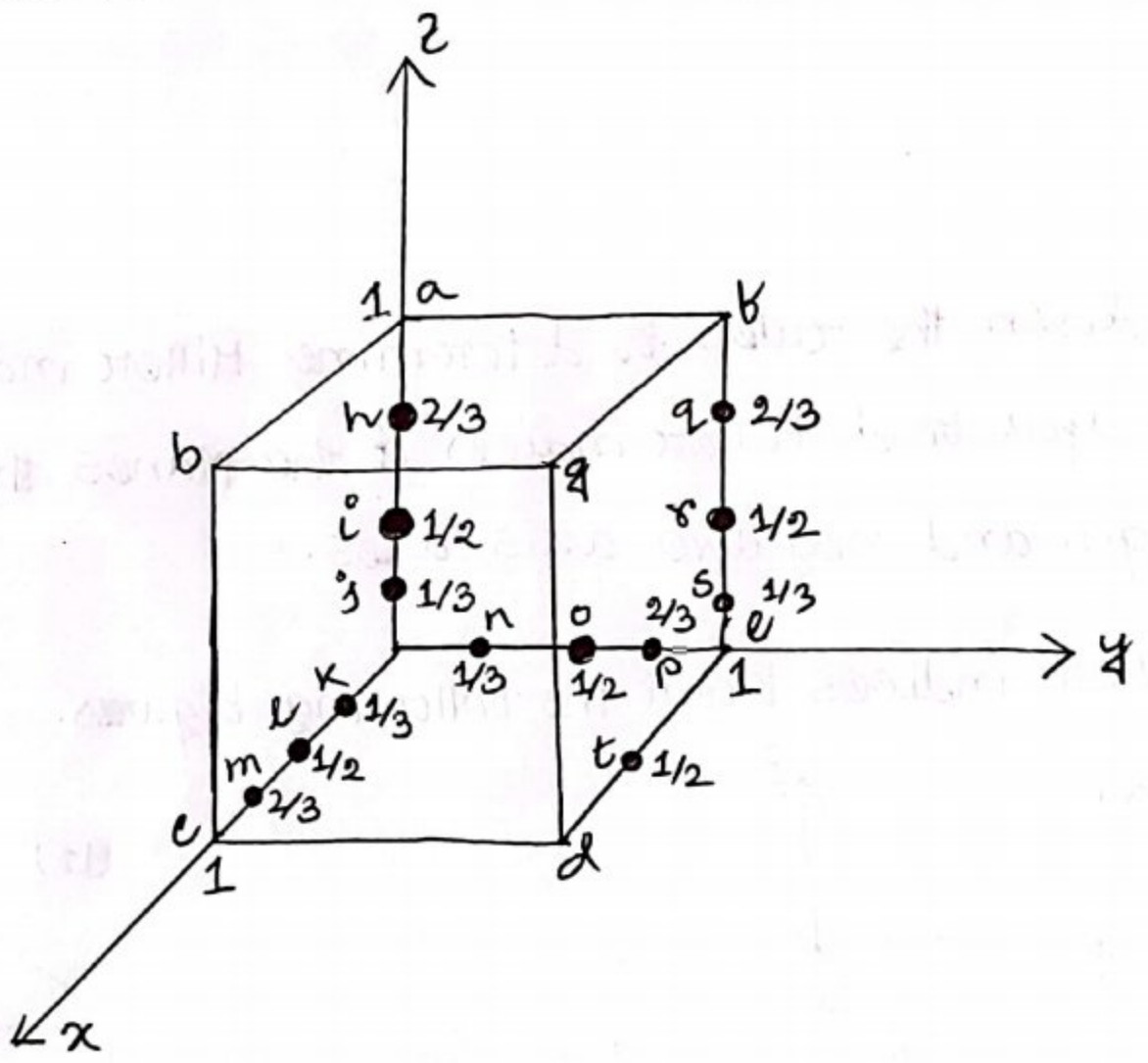
Module - 1
Crystal Structures.

1. Define lattice, basis and crystal.
2. How many types of Bravais lattices are there? Write short notes with proper diagram about all the types of Bravais lattice.
3. What is unit cell? How many unit cells are there? Write short notes with proper diagram about all the types of unit cells.
4. Define Miller indices. Find indices from the following figure according to the different indications.



(a) bqde
(b) jkn
(c) abqf
(d) amn
(e) bcdq
(f) bfec
(g) jstl
(h) jel
(i) abde
(j) abde
(k) aed
(l) ipk

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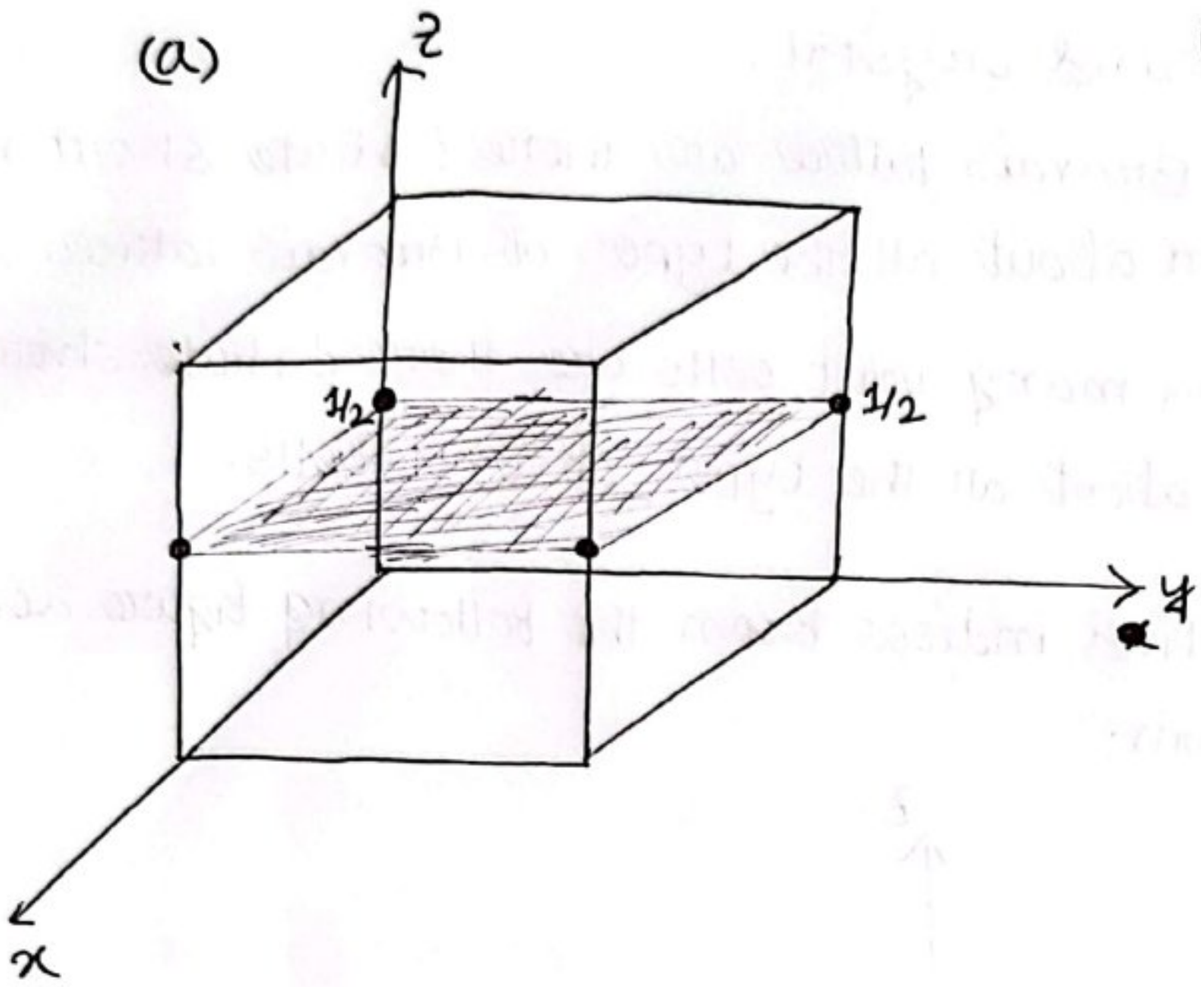
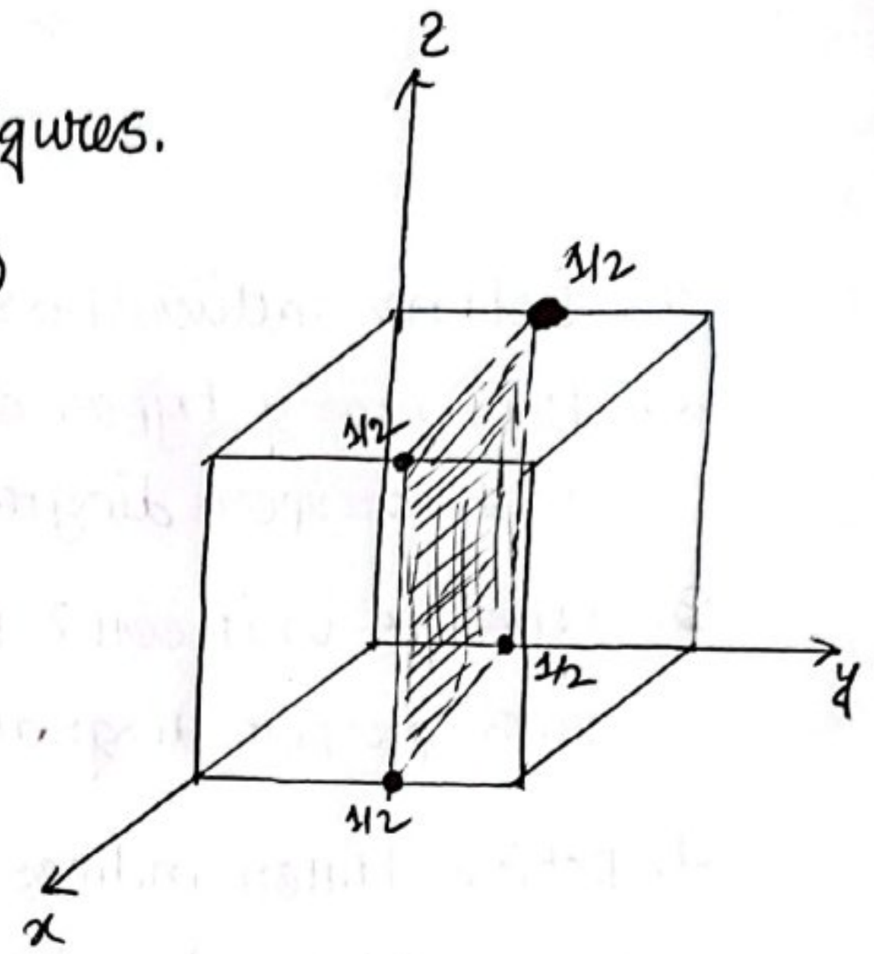
5. Find Miller indices from the following figures.

(a)



(b)

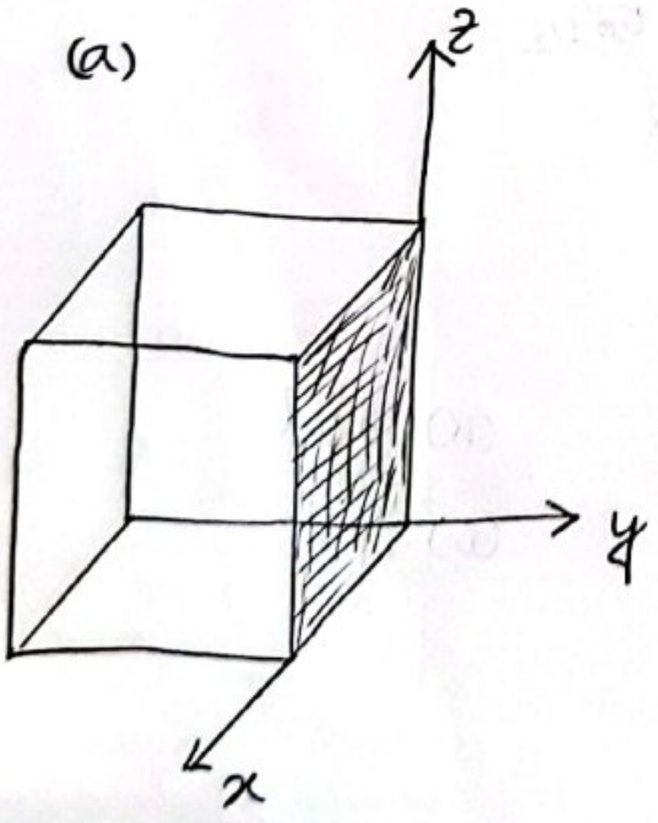


6. Write down the rules to determine Miller indices.

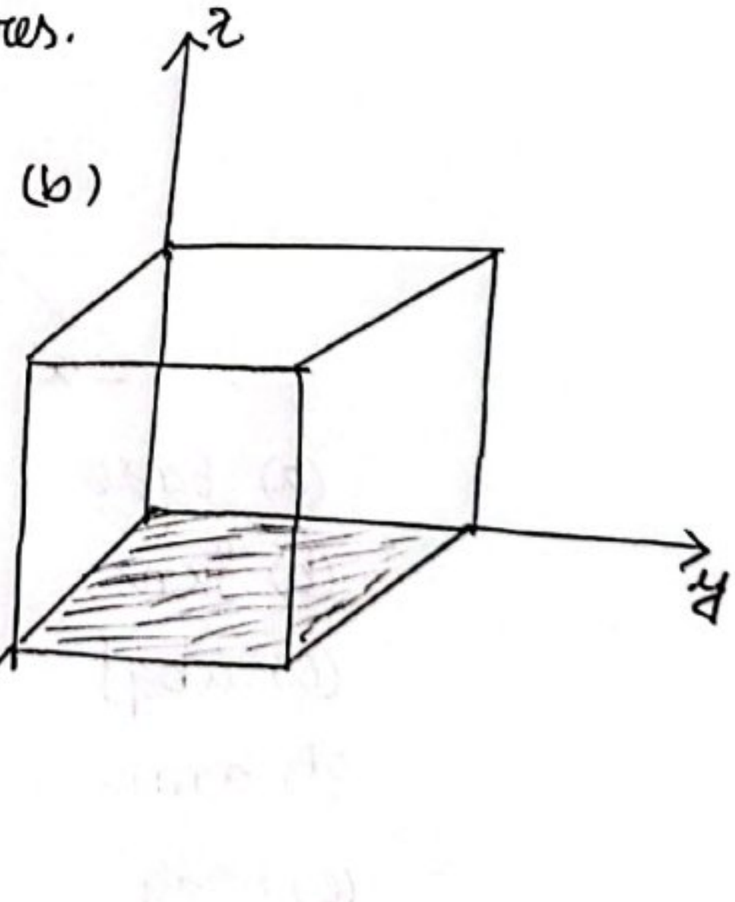
7. How do you find Miller indices of the planes that pass through the origin and negative axis/axes.

8. Find Miller indices from the following figures.

(a)



(b)



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9. What is family of planes? Write down all the members of the family of plane {100}

10. What are the applications of Miller indices?

11. What is d-spacing? If we have a crystal structure whose side of the cube is a= 0.361 nm and plane (220), find the d-spacing of the cubic structure.

12. How many types of crystals are there? Write down their properties. Give at least two examples of each type of crystal.

A → M

Module-2
Classical theory of electrical and thermal conduction

1. Define charge and current. Derive the relation $I = nAvq$.
2. What is drift velocity? Consider a current of 3A flowing in a copper conductor having a cross-section of $1\ mm^2$. Find the drift velocity. Assume $n = 8.5 \times 10^{28}/m^3$.
3. Define mobility and current density.
4. What is scattering? What do you mean by relaxation time/ average free time/ mean scattering time?
5. Derive the relation $\sigma = en\mu_d$
6. Derive the relation $\sigma_T = \frac{e^2 n \tau}{m_e T}$
7. What is Matthiessen's rule? Derive $\rho = \rho_T + \rho_R$.
8. What is Hall Effect? Write down some applications of Hall Effect.
9. What is Hall co-efficient? Derive $R_H = -\frac{1}{ne}$
10. Calculate the drift mobility and mean scattering time of conduction electrons of copper at room temperature, given that the conductivity of copper is $5.9 \times 10^5\ \Omega^{-1} m^{-1}$. The density of copper is $8.96\ g\,cm^{-3}$ and its atomic mass is $63.5\ g\,mol^{-1}$.
11. What is the applied electric field that will impose a drift velocity equal to 0.1 percent of the mean speed, $u\ (\sim 10^6\ ms^{-1})$ of conduction electrons in copper? What is the corresponding current density and current through a Cu wire of diameter 1 mm?

5//

~~12.~~ Given that the mean speed of conduction electrons in copper is $1.5 \times 10^6 \, ms^{-1}$ and the frequency of vibration of copper atoms at room temperature is about $4 \times 10^{12} \, s^{-1}$, estimate the drift mobility of electrons and conductivity of copper. The density d of copper is $8.96 \, g cm^{-3}$ and the atomic mass M_{at} is $63.56 \, g mol^{-1}$.

6/11

Module-3
Magnetic properties of materials

1. What is magnetic dipole? Define magnetic dipole moment.
2. Explain (with proper diagram) how a circular current carrying conductor works/acts as a bar magnet.
3. What is atomic magnetic moment? Derive $\mu_{orb} = -\frac{e}{2m_e} L$, and $\mu_{spin} = -\frac{e}{m_e} S$.
4. What is magnetization vector? Prove $M = I_m$
5. Define relative permeability.
6. What is magnetizing field or magnetic field intensity? Prove $\vec{H} = \frac{\vec{B}}{\mu_0} - \vec{M}$
7. What is magnetic susceptibility? Prove $\mu_r = 1 + \chi_m$
8. Classify magnetic materials. Explain them with examples.
9. What is magnetic domain? What's the reason behind formation of magnetic domain? Explain.
10. Explain the size of magnetic domains.

7

Module-1

Introduction to superconductivity:

1. Define superconductivity.
2. Define critical temperature for superconductor. Give some examples.
3. Explain Meissner effect.
4. What are Type-I and Type-II superconductors. Write down their differences.
5. Define critical current density.
6. Mention some technological applications of superconductivity.

Module 5

Dielectric Properties of materials

1. What is dielectric constant / relative permittivity?
2. Explain Electronic Polarization.
3. Define Polarization and bound charge density.
4. Prove $P = \sigma_p$
5. Define Polarizability. Prove $\chi_e = \frac{N\alpha_e}{\epsilon_0}$
6. Prove $\epsilon_r = 1 + \frac{N\alpha_e}{\epsilon_0}$
7. Derive Clausius - Mossotti Equation, i.e., $\frac{\epsilon_r - 1}{2 + \epsilon_r} = \frac{N\alpha_e}{3\epsilon_0}$
8. The electronic Polarizability of the Ar atom is $1.7 \times 10^{-40} Fm^2$. What is the static dielectric constant of solid Ar (below 84K) if its density is $1.8\ g\,cm^{-3}$?
9. Explain electronic polarization in covalent solid.
10. Consider a pure Si crystal that has $\epsilon_r = 11.9$.
    (a) What is the electronic Polarizability due to valence electrons per Si atom (if one could portion the observed crystal polarization to individual atoms)?
    (b) Suppose that a Si crystal sample is electroded on opposite faces and has a voltage applied accross it. By how much is the local field greater than the applied field?
    (c) What is the resonant frequency to corresponding to ω_0?

From the density of the Si crystal, the number of Si atoms per unit volume, N, is given as $5 \times 10^{28}\ m^{-3}$.

9//

11. Explain ionic polarization.

12. Explain orientational polarization.

13. Consider the CsCl crystal which has one Cs^+Cl^- pair per unit cell and a lattice parameter a of 0.412 nm. The electronic polarizability of Cs^+ and Cl^- ions is $2.7 \times 10^{-40}\ Fm^2$ and $4 \times 10^{-40}\ Fm^2$ respectively, and the mean ionic polarizability per ion pair is $5.8 \times 10^{-40}\ Fm^2$. What is the dielectric constant at low frequencies and that ~~of~~ at optical frequencies?

14. Define dielectric loss, dipole relaxation (dielectric resonance), dielectric strength.

15. What are the factors affecting dielectric strength?

16. Explain Piezoelectric crystal. Mention some application of Piezoelectricity.

17. A typical 1 MHz quartz crystal has the following properties:

$f_S = 1\ MHz$

$f_a = 1.0025\ MHz$

$C_0 = 5\ pf$

$R = 20\ ohm$

What are C and L in the equivalent circuit? What is the quality factor Q of the crystal? Given that $Q = \frac{1}{\pi 2 f_S RC}$.

10//

Module 6
Carrier Statistics

1. Explain Maxwell-Boltzmann Distribution.
2. Write down the characteristics of Maxwell-Boltzmann Distribution.
3. Define the following terms.
   (a) The most probable speed.
   (b) Arithmatic mean speed.
   (c) Root mean square speed.
4. Prove $V_{r.m.s} = \sqrt{\frac{V_1^2 + V_2^2 + --- + V_N^2}{N}}$
5. Explain Fermi-Dirac Distribution.
6. Define Fermi Energy.

11

Module 7
Band Theory of Solids.

1. Explain molecular band theory and define conduction band and valence band. What is forbidden gap?
2. Classify materials according to molecular band theory focussing the distance between valence band and conduction band.
3. What is Bloch theorem? Explain Block function.
4. Explain Kronig-Penny model.
5. What do you mean by effective mass?
6. Explain density-of-states.

12 → M

Module 8
Introduction to quantum mechanics.

1. What is wave nature of electron?
2. A 50 gram golf ball travelling at a velocity of 20 ms^{-1}. Find its wavelength.
3. A proton travelling at 2200 ms^{-1}. Find its wavelength. $m_p = 1.67 \times 10^{-27}$ kg.
4. An electron is accelerated by 100 V. Find its wavelength.
5. Write down the differences between classical Mechanics and Quantum Mechanics.
6. What is wavefunction? What are the characteristics of wavefunction?
7. Derive Time Independent Schrödinger equation.
8. Derive Time Dependent Schrödinger equation.
9. Derive energy and solve for the wavefunction of an electron confined to an infinite potential well (1-D). Sketch Energy levels, $\psi(x)$ and $|\psi(x)|^2$.
10. Define the following terms.
    (a) Eigen functions.
    (b) Eigen Energies
    (c) Ground state.
    (d) node
    (e) Even parity and odd parity.

11. Can a particle posses any value for its energy when confined to a certain region? Explain why. What's the case of a free electron?

12. Consider an electron in an infinite potential well of size 0.1 nm. What is the ground energy of the electron? What is the energy required to put the electron at the second energy level? How can this energy be provided?

13. Consider a macroscopic object of mass 100 g confined to move between two rigid walls separated by 1 m. What is the minimum speed of the object? What should the quantum number n be if the object is moving with a speed $1\ ms^{-1}$? What is the sp separation of the energy levels of the object moving with the speed?

14. What is Heisenberg's uncertainty principle?

15. Prove $\Delta E\, \Delta t \geq \hbar$

16. Consider an electron confined to a region of size 0.1 nm. What will be the uncertainty in its momentum and hence its kinetic energy?

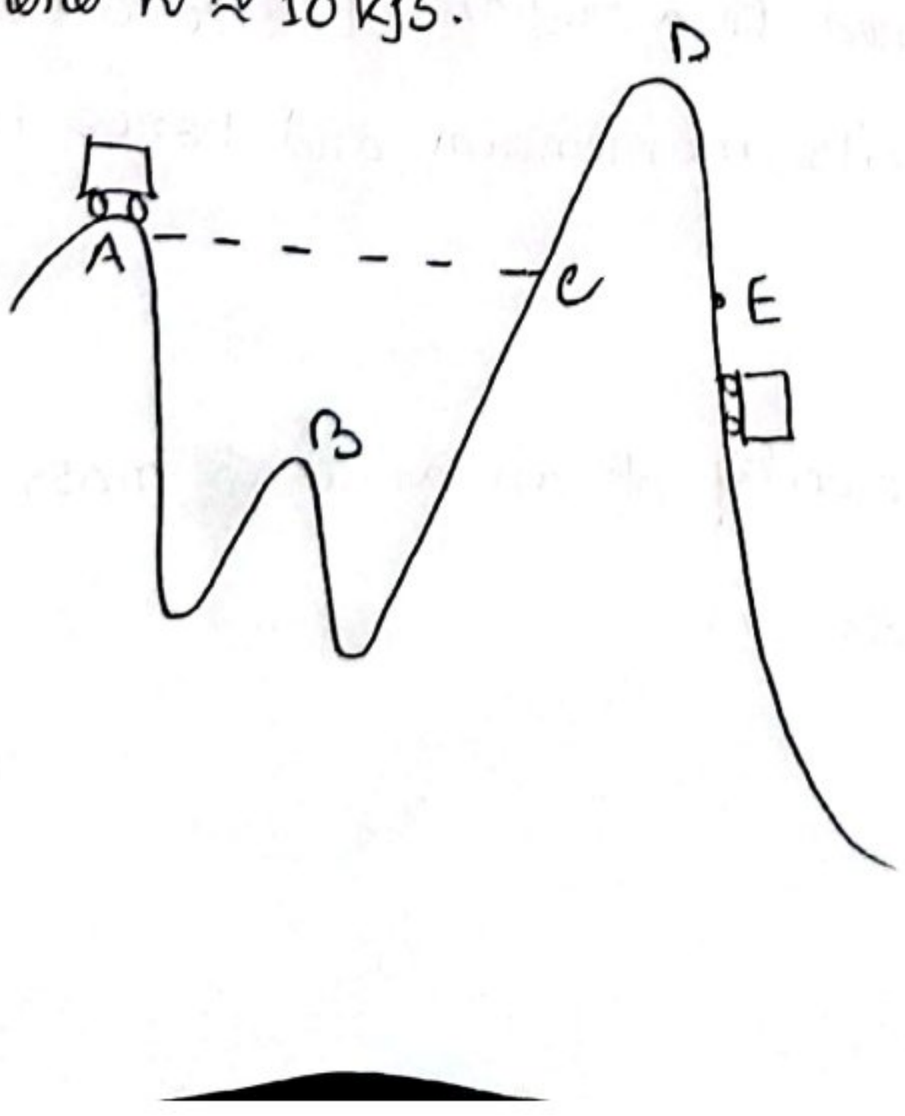
17. Estimate the minimum velocity of an apple of mass 100 g confined to a crate of size 1m.

18. What is potential barrier?

19. Solve Schrödinger's Time Independent Equation for an electron in a potential barrier and define quantum tunnelling, transmission co-efficient.

20. consider two copper wires separated only by their oxide layer (CuO). Suppose the energy of the free electrons is 7 eV (Kinetic Energy) and layer thickness is 5 nm. Evaluate the transmission co-efficient. Assume the energy barrier of the layer as 10 eV.
What will be the transmission co-efficient if the barrier is 1 nm?

21. Estimate the probability that a roller coaster carriage, that weighs 100 kg, releases from A, in the figure below, from a height at 10 m can reach point E over a hump that is 15 m high and 10 m wide. What will be the probability in a universe where $h \approx 10$ Kjs.



15

22. What is step potential? Explain it with the help of Time Independent Schrödinger equation.

23. Explain Potential Box in three dimension.

24. How many states (eigen functions) are there at energy level E_{493} for a square potential energy box?

16/11

Module-9

Modern Theory of metals:

1. Determine fermi energy and average energy of electrons.
2. What is specific heat.
3. Explain classical and quantum mechanical calculation of Specific heat.

"The End"

Assignment Groups:

	Roll No.
Module-1	: 1002, 03, 04, 06, 07, 08
Module-2	: 1009, 10, 11, 12, 13, 14
Module-3	: 1015, 16, 17, 18, 19, 20
Module-4 + Module-6	: 1021, 22, 23, 24, 25, 26
Module-5	: 1027, 28, 29, 30, 31, 32,
Module-8	: 1033, 35, 36, 37, 38, 39
Module-7 + Module-9	: 1040, 42, 43, 45, 47, 48.