UNIT 1

MECHANICS

1. **Define multi-partical dynamics.**

Multi-particle dynamics (or) dynamics in a system of particles, is defined as the study of motion in respect of a group of particles in which the seperation between the particles will be very small i.e., the distance between the particles will be negligible.

2. **What do you mean by centre of mass?**

If the mass of the entire particles in the objects is concentrated at a particular point, that point is called as centre of mass.

3. **Write the equation for Kinetic Engery of system of particles.**

The kinetic energy of system of particles.

$$E_K = \frac{1}{2} M \mathrm{v}_{\mathrm{cm}}^2 + \frac{1}{2} \sum_i m_i \mathrm{v}_{\mathrm{im}}^2$$

Term 1: $\frac{1}{2} M \mathrm{v}_{\mathrm{cm}}^2$ which represents the kinetic energy of centre of mass of the system and

Term 2: $\frac{1}{2} \sum_i m_i \mathrm{v}_{\mathrm{im}}^2$ which represents the sum of kinetic energy of all particles (moving with centre of mass) with respect to the origin.

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4. **Write short notes on rigid body.**

A rigid body (system of particles) is an object which has definite shape and size and does not change due to external force. In other hands, rigid body can be defined as "rigid body is an extended object in which distance between any particles is not altered during its motion".

5. **Write the kinematics of rotational motion.**

1 $\omega_f = \omega_i + \alpha t$

2 $\theta = \omega_i t + \frac{1}{2}\alpha t^2$

3 $\omega_f^2 = \omega_i^2 + 2\alpha\theta$

6. **Define moment of inertia.**

Moment of inertia of a body about an axis is defined as the summation of the "product of the mass and square of the perpendicular distance" of different particles of the body from the axis of rotation.

7. **State the parallel axis theorem.**

It states that moment of inertia with respect to any axis is equal to the sum of moment of inertia with respect to a parallel axis passing through the center of mass and mass times of square of the distance between the parallel axes

8. **State the perpendicular axis theorem.**

It states that the moment of inertia of a thin plane with respect to an axis perpendicular to the thin plane surface is equal to the sum of the moments of inertia of a thin plane with respect to two perpendicular axes lying in the surface of the plane and these three mutually perpendicular axes are meet at a common point.

9. **Define moment of a force.**

The moment of a force about a point is defined as the product of the magnitude of the force and the perpendicular distance from the point to the line of action of force.

10. **Define Couple**

A couple constitutes a pair of two equal and opposite forces acting on a body, in such a way that the lines of action of the two forces are not in the same straight line.

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11. Define torque.

Torque is defined as moment of force acting on the body in rotational motion with respect to the fixed point.

$$Torque = Force \times radius$$

12. State the Newton's first law for rotational motion.

An object continuous in its state of rest or uniform rotation with a constant angular velocity until it is acted upon by a non-zero net torque.

13. State the Newton's first law for rotational motion.

When an external torque is applied to an object, the torque produces an angular acceleration, which is directly proportional to the torque and inversely proportional to the moment of inertia of the object.

14. Prove that the rotational kinetic energy is conserved in the torque free motion of a rigid body.

The rotational kinetic energy $= \frac{1}{2} I\omega^2$

For torque free motion, the angular velocity is constant (ω-constant). The moment of inertia is time independent parameter, therefore the rotational kinetic energy is conserved if torque is not present.

15. State the law of conservation of angular momentum.

If net external torque does not act on the body, the angular momentum of the body will be a constant.

$\tau_{net} = 0 \Rightarrow \frac{dL}{dt} = 0$ Therefore, L is a constant.

Above equation is known as law of conservation of angular momentum.

17. When will be the angular momentum for a system of particles remains conserved?

If any net external torque does not act on the system, the angular momentum of the system of particles remains conserved. . Therefore, L is a constant.

18. Write short notes on gyroscope.

A gyroscope is a device which is used to measure (or) maintain the angular velocity and orientation, without changing its magnitude.

The main principle used in gyroscope is the product of angular momentum which is experienced by the torque on the wheel (or) disc is used to produce a gyroscopic procession in the spinning wheel.

19. What are the applications of gyroscope.

Gyroscopes are used in the following areas.

1. They are used as compasses in boats, aeroplanes, air crafts etc.,
2. Gyroscope is used in spacecraft in order to navigate the spacecraft to the desired target.
3. It is also used to stabilize the ships, satellites, ballistic missiles, etc.,
4. Gyroscopes are used in gyrotheodolites for maintaining the direction in tunnel mining.

20. Give the example of nonlinear oscillations.

1. Torsional Pendulum
2. Double pendulum.
3. Damped oscillator.

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UNIT 2

ELECTROMAGNETIC

THEORY

1. Write down the Maxwell's equations in differential form.

Maxwell's equations in differential form

S.No	Law	Differential form
1.	Gauss law in electric field	$\vec{\nabla} \cdot \vec{D} = \rho$
2.	Gauss law in magnetic field	$\vec{\nabla} \cdot \vec{B} = 0$
3.	Faraday's law	$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$
4.	Ampere's law	$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$

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2. Write down the Maxwell's equation in integral form

Maxwell's equation in integral form

S.No	Law	Integral form
1.	Gauss law in electric field	$\oint_s \vec{D}\cdot ds = \oint_V \rho \cdot dV$
2.	Gauss law in magnetic field	$\oint_s \vec{B}\cdot \vec{ds} = 0$
3.	Faraday's law	$\oint_l \vec{E}.dl = -\oint_s \frac{d\vec{B}}{dt}\cdot ds$
4.	Ampere's law	$\oint_l \vec{H}.dl = \oint_s \left(\vec{J} + \frac{\partial \vec{D}}{\partial t}\right)\cdot ds$

3. Write down the Maxwell's Equations for free space in differential form.

Maxwell's equations for a free space or vacuum in differential form are as follow

1. $\vec{\nabla}\cdot\vec{E} = 0$
2. $\vec{\nabla}\cdot\vec{B} = 0$
3. $\vec{\nabla}\times\vec{E} = -\frac{\partial \vec{B}}{\partial t}$
4. $\vec{\nabla}\times\vec{B} = \varepsilon_0\mu_0\frac{\partial \vec{E}}{\partial t}$

4. Define intrinsic impedance.

The ratio of magnitude of electric field to magnetic field is called intrinsic impedance.

The wave impedance or intrinsic impedance $\eta = \left|\frac{\vec{E}}{\vec{H}}\right|$

5. Write down the magnetic boundary conditions.

(i). $\vec{B}_{1N} - \vec{B}_{2N} = 0$ the field vector is continuous at the interface of the medium.

(ii). $\vec{H}_{1T} - \vec{H}_{2T} = \vec{J}_s$ the field vector is discontinuous at the interface of the medium. It is depends on the surface current density.

6. Write down the electric boundary conditions.

(i). $\vec{D}_{1N} - \vec{D}_{2N} = \rho_s$ the field vector is discontinuous at the interface of the medium. It is depends on the surface charge density.

(ii). $\vec{E}_{1T} - \vec{E}_{2T} = 0$ the field vector is continuous at the interface of the medium. .

7. Define pointing vector.

Poynting vector is defined as the amount of energy flow of electromagnetic wave per unit area per unit time along the wave propagation direction. It is denoted by $\vec{S}$ *and is given by*

$$\vec{S} = \vec{E} \times \vec{H}$$

8. What do you mean by radiation pressure?

When the electromagnetic wave strike the surface, then a force will appear due to the rate of change of momentum. The amount of pressure exerted per unit area on the surface due to the force is called **radiation pressure.**

9. What is mean by plane electromagnetic wave?

If the field vector of electromagnetic wave is constant over any plane that is perpendicular to the directon of wave propagation at any instant of time, then this wave is called **plane electromagnetic wave.**

10. Write down the wave equations of field vector in free space or vacuum.

(i). Wave equation in terms of electric field $\nabla^2 \vec{E} - \frac{1}{c^2}\frac{\partial^2 \vec{E}}{\partial t^2} = 0$

(ii). Wave equation in terms of magnetic field $\nabla^2 \vec{B} - \frac{1}{c^2}\frac{\partial^2 \vec{B}}{\partial t^2} = 0$

11. Write any two properties of plane electromagnetic waves in free space.

1. EM wave travel with the speed of light in vacuum.
2. EM wave field vectors $\vec{E}$ and $\vec{B}$ are perpendicular to each other and they are also perpendicular to the direction of wave propagation.
3. Field vectors $\vec{E}$ and $\vec{B}$ are in same phase.

12. Write any two properties of plane electromagnetic waves in dielectric medium.

1. Electricmagnetic wave in dielectric medium travel with a speed less than the speed of light.

2. EM wave field vectors $\vec{E}$ and $\vec{B}$ are perpendicular to each other and they are also perpendicular to the direction of wave propagation.

3. Field vectors $\vec{E}$ and $\vec{B}$ are in same phase.

12. What is meant by polarization.

Polarization refers to a relationship between orientation of electric (or) magnetic field vector and the direction of electromagnetic wave propagation.

13. What is meant by linearly polarized wave?

If the polarization vector components $E_{0X} \neq 0, E_{0Y} \neq 0$ then the resultant of these two components will make a constant angle $\theta = \tan^{-1}\left(\frac{E_{0X}}{E_{0Y}}\right)$ and the corresponding wave is said to be **linearly polarized.**

14. What is meant by accelerating charge particles?

The accelerating charged particle is defined as the charged particle oscillating with respect to an equilibrium position.

15. Define intensity of electromagnetic wave.

The magnitude of time average of poynting vector is called intensity of electromagnetic wave.

16. List out any four sources of electromagnetic waves.

S.No	Source	Electromagnetic waves
1.	Accelerating charges	Radio waves
2.	Fast collisions of electrons	X-rays
3.	Nuclear decay	Gamma rays
4.	Hot object, Human body and sun	Infra-Red rays

17. Write short notes on cell phone reception.

Cell phone is a two-way communicating radio, consisting of a radio wave transmitter and a radio wave receiver. Cell phones contain radio antenna to receive radio signals and it is a metallic element (such as copper) engineered to be an effective size and shape for transmitting and receiving definite frequencies of radio waves. Receiver antenna converts the radio wave to an electric signal, this receiving and converting function is said to be cell phone reception.

boundary condition for non-conducting and vacuum interface.

S.No	Field components	Medium-1-Medium-2 Dielectric-Free Space
1.	$\vec{E}_{Tangential}$	$\vec{E}_{1T} = \vec{E}_{2T}$
2.	$\vec{D}_{Normal}$	$\vec{D}_{1N} = \vec{D}_{2N}$
3.	$\vec{H}_{Tangential}$	$\vec{H}_{1T} = \vec{H}_{2T}$
4.	$\vec{B}_{Normal}$	$\vec{B}_{1N} = \vec{B}_{2N}$

19. What is meant by electromagnetic waves of transverse in nature.

Electric field vector and magnetic field vectors are mutually perpendicular to each other and also perpendicular to the wave propagation direction. These three are mutually perpendicular to each other. Therefore electromagnetic wave said to be transverse in nature.

20. Define transmission co-efficient (T).

The transmission coefficient is defined as the ratio of the intensity of the transmitted wave (I_t) to the intensity of the incident wave (I_i).

22. Define reflection co-efficient (R).

the reflection coefficient is defined as the ratio of intensity of the reflected wave (I_r) to the intensity of the incident wave (I_i).

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1. What are the types of motion? give examples.

Based on the motion of the physical bodies, it can be classified into two types *viz*.

1. Translational motion, in which the motion of the body moves linearly with time.

Examples : Train moving in a track, Rocket launching etc.

2. Rotational (or) Oscillatory motion, in which the motion of the body repeat itself after regular interval of Time.

Examples : Bob moving in a pendulum clock, Beating of heart, Movement of Earth around the Sun etc.

2. Define Simple harmonic motion.

Simple Harmonic motion is the motion in which the acceleration of a body is directly proportional to the displacement from a fixed point and is always directed towards the fixed point (or) equilibrium position.

3. Categorize the types of SHM, with examples,

There are two types of simple Harmonic motions, viz

1. *Linear Simple Harmonic motion* : Here the displacement of the particle executing simple Harmonic motion is **linear.**

Examples : 1. Motion of Simple pendulum.
2. Motion of point mass suspended with a spring etc.

2. *Angular Simple Harmonic motion* : Here the displacement of the particle executing simple harmonic motion is **Angular**.

Examples : 1. Oscillations of a compound pendulum.
2. Torsional oscillations etc.

4. Write down the characteristics of SHM.

The characteristics of simple harmonic motion are as follows.

(i) The motion of the particle is periodic.

(ii) The motion of the particle is along a straight line about its mean position.

(iii) The acceleration of the particle is proportional to the displacement and is directed towards its mean position.

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5. Define Amplitude data and phase.

Amplitude : The Maximum distance covered by the body on either side of its mean position is called its Amplitude.

Phase : It is the physical quantity that express the instantaneous position and direction of motion of an oscillating system.

6. Define Time period and frequency. Give its relation.

Time Period : The smallest time required to complete one vibration (or) oscillation is known as time period.

$$\text{Time period } T = \frac{2\pi}{\omega}$$

$$\text{(or) } T = \frac{2\pi}{\sqrt{Acceleration/Displacement}}$$

$$\text{(or) } T = 2\pi\sqrt{\frac{Displacement}{Acceleration}}$$

***Frequency*:** The number of oscillations (or) vibrations made by a body per second is known as frequency of oscillation. It is the reciprocal of the time period.

The relation between time and frequency is $n = \frac{1}{T}$

7. List out the types of Oscillatory motion.

There are three type of oscillatory motion, based on the force that is acting on the system, *viz.*

1. Free vibration
2. Damped Oscillation and
3. Forced Oscillation

8. What is ment by free vibration.

Free vibration : A system (or) body which vibrates freely without any resistance (Even air) (or) Frictional force is called **free vibrations**. In real situation this is not possible, because by nature always some resistance is offered to the oscillating system.

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9. **What is meant by damped vibrations? Give examples.**

Damped Oscillation : In a real situation, if a body is set into vibrations, the amplitude keeps on decreasing because of frictional resistance to the motion and hence after some time the vibrations (or) oscillations will die. This type of oscillation is said to be a **damped oscillation.** In this oscillation (or) vibration, the body vibrates with its natural frequency.

Examples:

1. When a Pendulum is displaced from its equilibrium position, it oscillates with a decreasing amplitude and finally it come to rest.
2. If a mass its suspended in a spring and is set into vibration in air, it will take long time to come to rest, when compared to the same mass set into vibration in water.

10. **What is meant by Forced vibrations? Give examples.**

Forced Oscillation : There are situations in which we need to give external force for the oscillations to sustain. This type of oscillation in which the body vibrates with a frequency other than natural frequency due to the external force applied in equal interval of time is called **Forced Oscillation**.

Examples :

1. A Tuning fork set into vibration due to external force.
2. A floor vibrating due to Marching of soldiers.
3. A bob of simple Pendulum held in hand and then given number of swings by the hand.

11. **What do you understand by the term DEAD BEAT? Give examples.**

During oscillation motion, when the displacement decreases drastically without performing any oscillations, then the motion is set to be Over-damped Oscillation (or) Dead beat.

Examples: 1. Pendulum moving in a very thick coil media.
2. Dead beat moving coil galvanometer.

12. **What is Meant by critical damped motion? Give examples.**

During oscillatory motion, when the displacement decreases to zero rapidly, then it is called critical damped motion.

Examples :

1. Movement of pointer in voltmeter, Ammeter etc.
2. Sensitive galvanometers.

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13. What is meant by under damped motion? Give examples.

During oscillatory motion, when the displacement (or) Amplitude decays with respect to the damping factor, then it is termed as under damped motion.

Examples :

1. Motion of a simple pendulum in air.
2. Motion of the coil in ballistic galvanometer.

14. What is meant by Resonance? Give example

Resonance is observed due to the frequency matching, i.e., when the driving frequency (ω) matches with the natural frequency (ω_0), then resonance occurs.

For example, All mechanical structures such as Air planes, bridges, buildings etc., have one or more natural frequencies (ω_0). Now, if such as a structure is subject to a driving frquency (ω), then,

When $\omega = \omega_0$ i.e., *When the driving frequency* (ω) *coincides with the natural frequency* (ω_0) ***,resonance occurs.***

Examples :

1. Collapse of bridges and roads due to Earthquake.
2. Shattering of glass due to sound waves.

15 What are the analogies of mechanical oscillations with LCR circuits.

(i) The mass (m) in spring mass system (mechanical oscillations) is analogous to the inductor 'L' in LCR circuit (electro magnetic oscillations).

(ii) The damping constant (b) in spring mass system (Mechanical oscillations) is analogous to the Resistance (R) in LCR circuit (electromagnetic oscillations)and

(iii) The force constant (k) in spring mass system (mechanical oscillations) is analogous to the capacitance $\left(\frac{1}{C}\right)$ in LCR circuit (electromagnetic oscillations .

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16. Define wave motion and give its types.

Definition

A wave motion can be defined as a disturbance which travels in the material medium and is due to the repeated motion of the particles in the medium, about their mean position wherein the motion is being transferred from one particle to the next at regular interval of time.

Types

There are two types of waves, *viz.*,

(i) Transverse waves.

(ii) Longitudinal waves.

17. What is meant by transverse wave motion? Give examples

Transverse waves

It is the wave motion in which the particles of the medium vibrate about their mean position perpendicular (right angles) to the direction of propagation.

Examples: (1) Waves produced on the surface of water in which the particles of the medium vibrate up and down

(2) Waves produced in stretched strings.

18. What is meant by longitudianl wave motion? Give examples.

Longitudinal waves

It is the wave motion in which the particles of the medium vibrate about their mean position along the same line as that of propagation of the wave.

Examples: (1) Condensation & rarefactions produced in air by the vibratory motion of a tuning fork.

(2) Compressions & rarefactions in air when one end is fixed & other end is moved with piston in a cylinder [Kundt's tube experiment].

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19. Write the differences between transverse and longitudinal waves.

Sl. No.	Transverse wave motion	Longitudinal wave motion
1.	It is the wave motion in which the particles of the medium vibrates perpendicular the direction of propagation.	1) It is the wave motion in which the particles of the medium vibrates along the direction of propagation.
2.	Crests & Troughs are formed	2) Compresions and rarefactions are formed.
3.	Transverse waves can travel through solids & liquids but not through gases.	3) Longitudinal waves can travel through any medium.
4.	Transverse waves can be reflected, diffracted and polarized.	4) Longitudinal waves can't be be polarised.

20. What are the laws of transverse vibrations.

Laws of transverse vibrations

1) Law of length

The frequency of transverse vibrations of a stretched string is inversely proportional to its vibrating length under a constant stretching force.

i.e, $n \, \alpha \, \frac{1}{l}$ Where T & m are constant

2) Law of tension

For a string of given length and material, the frequency is directly proportional to the square root of the stretching force (Tension).

i.e., $n \, \alpha \, \sqrt{T}$ Where l, m are constant

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3) Law of mass

The frequency various inversely as the square root of the mass per unit length, when the tension and the length are kept constant.

i.e., $n \alpha \frac{1}{\sqrt{m}}$ Where T, l are constant.

21. Define standing waves (or) stationary waves with examples.

Stationary waves

When two identical progressive waves travel through a medium along the same line in opposite directions with equal velocities, they superimpose over each other and produces a new type of wave called as Standing wave (or) stationary wave.

They are called stationary waves because there is no flow of energy along the waves. In a stationary wave the points at which the displacement is zero are called nodes. The points at which the displacement maximum are called antinodes. In a stationary wave all the points between successive nodes will be in phase.

Examples 1) Waves along a string.

2) Waves along the air-column of a pipe.

22. Define travelling waves (or) progressive waves. Give examples.

Progressive waves

*In a **travelling wave (or) progressive wave,** the energy is transferred from one place to another by the continuous vibration of the particles in an elastic material medium about their equilibrium position.*

In a travelling wave every point vibrates with same amplitude and the phase of vibration changes for different points along its path.

Examples 1) Waves passing through water.

2) Electromagnetic waves in which the electric and magnetic fields vary periodically at right angles to each other and to the direction of propagation.

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UNIT 3

OSCILLATIONS, OPTICS, LASER

1. Explain why colours are seen over a thin film of petrol on roads. **(Nov. 1997)**

When white light, (sunlight) falls on a thin film of petrol on roads, interference takes place between the reflected light from the top and bottom layer of the petrol film and thus it appear coloured.

> ***NOTE :*** *The same principle is applicable for the formation of colours in soap bubbles.*

2. How is optical flatness of a surface checked using interference phenomena? **(Dec.2003)**

(Or)

What is the principle of using air wedge method to test the planeness of a glass plate? **(May.2004)**

The material (OB) whose flatness has to be tested is kept over a glass plate (OA) and tied at one end (O). Thus an airwedge is formed between the two glass plates. Now, light is made to fall over the setup and the interference pattern is viewed through a microscope.

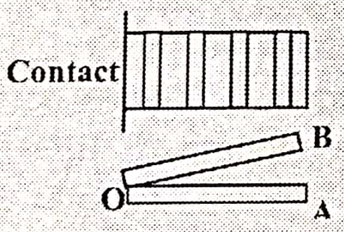

Fig. 4 (a)

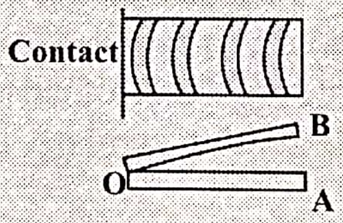

Fig. 4 (b)

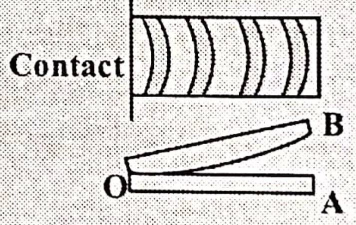

Fig. 4 (c)

i) If the bands appear regularly spaced, the surface is flat (***Fig.4a***)

ii) If the bands are curved towards the contact edge, the surface is concave (***Fig.4b***)

iii) If the bands are curved away from the contact edge, the surface is convex (***Fig.4c***)

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3. List out the conditions to be satisfied for total internal reflection?

(Jan. 2010)

(i) Light should travel from denser medium to rarer medium.

(ii) The angle of incidence (ϕ)at the interface should be greater than the critical angle (ϕ_c).

i.e. $\phi > \phi_c$

(iii) The refractive index of denser medium (n_1) should be greater than the refractive index of rarer madium. (n_2).

i.e. $n_1 > n_2$

1. What are Einstein's A and B coefficients?

The Einstein's Coefficients A and B accounts for spontaneous and stimulated emission / absorption probabilities of light by a system of particles. It also explains the importance of metastable states.

2. What are coherent sources.

Coherent sources are the sources which have the same wavelength and frequency. It has correlation with the amplitude and phase at any point with any other point.

3. What is meant by population inversion?

In general, the number of atoms in the ground state will be more than that of the atoms in the excited state and it is called usual population. The reverse of this (i.e.) a state of achieving more number of atoms in the higher energy level than that of the lower energy level is called population inversion.

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4. Define metastable state. **(Jan. 2009)**

Metastable state is the state for which the life time is more than the excited state, i.e., it is the more stable state, which lies between the excited state and the lower state.

5. Distinguish between spontaneous and stimulated emission?
(Dec.94, May 2005, Jan. 2009, Jan.2011, Jan.2012, Jan.2013)

S.No.	Spontaneous emission	Stimulated emission
1.	The atom in the excited state returns to ground state thereby emitting a photon, without any external inducement is called spontaneous emission.	An atom in the excited state is induced to return to ground state thereby resulting in two photons of the same frequency and energy is called stimulated emission.
2.	The emitted photons can move randomly.	The emitted photons move in the same direction and is highly directional
3.	The radiation given out is of less intensity and are incoherent.	The radiation is highly intense, monochromatic and coherent.
4.	The photons are not in phase.	The photons are inphase.
5.	The rate of transition is given by R_{21} (SP) $= A_{21}\ N_2$	The rate of transition is given by R_{21} (ST) $= B_{21}\ \rho_\nu\ N_2$

6. Define coherent length and coherent time? How are they related to each other? **(Dec.97)**

The maximum length upto which two waves trains have correlation with the amplitude and phase is called coherent length and the time upto which they are correlated is called coherent time.

They are related as, coherent time $= \dfrac{\textit{Coherent length}}{\textit{Velocity of light } (c)}$

7. What are the characteristics of Laser light. *(Or)* State the properties of laser beam. **(Dec.98, Dec.99, Nov.2001, May.03, May.04, Jan.05, Jan. 2009, Jan. 2010, Jan. 2011, Jan.2012)**

The four important characteristics of the laser beams are:

(i) It is highly directional.
(ii) It has high intensity.
(iii) The beam is purely monochromatic.
(iv) It has coherence.

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8. State some of the applications of lasers in engineering and Industry field. **(Nov.2001, Jan.2009, Jan. 2012)**

(i) High power lasers are useful to blast holes in diamonds and hardsteel.

(ii) They are used to test the presence of pores, cracks flows, blow holes etc in the materials.

(iii) They are used for welding and cutting.

9. Classify different types of lasers based on active medium, with one example for each. **(Nov.2002)**

S.No.	Type	Example
1)	Solid State Laser	Ruby Laser – Active medium is Ruby rod (Al_2O_3 doped with Cr_2O_3)
2)	Gas Laser	Carbon dioxide Laser – Active medium is the mixture of CO_2, N_2 and Helium (or) water vapour.
3)	Liquid Laser	Europium Chelate Laser. – Active medium is benzoyl accetonate dissolved in alcohol.
4)	Dye Laser	Coumarin Dye Laser – Active medium is coumarin compound.
5)	Semi Conductor Laser	Ga As Laser – Active medium is P-N junction diode made up of Ga and As.

10. What is the principle of semiconductor laser? **(Jan.2009)**

The electron in conduction band combines with a hole in the valence band and hence the recombination of electron and hole produces energy in the form of light. This photon, in turn may induce another electron in the conduction band to valence band and thereby stimulate the emission of another photon.

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11. **What is the role of nitrogen and Helium in CO_2 laser?**

(Jan.2009, Jan. 2010, Jan. 2011)

In CO_2 laser the nitrogen helps to increase the population of atoms in the upper level of CO_2 while helium helps to depopulate the atoms in the lower level of CO_2 and also to cool the discharge tube.

12. **What are the two types of transitions that are possible in a CO_2 gas laser? (Jan. 2011)**

i) Transition from Asymmetric mode [00°1] to bending mode [02°0] will emit laser of wavelength 9.6μm.

ii) Transition from Asymmetric mode [00°1] to symmetric mode [10°0] will emit laser of wavelength 10.6μm .

13. **What are different methods of pumping? (or)**
What are the different methods of achieving population inversion?

(Jan. 2010,Jan.2011)

There are five methods by which the pumping can be made, *viz.*,

(i) Optical pumping.
(ii) Direct electron excitation (Electron Discharge).
(iii) Inelastic atom–atom collision.
(iv) Direct conversion.
(v) Chemical process.

14. **What are the conditions required for laser action?** **(Jan.2010)**

The two important conditions required for laser action are:

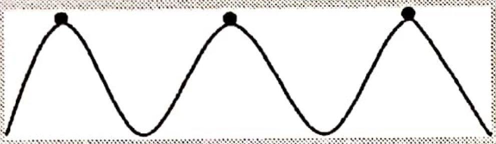
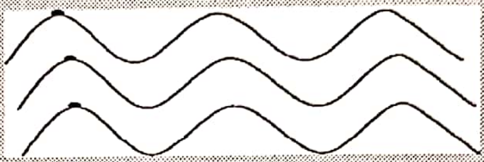
(i) Population inversion should be achieved.
(ii) Stimulated emission should be predominent over spontaneous emission.

15. **Can a two-level system be used for the production of laser? Why?**

(Jan. 2011, Jan. 2014)

No, two-level system cannot be used for the production of Laser, because for population inversion to be achieved, at least three levels are required.

16. Distinguish between temporal coherence and spatial coherence. **(Jan. 2011)**

S.No.	Temporal coherence	Spatial coherence
1.	Temporal coherence refers to the coherence between the two points of same wave at different time.	Spatial coherence refers to the coherence between two points in different waves over a time 't'
2.		
3.	Coherence length is small	Coherence length is large
4.	Coherence time is less	Coherence time is more.

17. What are differences between homojunction and heterojunction laser. **(Jan. 2009, Jan.2010)**

S.No.	Homojunction laser	Heterojunction laser
1.	Homojunction laser is made by a single crystalline material.	Heterojunction laser is made by different crystalline materials.
2.	Power output is low.	Power output is high.
3.	Pulsed output (sometimes continuous).	Continuous output.
4.	It has high threshold current density.	It has low threshold current density.
5.	Cost is less.	Cost is more.
6.	Life time is less.	Life time is more.
7.	Examples: (i) GaAS (ii) InP	Examples: (i) GaAs/GaAlAs (ii) InP / InAlP

18. How is a light emitting diode different from a semiconductor laser? (Dec.2003)

S.No.	LED	LASER
1.	It requires low current density.	It requires high current density.
2.	Junction of diode need not be polished.	Junctions of the diode should be highly polished.
3.	Minority carrier injection should take place	Stimulated emission will take place.
4.	Power output is low.	Power output is high.
5.	Intensity is less.	Intensity is very high.

19. Give some applications of laser in medical field. (Jan. 2013)

(i) It is used to drill minute holes in cell walls of human body.

(ii) It is used to treat cancer and tumour in human beings and animals.

(iii) It is used for the treatment of detached retina.

(iv) It is used to carry out microsurgery and bloodless operation.

(v) It is used to shatter the kidney stones.

(vi) It is used to cut the bones precisely.

20. What is the Principle for Laser action ? (Jan. 2016)

Principle: *Due to stimulated emission, the photons multiply in each step giving rise to an intense beam of photons that are coherent and moving in the same direction. Hence the Light is Amplified by Stimulated Emission of Radiation, termed as LASER.*

Explanation : Let us consider many number of atoms in the excited state. We know the photons emitted during stimulated emission has the same frequency, energy and are in phase as the incident photon. Thus results in 2 photons of similar properties. These two photons induce stimulated emission of 2 atoms in excited state thereby resulting in 4 photons. This 4 photons induce 4 more atoms and give rise to 8 photons etc., as shown in ***Fig. 5(a)***

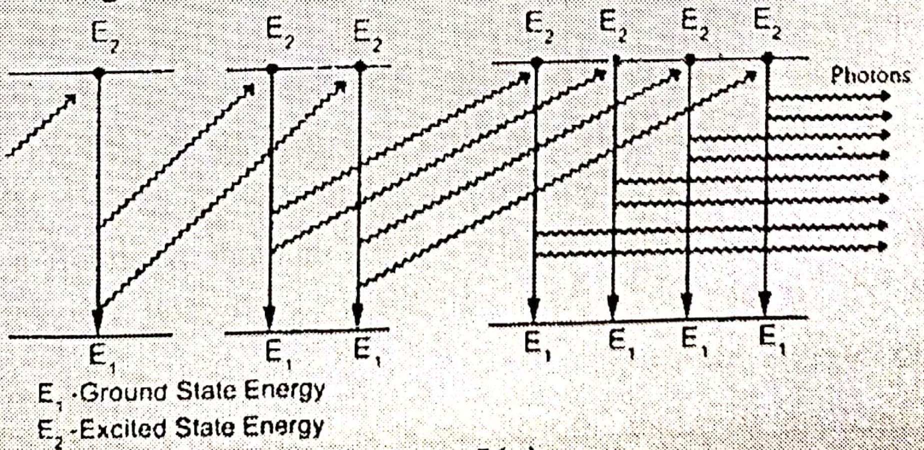


Fig. 5(a)

6. ***For a free particle moving within a one dimensional potential box, the ground state energy cannot be zero, Why?*** **(Jan. 2011, Jan. 2018)**

For a free particle moving within a one dimensional potential box, when $n=0$ the wave function is zero for all values of x i.e., it is zero even within the potential box. This would mean that the particle is not present within the box. Therefore the state with $n=0$ is not allowed. As energy is proportional to n^2 the ground state energy cannot be zero since $n=o$ is not allowed.

7. ***Define normalisation process and write down the normalised wave function for an electron in a one dimensional potential well of length 'a' metres.*** **(Jan. 2016)**

Normalisation is the process by which the probability of finding a particle inside any potential well can be done.

For a one dimensional potential well of length 'a' metre, the normalised wave function is given by

$$\psi_n = \sqrt{\frac{2}{a}} \sin \frac{n\pi x}{a}$$

---

1. ***What is meant by photon? Give any two properties.***

Definition: *Photons are discrete energy values in the form of small quantas of definite frequency (or) wavelength.*

Properties:

1. They do not have any charge and they will not ionise.
2. The energy and momentum of the photon is given by

$$E = h\nu \text{ and } p = mc.$$

where $\nu \rightarrow$ frequency

$m \rightarrow$ mass of photon

$c \rightarrow$ velocity of photon

h $\rightarrow$ Planck's Constant

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UNIT 4

QUANTUM

PHYSICS

1. *What is Compton wavelength? Give its value.*

(April 2003, Jan. 2009, Jan. 2010, Jan. 2011)

The shift in wavelength corresponding to the scattering angle of 90° is called Compton wavelength.

We know compton shift $\Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$

When $\theta = 90°$; $\cos\theta = 0$

$$\therefore \Delta\lambda = \frac{h}{m_0 c} = \frac{6.625 \times 10^{-34}}{(9.11 \times 10^{-31}) \times (3 \times 10^{8})}$$

$$\Delta\lambda = 0.02424 \text{ Å}$$

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2. State de-Broglie's hypothesis (or) Explain the concept of wave nature. (or) What is meant by matter waves? Give the origin of this concept.

(May 2004)

We know that, nature loves symmetry, since the light exhibits the dual nature (i.e) it can behave both as a particle and a wave, debroglie suggested that an electron, which is particle can also behave as a wave and exhibits the dual nature.

Thus, the wave associated with a material particle (electron) are called matter waves.

If v is the velocity and m is the mass of the particle then

de Broglie wavelength $\lambda = \frac{h}{mv}$

3. Define Compton effect and Compton shift. **(Jan. 2011)**

When a photon of energy '$h\nu$' collides with a scattering element, the scattered beam has two components, *viz.,* one of the same frequency (or) wavelength as that of the incident radiation and the other has lower frequency (or) higher wavelength compared to incident frequency (or) wavelength. This effect is called Compton effect.

The shift in wavelength is called Compton shift.

4. Mention any two important features of quantum free electron theory of metals. **(April 2003)**

(i) It shows that the energy levels of an electron are discrete

(ii) The Maximum energy level upto which the electrons can be filled is denoted by Fermi energy level.

5. What is the physical significance of a wave function?

(Dec. 2002, Nov. 2003, May 2004, Jan 2006, Jan. 2007, Jan. 2009, Jan. 2010, Jan. 2011, Jan. 2013)

1. The probability of finding a particle in space, at any given instant of time is characterised by a function $\psi(x, y, z)$, called wave function.
2. It relates the particle and the wave statistically.
3. It gives the information about the particle behaviour.
4. It is a complex quantity.
5. $|\psi|^2$ represents the probability density of the particle, which is real and positive.

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2. ***Explain the variation of Compton shift with respect to the scattering angle.***

The compton shift in wavelength increases with the increase in scattering angle. as shown below.

We know compton shift $\Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$

Case (i) When $\theta = 0$; $\Delta\lambda = 0$

Case (ii) When $\theta = 45°$; $\Delta\lambda = 0.0071$

Case (iii) When $\theta = 90°$; $\Delta\lambda = 0.02424$

Case (iv) When $\theta = 180°$; $\Delta\lambda = 0.0472$

3. ***What are the properties of matter waves?***

(i) Matter waves are not electromagnetic waves.

(ii) Matter waves are new kind of waves in which due to the motion of the charged particles, electromagnetic waves are produced.

(iii) Lighter particles will have high wavelength.

(iv) Particles moving with less velocity will have high wavelength.

(v) The velocity of matter wave is greater than the velocity of light.

4. ***What do you understand by the term 'wave function'.***

Wave function (ψ) is a variable quantity that is associated with a moving particle at any position (x, y, z) and at any time 't'. It relates the probability of finding the particle at that point and at that time.

Since ψ is a complex quantity, it has no meaning and hence the probability function $|\psi|^2 = \psi^* \psi$ is found, which is real and positive and has physical meaning, which is a measurable quantity too.

5. ***Write down the schroedinger wave equation and give any two applications of it.***

There are two types of schroedinger wave equations, *viz.*

(i) Schroedinger time dependent wave equation, given by

$$E\psi = H\psi$$

where $E \rightarrow$ Total energy of the particle

$H \rightarrow$ Hamiltonian operator

$\psi \rightarrow$ wave function

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(ii) Schroedinger time independent wave equation, given by

$$\nabla^2\psi + \frac{2m}{\hbar^2} = [E - v]\,\psi = 0 \quad \text{[3-dimensional]}$$

where $E \rightarrow$ Total energy of the particle

$V \rightarrow$ Potential energy of the particle

$m \rightarrow$ mass of the particle

$\hbar \rightarrow \frac{h}{2\pi}$ ($h \rightarrow$ Planck's constant)

Applications

1. It is used to find the electrons in metals.
2. It is used to find the energy levels of an electron in an infinite deep potential well.

6. *Write down the one dimensional schroedinger time independent equation and write the same for a free particle.*

The one dimensional (along x axis) schroedinger time independent equation is given by

$$\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}\;[E - V]\,\psi = 0$$

For a free particle, the potential energy is zero i.e., $V = 0$, Therefore the schroedinger equation becomes

$$\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}E\,\psi = 0$$

7. *Define Eigen value and Eigen function.*

Eigen value is defined as energy of the particle and is denoted by the letter (E_n)

Eigen function is defined as the wave function of the particle and is denoted by the letter (ψ_n).

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8. *What do you understand by the term "Probability of finding the particle"? Give examples.*

» $|\Psi|^2$ represents the probability density (or) probability of finding the particle per unit volume (or) ***Normalization of the wave function.***

» For a given volume $d\tau$, the probability of finding the particle is given by

$$\text{Probability } (P) = \iiint |\Psi|^2 \, d\tau$$

where $d\tau = dx \cdot dy \cdot dz$

» The probability will have any value between zero to one. (i.e.,)

(i) If $P = 0$ then there is no chance for finding the particle (i.e.,) there is no particle, within the given limits.

(ii) If $P = 1$ then there is 100% chance for finding the particle (i.e.,) the particle is definitely present, within the given limits.

(iii) If $P = 0.7$, then there is 70% chance for finding the particle and 30% there is no chance for finding the particle, within the given limits.

Example: If a particle is definitely present within a one dimensional box (x-direction) of length 'l', then the probability of finding the particle can be written as

$$P = \int_0^l |\Psi|^2 dx = 1$$

9. *What is meant by degenerate and non-degenerate states.*

(i) Degeneracy: It is seen from equation (28) and equation (29), for several combination of quantum numbers we have same energy eigen value but different eigen functions. Such states and energy levels are called ***Degenerate State.***

The three combination of quantum numbers (112), (121) and (211), which gives same eigen value but different eigen functions are called **3 fold degenerate state.**

(ii) Non-Degeneracy: For various combinations of quantum number if we have same energy eigen value and same (one) eigen function then such states and energy levels are called ***Non-Degenerate State.***

Example

For $n_x = 2\ n_y = 2\ n_z = 2$ we have $E_{222} = \dfrac{12\,h^2}{8ma^2}$ and

$$\Psi_{222} = \sqrt{\frac{8}{a^3}} \sin\frac{2\pi x}{a} \sin\frac{2\pi y}{a} \sin\frac{2\pi z}{a}$$

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UNIT 5

ADVANCED QUANTUM PHYSICS

1. ***List out the outcome (or) Characteristics of the particle executing simple harmonic motion in a harmonic oscillator.***

   1. The particles executing SHM will have discrete energy values.
   2. The energy valves are equidistant and are separated by $h\nu$.
   3. The minimum energy (for $n = 0$) is not zero.
   4. Energy levels are Non-degenerate.

2. ***Define zero point energy of a harmonic oscillator.***

The energy of the harmonic oscillator is quantised in steps of $h\nu$

$$\therefore E_n = \left[n + \frac{1}{2}\right] h\nu$$

Where $n = 0, 1, 2, 3 \ldots$

When $n = 0$, the above equation becomes

$$E_0 = \frac{1}{2} h\nu$$

Here E_0 represent the lowest energy value (or) zero point energy of the hamonic oscillator.

3. ***Give the energy eigen values and Hermite polynomials for a harmonic oscillator.***

The energy eigen values (E_n) for $n = 0, 1, 2, 3$ and the first four hermite polynomials $[H_n(y)]$ is given in table below.

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n	E_n	$H_n(y)$
0	$\frac{1}{2}h\nu$	1
1	$\frac{3}{2}h\nu$	$2y$
2	$\frac{5}{2}h\nu$	$4y^2-2$
3	$\frac{7}{2}h\nu$	$8y^3-12y$

4. Compare the energy values for a particle in a infinite potential well and the particle in a harmonic oscillator.

S.No.	Particle in a 1D Potential Well		Harmonic oscillator
1.	Energy eigen value is $E_n = \frac{n^2 h^2}{8ml^2}$	1.	Energy eigen value is $E_n = \left(n + \frac{1}{2}\right) h\nu$
2.	The minimum energy (for $n = 0$) is zero.	2.	The minimum energy (for $n = 0$) is not zero.
3.	The energy values are not at equal distance	3.	The energy values are at equal distances
4.	Energy levels are as shown in *Fig. 7(a)*	4.	Energy levels are as shown in *Fig. 7(b)*

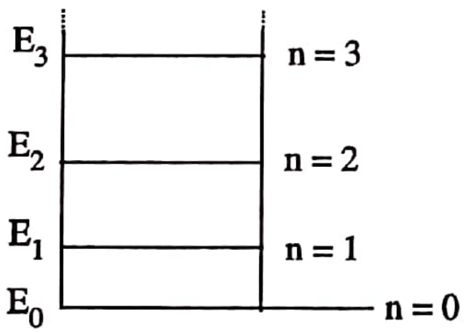

Fig. 7(a)

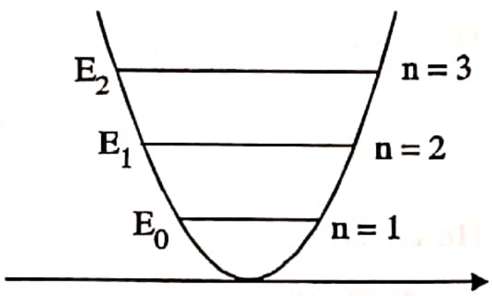

Fig. 7(b)

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5. *What do you understand by the term Transmission and reflection co-efficient?*

Transmission Co-efficient

We know that the probability density is the square of the amplitude of that function. Therefore the barrier transmission co-efficient (T) is the ratio between the square of the amplitudes of the transmitted wave $|C|^2$ and the incident wave $|A|^2$.

$$\therefore \text{ The transmission co-efficient } T = \frac{|C|^2}{|A|^2} \qquad ...(15)$$

The above equation is also called as the **"Penetrability"** of the barrier.

Reflection Coefficient

The reflection co-efficient (R) for the barrier surface at $x = 0$ is the ratio between the square of the amplitude of the reflected wave $|B^2|$ and the square of the amplitude of the incident wave $|A^2|$

$$\therefore \text{ The reflection co-efficient } R = \frac{|B|^2}{|A|^2} \qquad ...(16)$$

6. *What is meant by tunnelling effect?*

In quantum mechanics a particle having lesser energy (E) than the barrier potential (V) can easily cross over the potential barrier having a finite width 'l' even without climbing over the barrier by tunnelling through the barrier. This process is called Tunnelling.

7. *Mention any four occurrences of tunnelling effect.*

1. The tunnelling effect is observed in Josephson junction, in which electron pairs in the super conductors tunnel through the barrier layer, giving rise to Josephson current.
2. This effect is also observed in the case of emission of alpha particles by radioactive nuclei.
   Here, though the 'α' particle has very less kinetic energy they are able to escape from the nucleus whose potential wall is around 25 MeV high.
3. Tunnelling also occurs in certain semiconductor diodes called resonant tunnelling diodes.
4. Electron tunnels through insulating layer and act as a switch by tunnelling effect.

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8. What is the principle used in scanning tunnelling microscope?

The basic principle used in scanning tunnelling microscope (STM) is the tunnelling of electron between the sharp metallic tip of the probe and the surface of a sample.

Here, constant tunnelling current is maintained by adjusting the distance between the tip and the sample, with an air gap for electron to tunnel. In a similar way the tip is used to scan atom by atom and line by line of the sample and the topography of the sample is recorded in the computer.

9. What are the advantages and disadvantages of STM?

Advantages

1. It can scan, the positions & topography atom by atom (or) even electrons.
2. It is the Latest techniques used in Research laboratories for scanning the materials.
3. Very accurate measurement shall be obtained.
4. Magnification is upto nano-scale.

Disadvantages

1. Even a very small sound (or) vibrations will disturb the measurement setup.
2. It should be kept in vacuum, as even a single dust particle may damage the tip of the probe
3. Cost is high.
4. More complexity.

10. Given any two applications of STM.

1. It is used to produce Integrated circuit.
2. It is used in Biomedical devices.
3. Research labs are the major areas in which it is used.
4. They are used in material science studies for both bump and flat surfaces.

11. What is the principle used in Resonant tunnelling diode.

Resonant resonant tunnelling diode works on the principle of tunnelling effect, in which the charge carriers cross the energy barrier even with lesser energy than the barrier potential, Quantum mechanically. The probability of tunnelling increases with the decreasing barrier energy.

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12. Draw the symbol and write the theory behind resonant tunnelling diode.

The symbol of a resonant tunnelling diode is as shown in ***Fig. 7(c)***

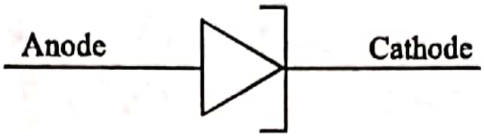

Fig. 7(c)

A resonant tunnelling diode also called as Essaki diode is formed using p and n-materials, with heavy doping say 1000 times larger than the conventional $p-n$-junction diode. Due to heavy doping, the barrier potential decreases drastically, in turn will help the charge carriers to easily tunnel the junctions, quantum mechanically.

13. When a resonant tunnelling diode behaves as a normal diode?

When a resonant tunnelling diode (or) resonant diode is forward biased, the current increases and then decreases at a voltage called valley voltage point.

Now, when the applied voltage is further increased ***beyond the valley-point voltage, the resonant tunnelling diode behaves as a normal diode.***

14. List out the current components in a resonant diode.

The current in resonant diode is due to 3 components *viz.*,

(i) Tunnelling current (I_T)

(ii) Diode current (I_D)

and (iii) Excess current (I_E)

∴ Total current $$I_{\text{Total}} = I_T + I_D + I_E$$

15. What is meant by Peak Current and Valley Current?

When the forward biasing voltage is increased the electrons from the n-region tunnel into the potential barrier and reaches the p-region.

Therefore the current increases rapidly due to tunnelling effect and reaches the peak-point 'p' as shown in ***Fig. 7(d)*** *and this current, is called peak current* (I_p). *The voltage at which the diode reaches peak current is called peak voltage* (V_p).

Now when the applied voltage is further increased, the tunnelling effect decreases as most of the electrons would have exhausted in tunnelling process. Therefore the current decreases and reaches the valley point '*V*' as shown in ***Fig. 7(d)***.

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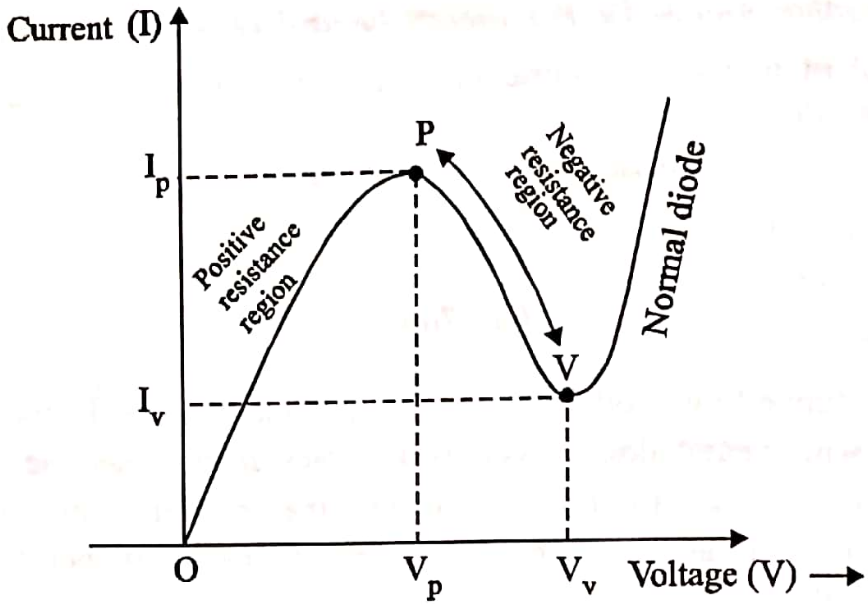

Fig. 7(d)

This minimum current is called valley current (I_v) and the corresponding voltage is called ***valley voltage*** ***(V_v)***.

16. What are the advantages and disadvantages of a resonant diode.

Advantages

1. Cost and noise is low.
2. Fabrication is very simple.
3. Operation speed is very high.
4. Power dissipation is low and hence it is environmental friendly device.

Disadvantages

1. Since it is a two terminal device, it is difficult to isolate the input and output.
2. It is a low output swing device.

17. What are the applications of resonant tunnelling diode.

1. As resonant tunnelling diode has both positive resistance [From point *O* to *P*] and negative resistance [From point *P* to *V*], it has many applications in the switching devices.
2. It can be used as normal diodes also.
3. They are used as high frequency microwave oscillators.
4. When resonant tunnelling diode is operated under negative resistance region, then it can be used as an oscillator (or) a switch.

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18. *Is there any chance for finding the particle outside the finite square potential well?*

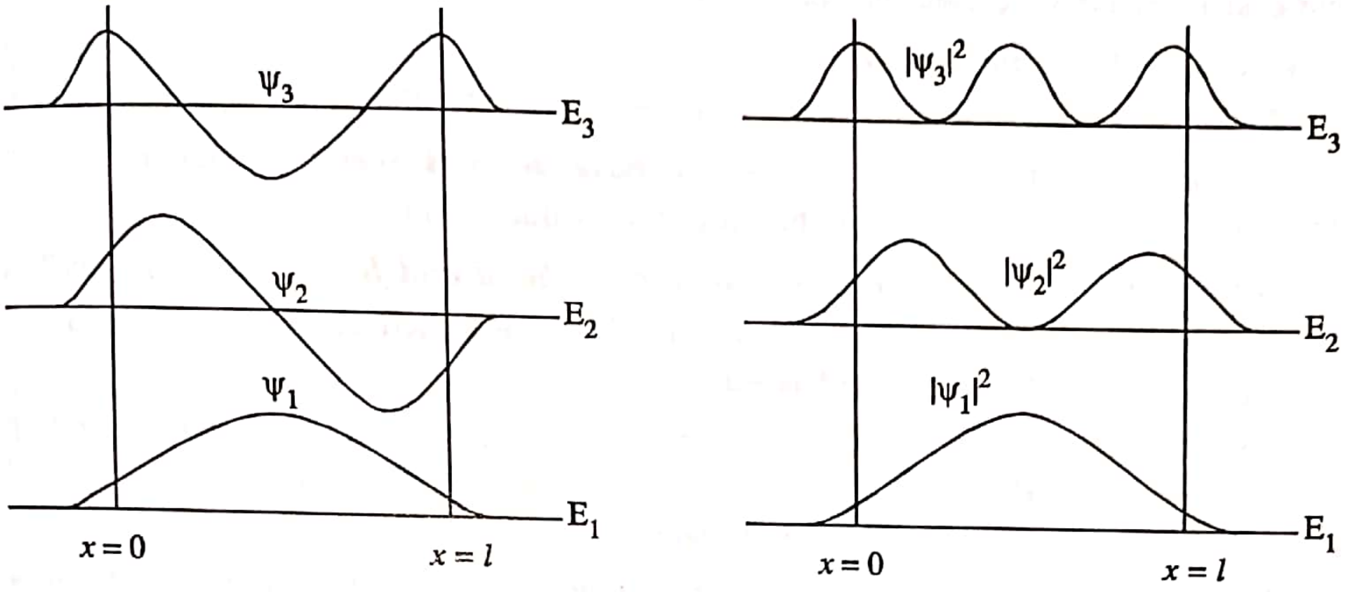

Fig. 7(e)

Yes, from the above figures ***fig. 7(e)*** we can see that when a particle is enclosed in a finite potential well, then the probability densities of the wave functions shows that there ***are some chances for finding the particle outside the well.***

19. *What are the differences between quantum theory and zone theory?*

S.No.	Quantum theory	Zone theory
1.	Here the electron is assumed to move in a region of constant potential.	In zone theory the electron is assumed to move in a region of periodic potential
2.	According to this theory the mass of the electron remains constant, when it moves through constant potential	Accordingly to zone theory the mass of the electron varies when it moves through periodic potential and is called effective mass of an electron.
3.	If fails to explain why some solids behaves as conductors, some behave as insulators and semi conductors.	It explains the behaviour of solids as conductors, semiconductors and insulators

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