100nm.Their properties are dependent on their dimensions. Many parameters such as density of states, energy gap, electrical &, thermal conductivity etc, are different from that from their bulk counterparts.

Classification

Bulk Material (3Dimensional): **(1 mark)**

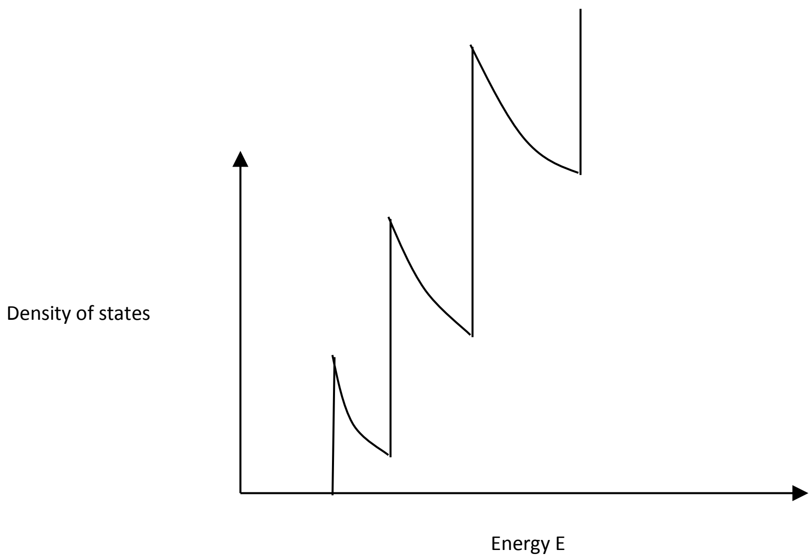


(2dimensional) **(2 marks)**



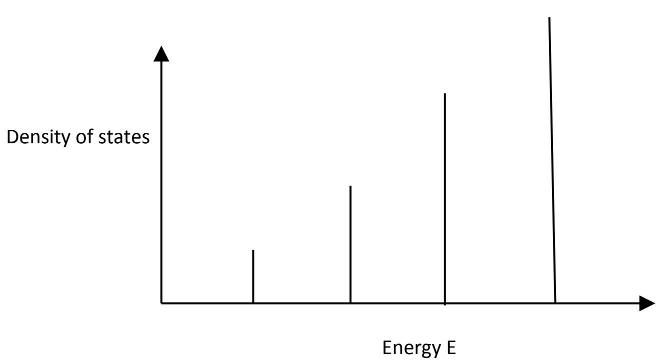
$$g(E)(dE) = \frac{m^*}{\pi\left(\frac{h}{2\pi}\right)^2}(E - E_i)\,dE$$

(1Dimensional) **(2 marks)**



$$g(E)(dE) = \frac{1}{\left(\frac{h}{2\pi}\right)}\sqrt{\frac{m*}{2(E - E_i)}}\,dE$$

0D **(2 marks)**



6B (Formula -1mark, Substitution- 1mark, Answer- 1 mark)

From Braggs Law

$$2d \sin\theta = n\lambda$$

$$\lambda = 2x2.8x10^{-10}\, x \sin 60 = 4.84x10^{-10}\, m$$

7A

Scanning Electron Microscope

Principle **(1 mark)**

The principle used in the working of an SEM is the wave nature of electrons. An electrons accelerated under a potential difference of V volts behave like a wave of wavelength,

$$\lambda = \frac{h}{\sqrt{2meV}} = \frac{1.226}{\sqrt{V}}\,nm$$

This is the basic principle which is used in all kinds of electron microscope. The primary electrons are accelerated and strike the sample, which in turn produces the secondary electrons and back scattered electrons. These secondary electrons are collected by a positively charged electron detector, which gives the three dimensional image of the sample

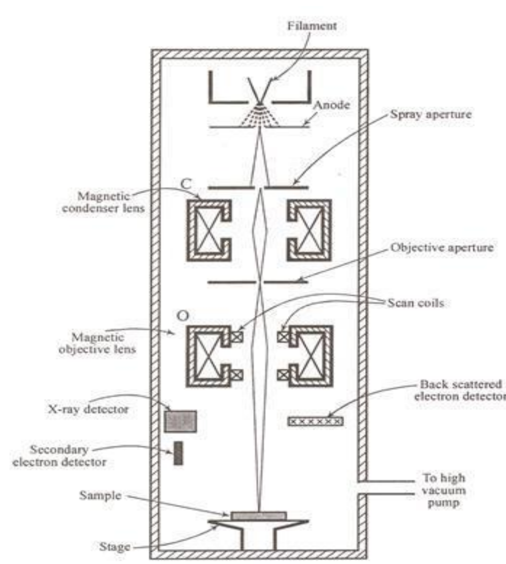
Construction **(2 marks)**

The apparatus consists of a highly evacuated chamber inside which there is an electron gun which consists of filament and anode. There are two magnetic lenses; one is the condensing lens C and the other one is the objective lens O whose purpose is to just focus the beam to the spot. A scan coil accompanies the lens O. Using different apertures produced electrons are made into fine beam. A flat surface called stage is provided at the bottom portion of the apparatus to place the specimen under study.

Working **(3 marks)**

The sample is to be investigated is placed on the specimen stage after which, inside of the chamber is evacuated by connecting to a high vacuum. The electron beam is suitably accelerated by applying a voltage between the filament and the anode. The electrons thus produced pass through the spray aperture using which, spherical aberration during focusing will be minimized the electron beam emerges. The condensing lens C converges beam and eliminates some high beam electrons. The beam then passes through the objective aperture where the size of the beam can be controlled. A thinner beam then enters into the field of objective lens O which focuses the beam onto the desired part of the specimen. Scan coils which are connected raster scan generator, placed along with the objective lens, enable the beam to scan the specimen in a particular way called raster.

The primary electrons interact with the sample and produce secondary electrons, back scattered electrons and X-ray which are detected by respective detectors. The collected signals are suitably amplified and converted into electrical signals by necessary electronic circuitry and are displayed on the CRT screen. In order to get the three dimensional image of the sample, the electron beam scans the sample many times with use of scan coils.



SCANNING ELECTRON MICROSCOPE (SEM)

Application**(1 mark)**

1. To study Chemical composition
2. To study external morphology of Biological Organism
3. To study Crystalline Structure
4. It is used in Forensic Investigation to examine gunshot residues and post explosion residues.
5. In material science SEM images are useful in viewing the structure of metals, ceramics and plastics.

7B

ATOMIC FORCE MICROSCOPY

PRINCIPLE: **(2 marks)**

In AFM, a sharp tip is mounted on a very flexible cantilever. As in the STM, it is rastered over the surface by means of piezoelectric transducers. Tip-surface interaction forces are sensed in AFM by the deflection of the lever. AFM is therefore ideal for studies of insulating materials that are not directly accessible to STM imaging. The resolution of AFM is not truly atomic, as is the case with STM. The forces of interaction produce a contact spot that is several tens of angstroms in diameter, depending on the applied load. Thus atomic-size point defects are not observed in AFM.

Applications: **(2 marks)**

Atomic force microscopy (AFM) is a powerful technique that enables the imaging of almost any type of surface, including polymers, ceramics, composites, glass and biological samples. AFM is used to measure and localize many different forces, including adhesion strength, magnetic forces and mechanical properties. The AFM has been applied to problems in a wide range of disciplines of the natural sciences, including solid-state physics, semiconductor science and technology, molecular engineering, polymer chemistry and physics, surface chemistry, molecular biology, cell biology, and medicine.

Applications in the field of solid state physics include (a) the identification of atoms at a surface, (b) the evaluation of interactions between a specific atom and its neighbouring atoms, and (c) the study of changes in physical properties arising from changes in an atomic arrangement through atomic manipulation.

In molecular biology, AFM can be used to study the structure and mechanical properties of protein complexes and assemblies. For example, AFM has been used to image microtubules and measure their stiffness.

In cellular biology, AFM can be used to attempt to distinguish cancer cells and normal cells based on a hardness of cells, and to evaluate interactions between a specific cell and its neighbouring cells in a competitive culture system. AFM can also be used to indent cells, to study how they regulate the stiffness or shape of the cell membrane or wall.

8A

X-ray diffraction spectrometer:

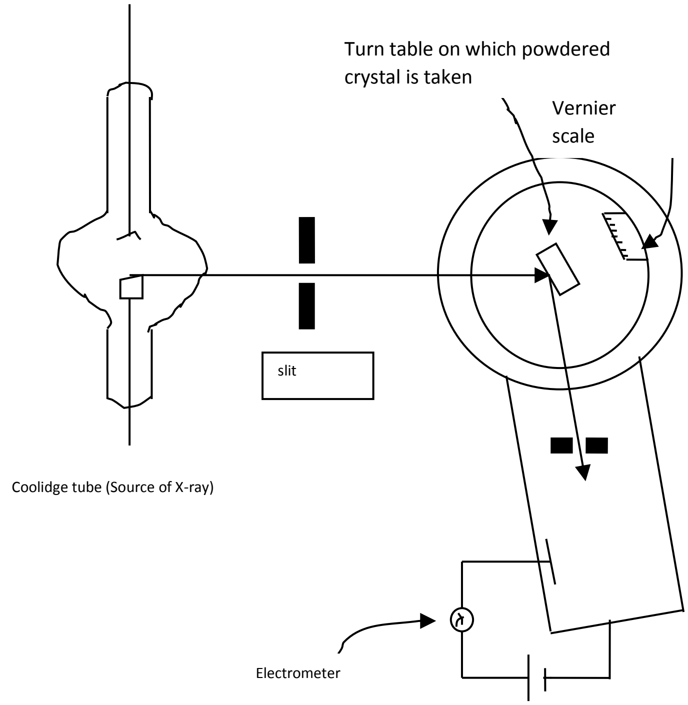
Construction: (3 marks)

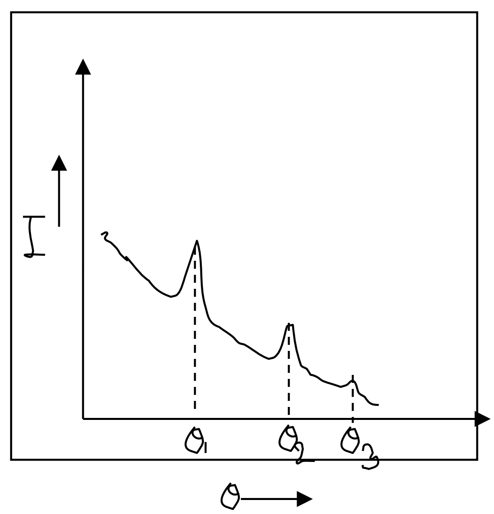
X –ray beam after reflection from the crystal enters the ionization chamber mounted on a mechanical arm which can turn co axially with the turn table .This ionization chamber is coupled with the turn table so that if the turn table rotates through an angle ‘θ’, the ionization chamber rotates through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

Working: (4 marks)

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 sinθ = nλ ,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 θ = 1λ ,2λ,3λ etc and Interplanar distance d for the crystal can be determined.





8a

(Formula -1mark, Substitution- 1mark, Answer- 1 mark)

$$peakwidth = \frac{k\lambda}{D\cos\theta}$$

$$D = \frac{k\lambda}{peakwidthx\cos\theta} = 1.18x10^{-6}m$$