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CMR INSTITUTE OF TECHNOLOGY, BENGALURU. ACCREDITED WITH A+ GRADE BY NAAC

Internal Assessment Test 3 – May 2018

Sub:	Engineering Physics					Sub Code:	17PHY22	Branch:	All
Date:	22/05/2018	Duration:	90 mins	Max Marks:	50	Sem/Sec:	II/ C,D,E,F,G		OBE

<u>Answer any **FIVE FULL** Questions</u>

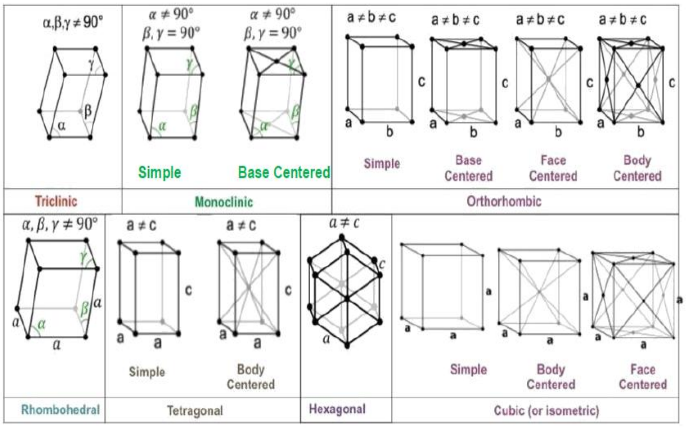
Note: Value of Constants: $h = 6.625\times10^{-34}$Js $k = 1.38\times10^{-23}$ J/K $m = 9.11\times10^{-31}$ kg. $e = 1.6 \times 10^{-19}$C, $c = 3\times10^{8}$ m/s

		MARKS	CO	RBT
1 (a)	Explain in brief the seven crystal system with neat diagrams.	[07]	CO4	L2
(b)	Draw the following planes in a cubic unit cell: (001), (210), $(10\bar{1})$.	[03]	CO4	L2
2 (a)	Define packing factor. Calculate the packing factor for sc, bcc and fcc structures.	[07]	CO4	L3
(b)	If the lattice constant of a cubic crystal is 2 Å, find the interplanar spacing for (121) and (101) planes.	[03]	CO4	L2
3 (a)	What are Miller indices? Derive an expression for interplanar spacing in terms of Miller indices for cubic lattice.	[07]	CO4	L3
(b)	Define the following: Bravais lattice, Primitive cell, Allotropy	[03]	CO4	L1

4 (a)	With a neat diagram explain the structure of the diamond.	[06]	CO4	L3
(b)	A monochromatic X-ray beam of wavelength 0.4 Å undergoes first order Bragg reflection from the plane (102) of a cubic crystal at a glancing angle of 60^{o}. Calculate the lattice constant.	[04]	CO4	L3
5 (a)	What are nanomaterials? Explain density of sates for various quantum structures.	[05]	CO5	L2
(b)	With a neat diagram describe any one method of preparation of nanomaterials.	[05]	CO5	L2
6 (a)	Explain the construction and working of SEM.	[07]	CO5	L2
(b)	Write a short note on properties of CNTs.	[03]	CO5	L2
7 (a)	What are shock waves? Explain the construction and working of Reddy's shock tube.	[07]	CO5	L3
(b)	Define the following: i) Mach number ii) subsonic waves iii) supersonic waves.	[03]	CO5	L1
8. (a)	Discuss the basic equations of Fluid mechanics.	[06]	CO5	L3
(b)	Discuss the applications of shock waves	[04]	CO5	L1

Scheme of evaluation-TEST 3 MAY 2018

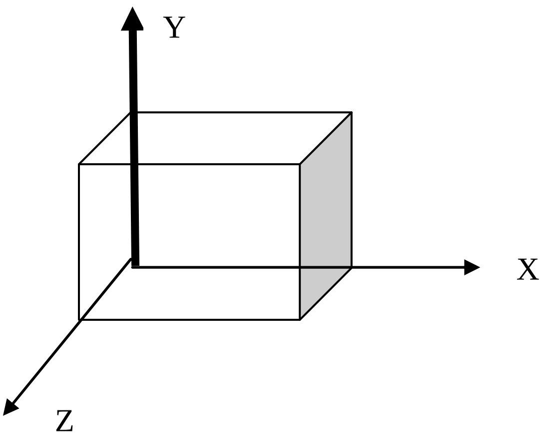
1.A [7]



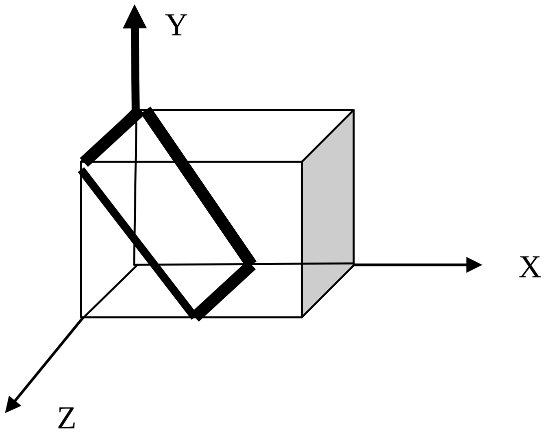
Crystal systems	Type and No. of Bravais lattices		Unit cell axes	Interfacial angles	Example
Cubic	Simple Body centered Face centered	3	a=b=c	$\alpha=\beta=\gamma=90^0$	Au,Cu, NaCl
Tetragonal	Simple Body centered	2	a=b≠c	$\alpha=\beta=\gamma=90^0$	SnO_2, TiO_2
Orthorhombic	Simple Body centered Face centered 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

1.B[3]

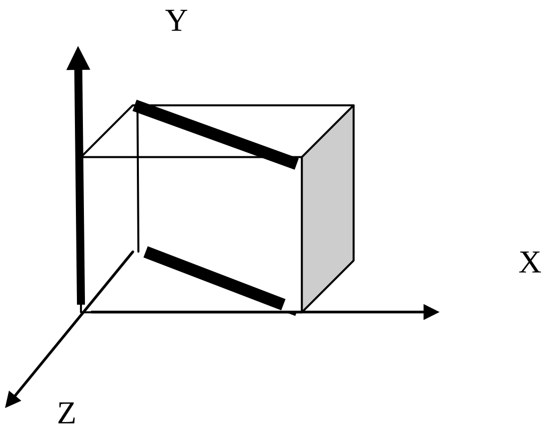
(001)



(210)



(10$\bar{1}$)

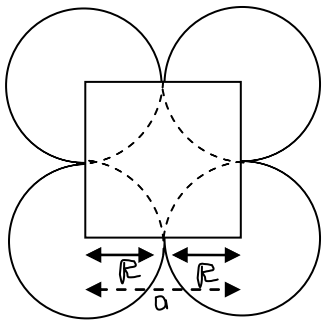


2.a. [7]

Packing factor:

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 simple cubic structure: [2]



Number of atoms per unit cell = 1

Volume of one atom $= \frac{4}{3}\Pi R^3$

Volume of the unit cell $= a^3$

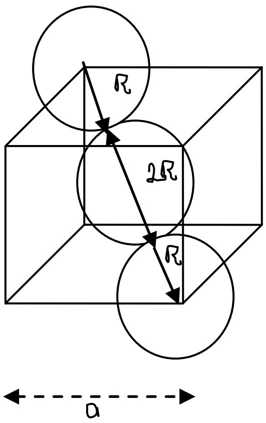
Here a = 2R,

$\therefore$ Volume of the unit cell = $8R^3$

Packing factor = $\frac{4\Pi R^3}{3a^3} = 0.52$

For BCC structure: [2]

BCC:



Number of atoms per unit cell = 2

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

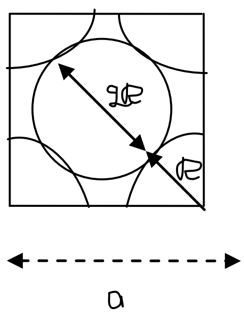
Volume of the unit cell $= a^3$

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 X $\frac{4}{3}\Pi R^3$

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

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

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

2.b. [3]

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

Case 1: d = 0.816Å

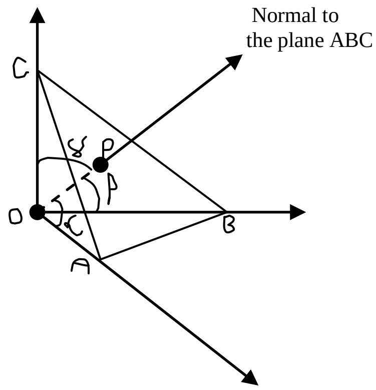
Case 2: d = 1.41Å

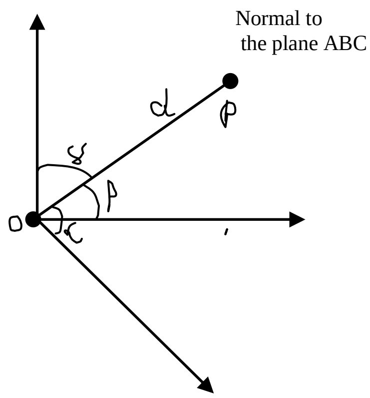
3.a.

Miller indices: [7]

Miller introduced a system to represent a plane in a crystal .He defined a set of three numbers to specify a plane in a crystal. These are the reciprocal of the intercepts made by the crystal plane on crystallographic axis reduced to smallest integers.

Expression for interplanar spacing in terms of Miller indices:





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.

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

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

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

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

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

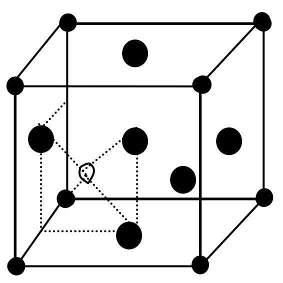
3.b. **[3]**

Bravais lattice: It is a lattice with identical atoms at all the lattice points and each atom has identical environment

Primitive cell : It is a unit cell with one atom.

Allotrophy: Under different conditions, many solid substances can produce different crystal structures of the same chemical constitution. This phenomenon is known as *Allotrophy.*

4.a. Structure of Diamond: [6]



Diamond structure consists of two inter penetrating face centered cubic lattices. The two lattices are separated by (1/4) of the body diagonal. The coordination number is 4 as 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 .Number of atoms per unit cell is 8.The positions of two basis atoms are (0 0 0)and $(\frac{1}{4}\frac{1}{4}\frac{1}{4})$.

Packing factor = Volume occupied by atoms/ volume of unit cell

$$= 8\left(\frac{4}{3}\right)\frac{\pi R^3}{a^3}$$

From the diagram $$2r = \frac{2\left(\frac{a}{4}\right)^2+\left(\frac{a}{4}\right)^2}{}$$

Simplify $$a = 4r/\sqrt{3}$$

So, APF = 0.34

4.b. [4]

From Bragg's Law

2d sinΘ =nλ

On substitution, we get d =0.23À

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

a = 0.51À

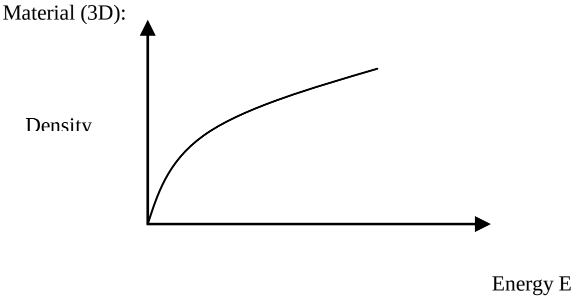
5.a. **[5]** Nano materials possess dimensions of 0.1 to 100nm.Their properties are dependent on their dimensions. Many parameters such as density of states, energy gap, electrical &, thermal conductivity etc, are different from that from their bulk counterparts.

. Density of states:

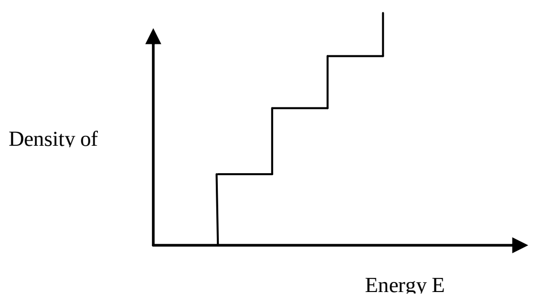
It is defined as the number of energy levels per unit energy range per unit volume.

$$g(E)(dE) = \left[\frac{8\sqrt{2}\pi m^{\frac{3}{2}}a^3}{h^3}\right]E^{\frac{1}{2}}\,dE$$

Bulk Material (3D):



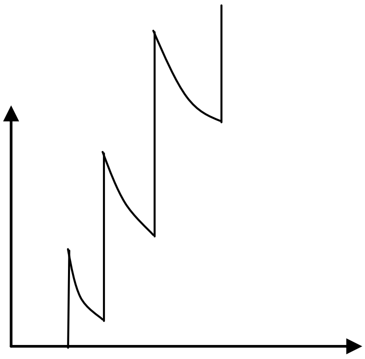
(2D)



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

(1D)

Density of

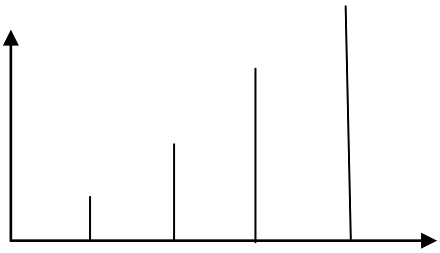


Energy E

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

0D

Density of states



Energy E

5.b. **[5]**

. Sol-gel Method:

This method involves two types of materials ‘Sol’ and ‘Gel’.

Principle:Sol-Gel method involves formation of ‘sols’ in a liquid and then connecting the sol particles to form a network.By drying the liquid, it is possible to obtain powders, thin films etc.,

Methods for sol-gel formation: Sol can be obtained by,

•Hydrolysis

•Condensation and Polymerization of monomers to form particles

•Agglomeration of particles

After the formation of sol by hydrolysis, evoparation of solvent results in formation of network (gelation) which extends throughout the liquid medium known as gel. Si-O_2-ZnS :Mn^{2+} sol is prepared by this method.

6.a. **[7]**

Scanning electron Microscope:

7

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.

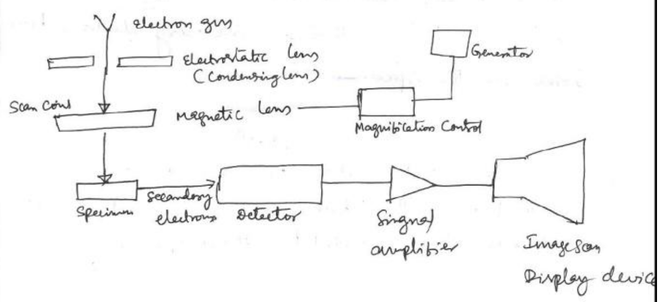
Working :

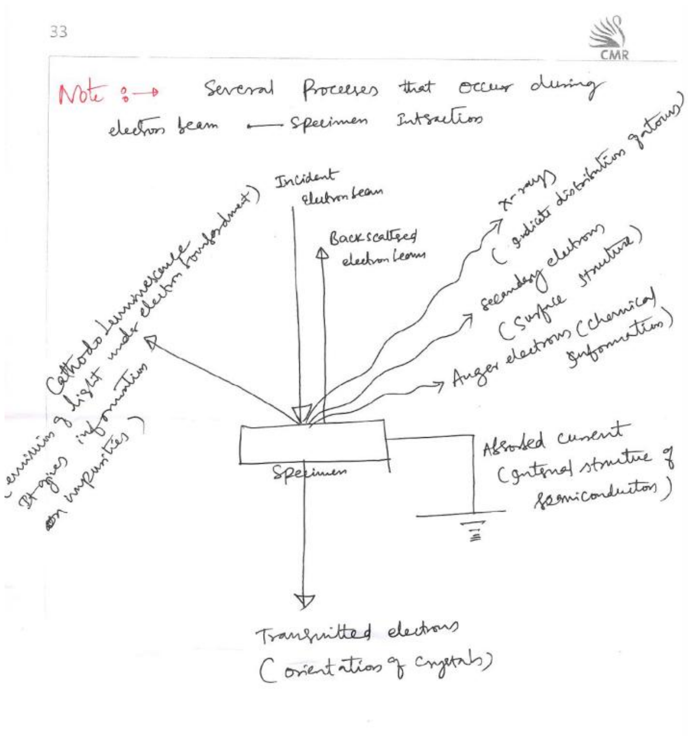
1) when accelerated (30keV) electrons enter a solid, they are scattered elastically (back scattered electrons) and inelastically (secondary electrons emitted from the sample).

8

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 structure of the specimen.



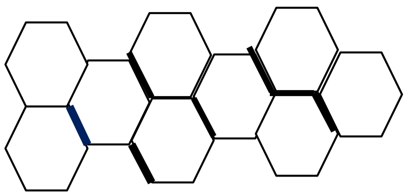


6.b. **[3]**

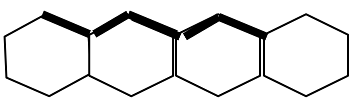
Carbon nano tubes:

A carbon nano tube (CNT) is a cyclindrical rolled up sheet of graphene which is a single layer of Graphite atoms arranged in hexagonal pattern.Each nanotube is a single molecule composed of millions of atoms. The length of CNT is around 100µm.Their hexagonal structure provides great tensile strength and elastic properties. Graphene sheet can be rolled in more than one way, producing different types of CNT's like arm chair, Zig-Zag and Chiral structures.
They possess high thermal and electrical conductivity,chemical reactivity.

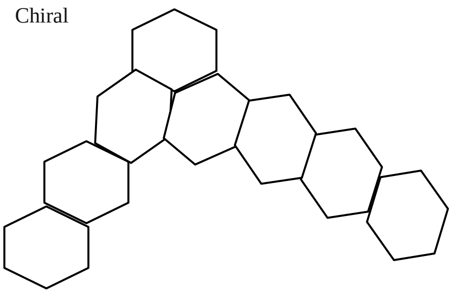
Arm Chair:



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.

Properties & Applications :

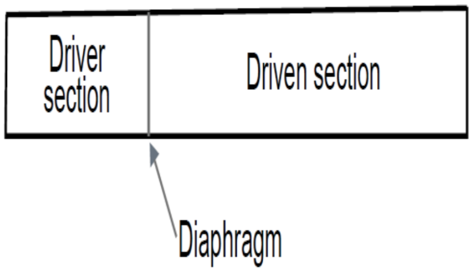
1.Hydrogen storage:Suitable Hydrogen storage system is necessary for fuel cells.Due to their small dimensions, CNT can store Hydrigen in inner cores.
2.Supercapacitors:They have hig capacitance.Very large capacities result from the high nanotube surface area.
3.Making of Nanoprobes and sensors
4. High efficiency PV cells.

7.a. **[7]**

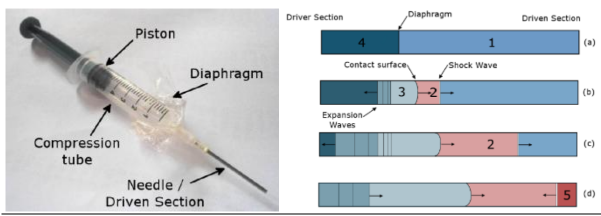
Shock waves: When air undergoes large and rapid compression (following an explosion/the release of engine gases in to an exhaust pipe/when an air craft or a bullet flies at supersonic velocity) a thin wave of large pressure change is produced. This discontinuity is pressure propagates as a wave known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



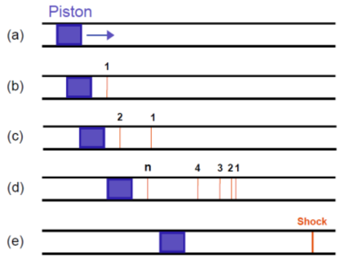
- A high pressure (driver) and a low pressure (driven) side separated by a diaphragm.
- When diaphragm ruptures, a shock wave is formed that runs along the driven section.
- Shock strength is decided by driver to driven pressure ratio, and type of gases used.

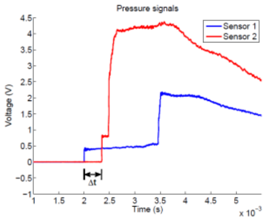


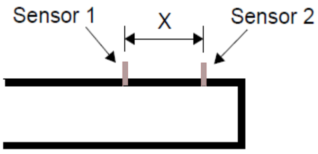
Working:

- 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.







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

7.b. **[3]**

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.

8.a.[6]

Ideal gas equation : pv =n RT or p = ρRT

Here p is pressure , v is volume, ρ is density, T is absolute temperature

Equation of continuity/Law of conservation of mass: ρVA = constant

Here V is velocity of the fluid, A is are of cross section

Law of conservation of energy / Bernoullie's equation :

$$\frac{p}{\rho} + \frac{V^2}{2} + gh = \text{Constant}$$

$$\frac{\rho V^2}{2} + p + \rho gh = \text{Constant}$$

$$\frac{k}{k-1} RT + \frac{1}{2} u^2 = \text{constant}$$

$$\frac{k}{k-1} \frac{p}{\rho} + \frac{u^2}{2} = \text{constant}$$

k is the ratio of specific heat at constant pressure to specific heat at constant volume

Rankine –Hugonitt wquation:

The pressure jump across the primary shock wave , 1 → 2

$$\frac{\rho_2}{\rho_1} = \frac{(\gamma+1) M^2}{2 + (\gamma-1) M^2} \qquad \frac{P_2}{P_1} = 1 + \frac{2\gamma}{\gamma+1}\left(M^2 - 1\right)$$

$$\frac{T_2}{T_1} = \frac{p_2}{p_1}\left[\frac{\left(\frac{\gamma+1}{\gamma-1}\right) + \frac{p_2}{p_1}}{1 + \left(\frac{\gamma+1}{\gamma-1}\right)\frac{p_2}{p_1}}\right]$$

The pressure jump across the reflected shock wave, 2 → 5

$$\frac{T_5}{T_2} = \frac{p_5}{p_2}\left[\frac{\left(\frac{\gamma+1}{\gamma-1}\right) + \frac{p_5}{p_2}}{1 + \left(\frac{\gamma+1}{\gamma-1}\right)\frac{p_5}{p_2}}\right] \qquad \frac{p_5}{p_2} = \frac{(3\gamma-1)\frac{p_2}{p_1} - (\gamma-1)}{(\gamma-1)\frac{p_2}{p_1} + (\gamma+1)} \qquad \frac{\rho_5}{\rho_2} = \left[\frac{1 + \left(\frac{\gamma+1}{\gamma-1}\right)\frac{p_5}{p_2}}{\left(\frac{\gamma+1}{\gamma-1}\right) + \frac{p_5}{p_2}}\right]$$

8.b. **[4]**

Applications of Shock waves:

- 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