CMR INSTITUTE OF TECHNOLOGY

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Improvement Test

Sub:	**Engineering Physics**							Code:	**15PHY22**
Date:	30/ 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, $m_0 = 9.11\text{x}10^{-31}$ kg

			Marks	OBE CO	OBE RBT
1	(a)	Derive an expression for time independent Schrodinger wave equation for a free particle in one dimension.	[6]	CO2	L3
	(b)	Calculate the ground state energy (in eV) for an electron trapped in a one dimensional potential well of width 2 Å.	[4]	CO2	L2
2	(a)	What is superconductivity? Explain superconductivity on the basis of BCS theory.	[6]	CO2	L2
	(b)	Write a note on Maglev vehicles.	[4]	CO2	L2
3	(a)	Explain the construction and working of a semiconductor laser.	[6]	CO3	L2
	(b)	The output power of the laser is 2mW. Calculate the number of photons emitted/sec if the wavelength of light emitted is 6328 Å.	[4]	CO3	L3
4	(a)	Derive an expression for inter-planar spacing in a cubic crystal system in terms of Miller indices.	[6]	CO4	L3
	(b)	Explain briefly the crystal structure of Perovskites.	[4]	CO4	L1
5	(a)	Explain basic laws of conservation and obtain Rankine-Hugoniot equations for normal shock waves.	[7]	CO5	L2
	(b)	Define i) Mach number, ii) Subsonic wave and iii) Supersonic waves.	[3]	CO5	L1
6	(a)	Explain the construction and working of a Reddy shock tube with the help of a diagram.	[7]	CO5	L2
	(b)	What are shock waves? Mention three applications of shock waves.	[3]	CO5	L1
7	(a)	What are nanomaterials? Explain density of states for various quantum structures.	[6]	CO5	L2
	(b)	With the help of a suitable diagram, explain ball milling method of preparation of nano materials.	[4]	CO5	L2
8	(a)	Explain the construction and working of scanning electron microscope (SEM).	[6]	CO5	L2
	(b)	Illustrate with diagrams the different structures of carbon nanotubes.	[4]	CO5	L2

Scheme of evaluation-TEST 3 May 2017

1.a. **Time independent Schrödinger equation**

This equation is used to study the motion of subatomic particles..

Time independent Schrödinger equation

A matter wave can be represented in complex form as

$$\Psi = A\sin kx(\cos wt + i\sin wt)$$

$$\Psi = A\sin kxe^{iwt}$$

Differentiating wrt x

$$\frac{d\Psi}{dx} = kA\cos kxe^{iwt}$$

$$\frac{d^2\Psi}{dx^2} = -k^2 A\sin kxe^{iwt} = -k^2\Psi \text{ ……………………. (1)}$$

From debroglie's relation

$$\frac{1}{\lambda} = \frac{h}{mv} = \frac{h}{p}$$

$$k = \frac{2\pi}{\lambda} = \frac{2\Pi p}{h}$$

$$k^2 = 4\Pi^2\frac{p^2}{h^2} \text{ ……………………… (2)}$$

Total energy of a particle E = Kinetic energy + Potential Energy

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

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

$$p^2 = (E - V)2m$$

Substituting in (2)

$$k^2 = \frac{4\Pi^2(E - V)2m}{h^2}$$

$\therefore$ From (1)

$$\boxed{\frac{d^2\Psi}{dx^2} + \frac{8\Pi^2 m(E - V)\Psi}{h^2} = 0}$$

1.b.

Energy of a particle in an infinite potential well $E = \dfrac{n^2h^2}{8ma^2}$

For the ground state, n =1

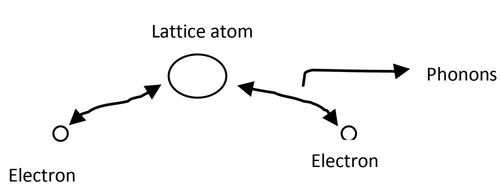
$$E = \frac{1^2 x^2 h^2}{8.(9.1x10^{-31}).(2x10^{-9})^2} = 0.15x10^{-17} J = 9.46 eV$$

2.a. **Superconductivity** is a phenomenon in which some materials loose their resistance completely below certain temperature.

BCS Theory :[Bardeen , Cooper, Schrieffer]

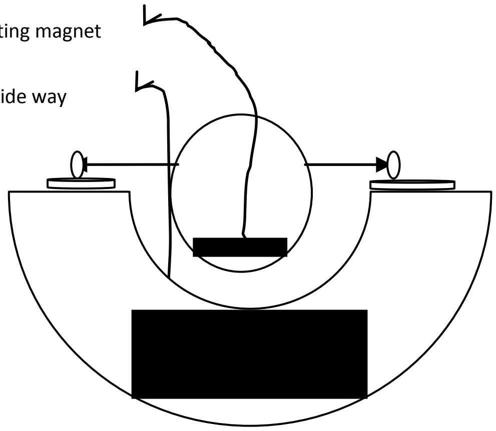
According to this theory superconductivity occurs when an attractive interaction known as electron-lattice-electron interaction is established resulting in the formation of cooper pairs.

In a lattice, an electron passing close to a lattice atom is attracted towards it and displaces it. This lattice atom will interact with another electron and in turn forms an **electron – lattice –interaction.** This system of two electrons of equal and opposite momentum attached to a lattice atom is known as a **cooper pair**. The electrons are bound to the lattice atom through the exchange of phonons (Lattice vibrations).Collective flow of cooper pairs under the influence of applied electric field reduces resistance. The energy gap between the normal state and superconducting state is of the order of milli electron volts. The thermal energy at low temperatures is not sufficient to break cooper pair interaction. Cooper pairs are represented collectively by a coherent matter wave function.



2.b. **Maglev vehicles:**

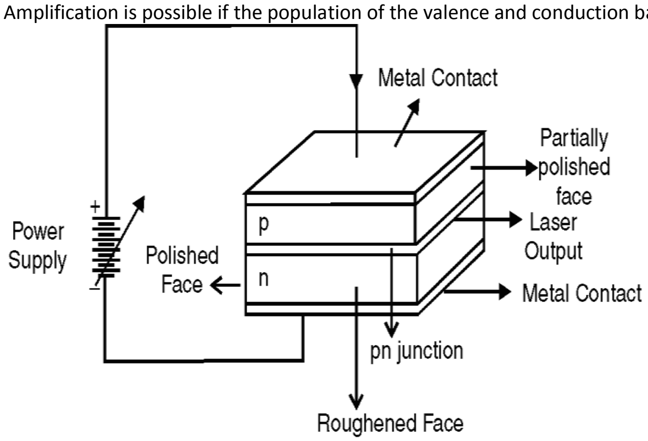
These are the vehicles which are set afloat above the track reducing the friction. With such an arrangement, great speeds could be achieved with low energy consumption. The vehicle consists of superconducting magnets built at the base. Large currents are passed through aluminum guide way. Due to the interaction between the magnetic fields produced by the superconducting magnet and the aluminum guide way, the vehicle is set afloat. These magnetic fields also propel the vehicle.

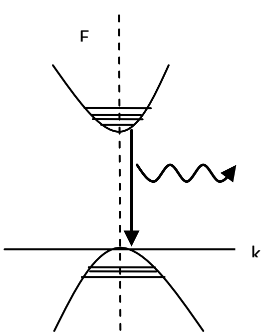


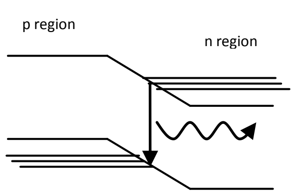
3.a. Gallium – Arsenide Semiconductor laser :

It is the only device which can be used for amplification in the infrared and optical ranges.

Amplification is possible if the population of the valence and conduction bands could be inverted as shown in the diagram.







The first laser action was observed in a GaAs junction(8400Å) which is a direct gap semiconductor.

When a heavily doped junction is forward biased, electrons from n side are injected into p side causing population inversion. They combine with holes on the p side releasing photons. The junction region is the active region .The optical cavity is formed by the faces of the crystal itself which are taken on the cleavage plane and are then polished. The wavelength of the radiation depends on temperature. The wavelength of laser increases as the temperature increases as the energy gap decreases. The frequency can be increased to the optical region by alloying with phosphor according to the relation $GaAs_{1-x}P_x$.

Requirements: The population inversion must be strong enough such that the downward transitions are larger than absorption effects by free carriers. There is a threshold carrier concentration (n) which can be related to junction current.

$$\frac{I}{d} \cong \frac{en}{\tau}$$

where τ is the carrier recombination time.

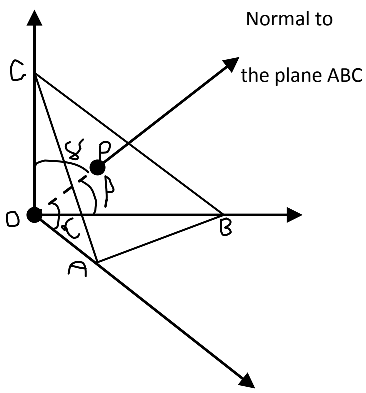
Ex: ZnS, CdS,InSb,PbS

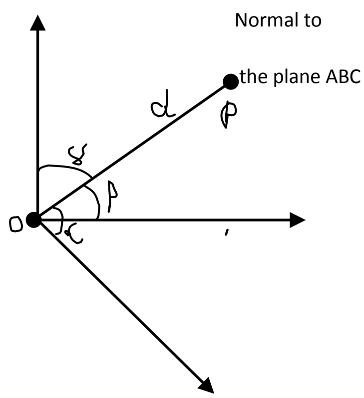
3.b.

Number of Photons emitted /sec = (P X λ)/(h x C)

$=(0.002 \times 6328\times10^{-10})/(6.64\times10^{-34}\times3\times10^{8}) = 6.3\times10^{16}$

4.a. <u>Expression for interplanar spacing in terms of Miller indices</u>:





Let ABC be one of the parallel planes represented by the Miller indices [h,k,l].Let its intercepts be x,y,z. Imagine another plane passing through the origin O .OD is the perpendicular from O to the plane ABC and OP is the interplanar distance .Let the angle made by OP with X,Y and Z axis be α, β and γ respectively.

Now [h, k, l] = $\left[\frac{a}{x}, \frac{b}{y}, \frac{c}{z}\right]$ where a, b, c are constants.

[x,y,z] = $\left[\frac{a}{h}, \frac{b}{k}, \frac{c}{l}\right]$ ....(1)

Also from figure d=x cos $\alpha = y\cos\beta = z\cos\gamma$

$\cos\alpha = \frac{d}{x}$, $\cos\beta = \frac{d}{y}$, $\cos\gamma = \frac{d}{z}$

Squaring and adding after Substituting for x, y, z from (1)

$$d^2\left[\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}\right]=1$$

$$\because \cos^2\alpha+\cos^2\beta+\cos^2\gamma=1$$

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

If a = b =c, then

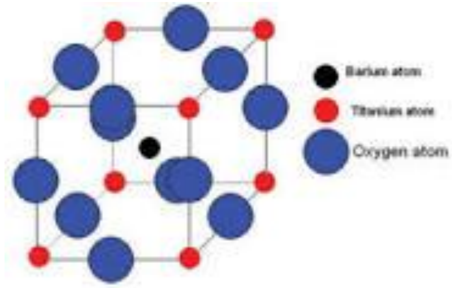
$$d_{hkl}=\frac{a}{\sqrt{h^2+k^2+l^2}}$$

4.b. **Perovskite structure:**

Perovskites are those materials having same structure as $CaTiO_3$. These are named after Russian scientist Provski. They have a general formula of the form ABX_3. A and B are metal cations and X is an oxide anion.

Ex: $MgSiO_3$, $BaTiO_3$,$SrRuO_3$,$NaTaO_3$

They exhibit superconductivity, ferroelectricity and owing to their photosensitive nature, they are used in making solar cells.



5.a.

Shock wave : When a medium undergoes large and rapid compression (following an explosion/the release of engine gases in to an exhaust pipe/when an air craft or a bullet flies at supersonic velocity) a thin wave of large pressure change is produced. This discontinuity is pressure propagates as a wave known as shock wave. A shock wave develops when the flow is supersonic.

Derivation of Rankine –Hugoniot equation

This equation relates pressure, density, temperature ahead and behind a shock wave.

Consider a shock tube with partition separating two regions .

Continuity equation $\rho_1 u_1 = \rho_2 u_2$ since area A is constant in this case ....(1)

Equation for Energy conservation $\frac{k}{k-1}\frac{p_1}{\rho_1}+\frac{u_1^2}{2}=\frac{k}{k-1}\frac{p_2}{\rho_2}+\frac{u_2^2}{2}$ ....(2)

Equation for momentum conservation

$p_1+\rho_1 u_1^2 = p_2+\rho_2 u_2^2$ ....(3)

From (2)

$$u_1^2-u_2^2=\frac{2k}{k-1}\left(\frac{p_2}{\rho_2}-\frac{p_1}{\rho_1}\right)$$

From (1) and (3) ....(4)

$$u_1^2=\frac{p_2-p_1\rho_2}{\rho_2-\rho_1\rho_1}- \qquad u_2^2=\frac{p_2-p_1\rho_1}{\rho_2-\rho_1\rho_2}$$

From (4)

$$\frac{\rho_2}{\rho_1}=\frac{[(k+1)/(k-1)](p_2/p_1)+1}{(k+1/k-1)+p_2/p_1}=\frac{u_1}{u_2}$$

$$\text{since } p=\rho RT$$

$$\frac{T_2}{T_1}=\frac{(k+1/k-1)+p_2/p_1}{(k+1/k-1)+p_1/p_2}$$

5.b.

Mach number is the ratio of velocity of fluid causing the shock wave generation to the velocity of sound in the medium. It represents the compressibility nature of the medium.

Subsonic waves: These are sound waves with Mach number less than 1. Velocity of the object is less than velocity of sound.

Ex: Low intensity shock waves produced during the motion of ordinary aircrafts.

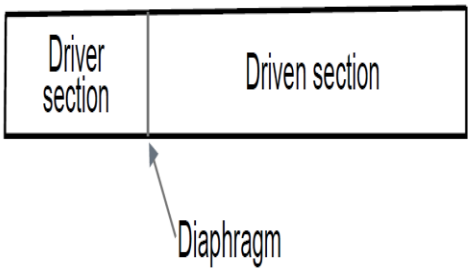
Super sonic waves: These are shock waves with Mach number greater than 1. Velocity of the object is greater than velocity of sound.

Ex: shock waves produced during the motion of jet planes, bullets etc.

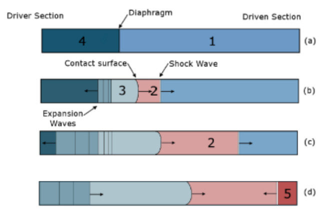
6.a. **Reddy shock tube:**

A shock tube is a device used to study the changes in pressure & temperature which occur due to the propagation of a shock wave. A shock wave may be generated by a small explosion caused by the buildup of high pressure which cause diaphragm to burst.

It is hand driven open ended shock tube.It was conceived with a medical syringe. A plastic sheet placed between the plastic syringe part and the needle part constitutes the diaphragam.



- A high pressure (driver) and a low pressure (driven) side separated by a diaphragm.
- When diaphragm ruptures, a shock wave is formed that runs along the driven section.
- Shock strength is decided by driver to driven pressure ratio, and type of gases used.

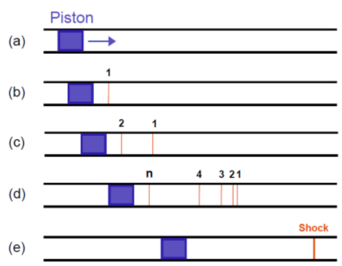


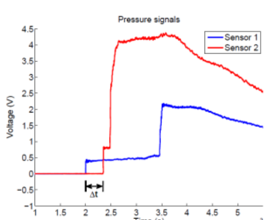
Working:

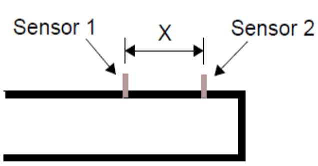
- The piston is initially at rest and accelerated to final velocity V in a short time t.
- The piston compresses the air in the compression tube. At high pressure, the diaphragm ruptures and the shock wave is set up. For a shock wave to form, $V_{piston} > V_{sound}$.

  Formation of shock wave:

  As the piston gains speed, compression waves are set up. Such compression waves increase in number. As the piston travels a distance, all the cpmpression waves coalesce and a single shock wave is formed. This wave ruptures the diaphragm.







$$U_s = \frac{X}{\Delta t}$$

6.b. **Shock waves:** When air undergoes large and rapid compression (following an explosion/the release of engine gases in to an exhaust pipe/when an air craft or a bullet flies at supersonic velocity) a thin wave of large pressure change is produced. This discontinuity is pressure propagates as a wave known as shock wave. A shock wave develops when the flow is supersonic.

Applications:

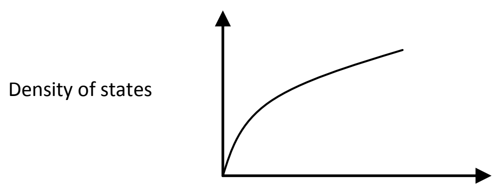
- Aerodynamics – hypersonic shock tunnels, scramjet engines.
- High temperature chemical kinetics – ignition delay
- Rejuvenating depleted bore wells
- Material studies – effect of sudden impact pressure, blast protection materials

- Investigation of traumatic brain injuries
- Needle-less drug delivery
- Wood preservation

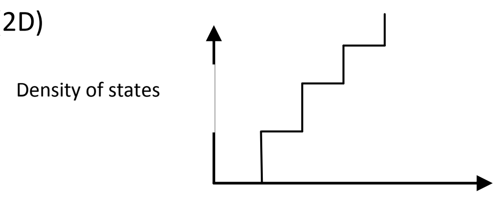
7.a. Nano materials possess dimensions of 0.1 to 100nm.Their properties are dependent on their dimensions. Many parameters such as density of states, energy gap, electrical &, thermal conductivity etc, are different from that from their bulk counterparts.

Density of states:

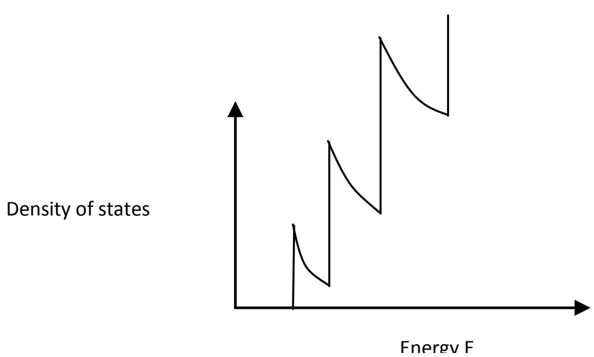
Bulk Material (3D):



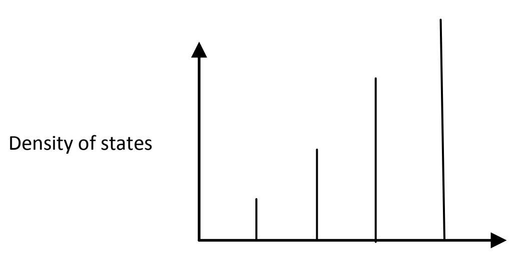
(2D)



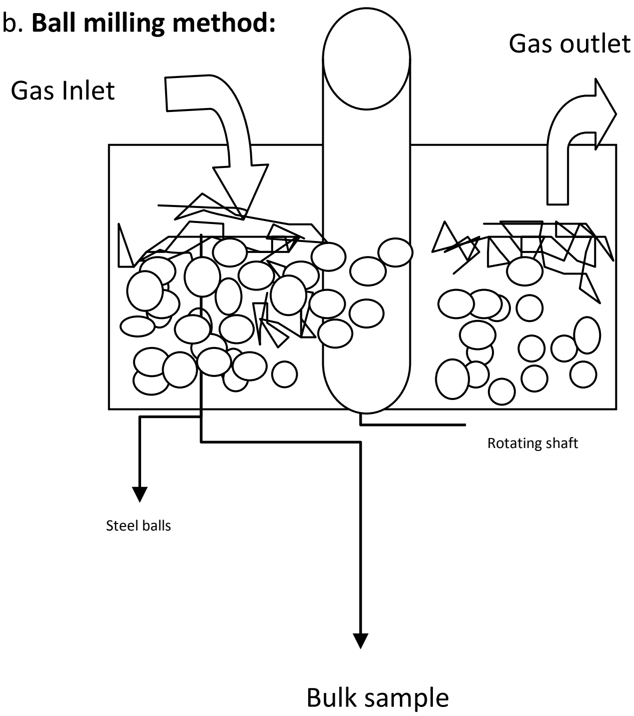
(1D)



0D



7.b. **Ball milling method:**



Principle: Small hard balls are allowed to rotate inside a container. The bulk sample is sprinkled. The steel balls crush the solid into nano crystal.

Stainless steel balls of few millimeter diameter are taken in a container and the material to be crushed is added in the form of a powder of 50µm diameter. The rotating shaft grinds the material. When the container is rotating around the central axis, the material is forced to press against the walls. The milling balls impart energy on collision and produce smaller grain size of nano particle. Ball milling is also known as Mechanical alloying or crushing. Few mg to several kgs of nanoparticle can be synthesized in a short time.

8.a.**Scanning electron Microscope:**

Scanning Electron Microscope (SEM)

Reference Book : physical Principles of Electron Microscopes. By Egerton

Advantages over Transmission electron Microscope (TEM)
- (a) High resolving power (≈10nm)
- (b) Thick sample could be used
- (c) Small area of the sample can be studied.

Principle :- Electron beam is focussed into a small diameter on the specimen making use of electrostatic / magnetic fields (electric / magnetic lens) ~~applied~~ which can be used to change the direction of beam. By scanning simultaneously in two directions, a rectangular area of specimen can be scanned and an image of this area can be formed by collecting secondary electrons from each point on the specimen.

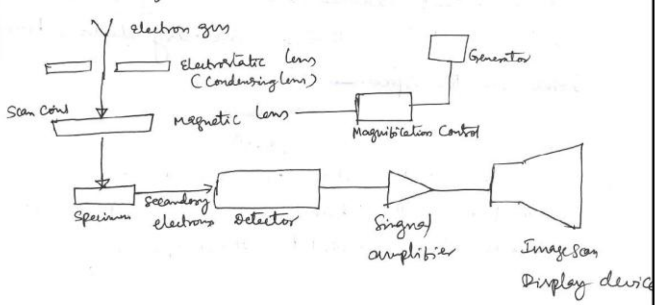
Working :

1) When accelerated electrons (30keV) enter a solid, they are scattered elastically (back scattered electrons) and inelastically (secondary electrons emitted from the sample).

2) The primary electrons incident on the specimen transfer energy to atomic electrons and cause their emission. The depth (below the sample surface) at which this occurs is called the penetration depth or electron range. The volume of sample containing secondary electron is called the Interaction volume

3) The secondary electrons are attracted toward a scintillator (detector) biased positively at few hundred volts. The scintillator can be phosphor screen or a light emitting material. The number of photons generated depends on kinetic energy of electrons. These photons are used to generate an image indicating surface

4) structure of the specimen.



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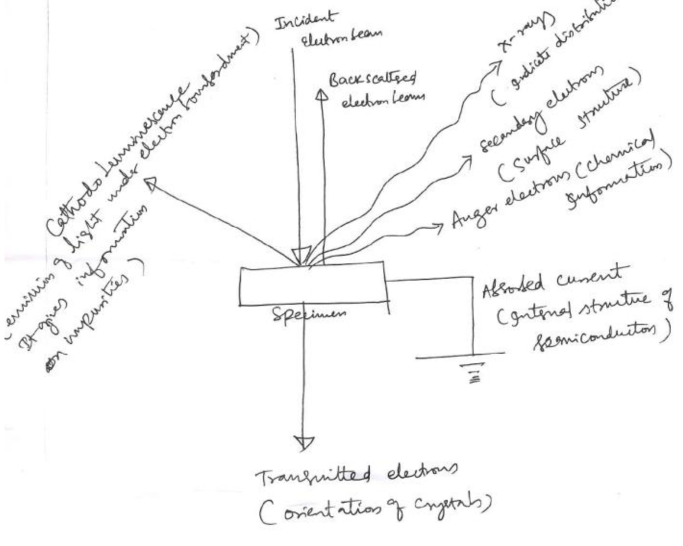
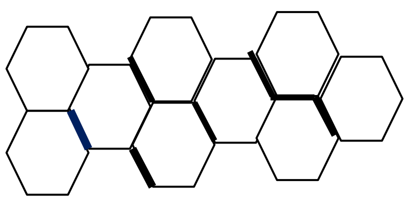
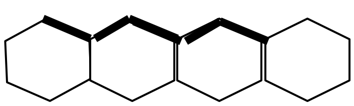
Note :→ Several Processes that occur during electron beam — Specimen Interaction



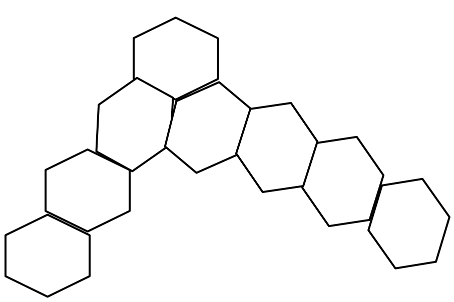
8.b.

Arm Chair:





Zig Zag



Chiral

Rolling up the carbon sheet along one of the symmetry axis gives either a zig-zag (m=0) tube or an armchair tube. If the carbon-carbon bonds that parallel to the tube axis it produces a "zig-zag" pattern at the open end. These tubes are referred to as "zig-zag" tubes. If the carbon-carbon bonds are perpendicular to the tube axis, they are referred as "armchair" tubes.It is also possible to roll up the sheet in a direction that differs from a symmetry axis to obtain a chiral nanotube. As a well as the chiral angle, the circumference of the cylinder can also be varied.