

PH3151 Engineering Physics R-2021

Question Bank

UNIT – I MECHANICS

PART A

1. Define multiparticle dynamics.

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

The dynamics of a particle system consists of the application of Newton's laws of motion to a set of particles, which can be discrete (the particles can be counted) or form part of an extended object, in this case the system it is continuous. To explain the motion of a system of particles, it is inconvenient to analyze each one separately and see what forces act on it. Instead, a representative point of the set is defined, called the center of mass.

2. Define centre of mass of the system.

Centre of mass is the point in the body or a system of particles where the mass of the whole body seems to be concentrated. It is found by taking the weighted average position of the mass. Centre of mass is the point at which the distribution of mass is equal in all directions and does not depend on gravitational field.

Taking first the simple case of a system of just two particles of masses m_1 and m_2 and of a total mass M , with r_1 and r_2 as their position vectors with respect to some origin, if R vector be the position vector of the centre of mass, we have

$$\vec{R} = \frac{m_1 \vec{r}_1 + m_2 \vec{r}_2}{m_1 + m_2} = \frac{m_1 \vec{r}_1 + m_2 \vec{r}_2}{M}$$

Or,

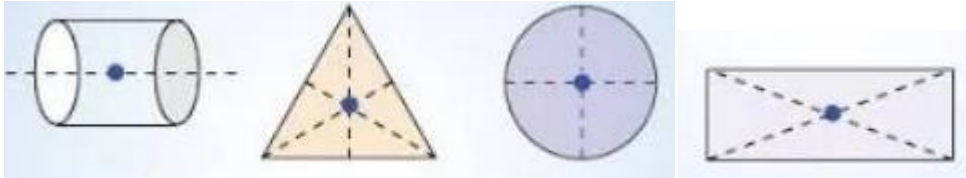
$$M \vec{R} = m_1 \vec{r}_1 + m_2 \vec{r}_2,$$

i.e., the product of the total mass of the system and the position vector of the centre of mass (CM) is equal to the sum of the products of the individual masses and their respective position vectors. The position of the CM of the system may thus be easily obtained.

3. What is centre of mass (CM)?

Centre of mass of a body or system of a particle is defined as, a point at which the whole of the mass of the body or all the masses of a system of particle appeared to be concentrated. In physics, we can say that the centre of mass is a point at the centre of the distribution of mass in space (also known as balance point). For simple rigid objects with uniform density, the centre of mass is located at the centroid.

- The center of mass of a two-particle system lies on the line connecting the particles (or, more precisely, their individual centers of mass). The center of mass is closer to the more massive object.
- The center of mass of a solid triangle lies on all three medians and therefore at the centroid, which is also the average of the three vertices.
- The center of mass of a rectangle is at the intersection of the two diagonals.
- In a spherically symmetric body, the center of mass is at the center.



4. Give the example for motion of centre of mass

The moon revolving around the earth in a circular orbit

- We know that the moon revolves around the earth in a circular orbit. The force of attraction between the moon and earth is the gravitational force which is again an internal force.
- To eliminate the chances of the moon and earth colliding with each other due to the presence of internal forces, we assume that both moon and earth are revolving around their centre of mass, such that they are always at the opposite side of their centre of mass.

5. How centre of mass is determined for rigid body and regular shape?

- The center of mass of a body is defined as a point where the entire mass of the body appears to be concentrated. Therefore, this point can represent the entire body.
- For bodies of regular shape and uniform mass distribution, the center of mass is at the geometric center of the body.
- For simple rigid objects with uniform density, the center of mass is located at the centroid.

6. Define rigid body.

A rigid body is usually considered as a continuous distribution of mass. It can be also defined as a collection of particles with the property that the distance between particles remains unchanged during the course of motions of the body.

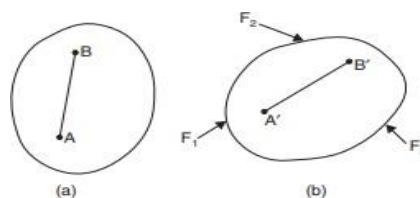
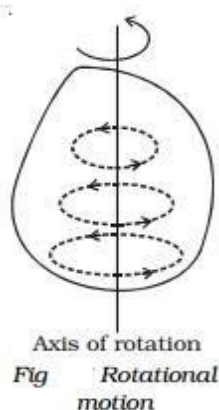


Fig. 1.1

A rigid body (also known as a rigid object) is a solid body in which deformation is zero or so small it can be neglected. The distance between any two given points on a rigid body remains constant in time regardless of external forces exerted on it.

7. Define rigid body rotation

Rigid body rotation is featured prominently in science, sports, and engineering. Theoretically, it is a collection of particles that are at a fixed distance from one another. In an ideal scenario, these bodies do not change their shape or deform. These kinds of bodies are usually a continuous distribution of mass. For analyzing the motion of such bodies, the position of the center of mass is required. When forces are applied to such bodies, it produces an angular acceleration and linear acceleration. It becomes essential to study how these forces affect rigid bodies and produce an angular and linear acceleration in them.



Let's see them in the detail about the rotational motion of a rigid body. Rotational motion is more complicated than linear motion, and only the motion of rigid bodies will be considered here. A rigid body is an object with a mass that holds a rigid shape. Many of the equations for the mechanics of rotating objects are similar to the motion equations for linear motion.

- Rigid body rotation is a motion that occurs when a solid body moves in a circular path around something. The rotational motion can be broken down into two types of rotation – Rotation about a fixed axis and rotation about a fixed point. Rotation about a fixed axis is said to be when the body is rotating about an axis that has a fixed location and orientation relative to the body.
- Example of such rotations includes – hinged door.
- The second type of rotational motion involves the rotation of the body around a point. A child's spinning top is one example of this type of rotational motion.

9. Write down the equation of motion for rotational motion.

In the case of rotational motion, different constituent particles have different linear velocities but all of them have the same angular velocity.

$$\omega = \omega_o + \alpha t$$

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

$$\omega^2 = \omega_o^2 + 2\alpha \theta$$

10. Define moment of inertia of a body

Moment of inertia from a Physics point of view is basically a quantitative measure of the rotational inertia or the angular mass of a body. In simple terms, it is the opposition that the body exhibits to the change in rotation about an axis which may further be internal or external.

The moment of inertia (I) is mostly specified based on the distribution of mass in the body with respect to the axis of rotation.

The moment of inertia is a measure of how resistant an object is to changes in its rotational motion. The moment of inertia of the cross-section of a body is its resistance to changes in its rotation.

11. Define moment of inertia of a particle.

- Moment of inertia of a particle is defined as the quantity expressed by the body resisting angular acceleration which is the sum of the product of the mass of every particle with its square of a distance from the axis of rotation.
- The formula for the moment of inertia of a particle is the “sum of the product of mass” of each particle with the “square of its distance from the axis of the rotation”. The formula of Moment of Inertia of a particle is expressed as **$I = mr^2$**

12. Define moment of inertia of a rigid body.

The expressions of moments of inertia (MI) for different object forms as :

$$1. \text{ For a particle : } I = mr^2$$

$$2. \text{ For a system of particles : } I = \sum m_i r_i^2$$

$$3. \text{ For a rigid body : } I = \int r^2 dm$$

Rigid body is a continuous aggregation of particles. We, therefore, need to modify the summation in the expression of moment of inertia by integration as :

$$I = \int r^2 dm$$

13. What factors the moment of inertia depends?

The moment of inertia of a body is directly proportional to its mass and the distance of the particles of the body from the axis of rotation. Hence, the moment of inertia depends on **mass and distance from the rotating axis**, and force and density do not affect the moment of inertia of a body.

$$I = mr^2$$

14. What is the physical significance of moment of inertia?

The physical significance of moment of inertia is that it performs the same role in rotational motion that the mass does in linear motion. Just as the mass of a body resists change in its state of linear motion, the moment of inertia resists a change in its rotational motion. This property of the moment of inertia has been put to a great practical use. Most machines, which produce rotational motion have as one of their components a disc which has a very large moment of inertia.

Examples of such machines are the steam engine and the automobile engine. The disc with a large moment of inertia is called a flywheel. To understand how a flywheel works, imagine that the driver of the engine wants to suddenly increase the speed. Because of its large moment of inertia, the flywheel resists this attempt. It allows only a gradual increase in speed. Similarly, it works against the attempts to suddenly reduce the speed, and allows only a gradual decrease in the speed. Thus, the flywheel, with its large moment of inertia, prevents jerky motion and ensures a smooth ride for the passengers.

15. What is radius of gyration?

The moment of inertia of a rotational rigid body is often written as

$$I = M K^2$$

Where M is the total mass of the body

and K is called the radius of gyration of the body.

The radius of gyration is that distance from the axis of rotation where the whole mass of the body can be assumed to be placed to get the same moment of inertia which the body actually has. It is important to remember that the moment of inertia of a body about an axis depends on the distribution of mass around that axis. If the distribution of mass changes, the moment of inertia will also change.

16. What are the theorems on moment of inertia?

The two theorems of Moment of Inertia are

- (i) Parallel axes theorem
- (ii) Perpendicular axes theorem

17. State parallel axis theorem.

The moment of inertia of a body about any axis is equal to the sum of its moment of inertia about a parallel axis through its centre of gravity and the product of the mass of the body and the square of the distance between the two axes.

$$I_{zz} = I_{xx} + I_{yy}$$

18. State perpendicular axis theorem.

The moment of inertia of a plane lamina body about an axis perpendicular to the plane is equal to the sum of the moments of inertia about two mutually perpendicular axes in the plane of the lamina such that the three mutually perpendicular axes have a common point of intersection.

$$I_{AB} = I_{GG} + Ay_c^2$$

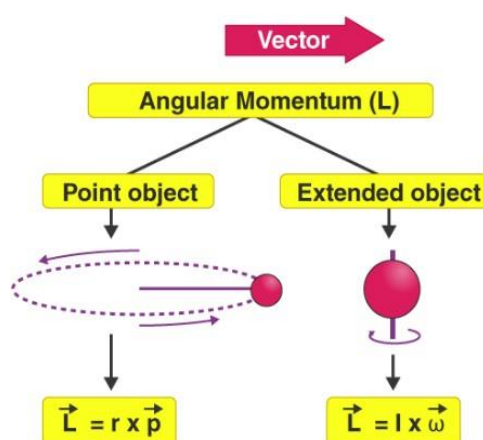
19. Define angular momentum.

Like linear momentum, angular momentum is the measure of the "quantity of motion". From Newton's second law, we know that first time derivative of linear momentum gives net external force on a particle. By analogy, we expect that this quantity (angular momentum) should have an expression such that its first time derivative yields torque on the particle.

1: Angular momentum of a particle in general motion is given as:

$$\ell = \mathbf{r} \times \mathbf{p} = m(\mathbf{r} \times \mathbf{v})$$

where " $\mathbf{r}$ " is the linear vector connecting the position of the particle with the "point" about which angular momentum is measured and " $\mathbf{p}$ " is the linear momentum vector. In case, the point coincides with the origin of coordinate system, the vector " $\mathbf{r}$ " becomes the position vector that small letter " ℓ " is used to denote angular momentum of a particle. The corresponding capital letter " L " is reserved for angular momentum of a system of particle or rigid body.



2: For rotation of a particle, angular momentum has additional expression in terms of moment of inertia and angular velocity as :

$$\ell = I\omega = mr^2\omega$$

20. Define torque.

Torque is the measure of the force that can cause an object to rotate about an axis. Force is what causes an object to accelerate in linear kinematics. Similarly, torque is what causes an angular

acceleration. Hence, torque can be defined as the rotational equivalent of linear force. The straight line about which the object rotates is called the axis of rotation.

In physics, torque is simply the tendency of a force to turn or twist. Different terminologies such as moment or moment of force are interchangeably used to describe torque. The distance of the point of application of force from the axis of rotation is sometimes called the moment arm or lever arm.

How is Torque Calculated?

A simple way to calculate the magnitude of the torque is to first determine the lever arm and then multiply it times the applied force.

Now, from the above observation, we conclude that the torque produced depends on the magnitude of the force and the perpendicular distance between the point about which torque is calculated and the point of application of force. So, mathematically torque is represented as:

$$\tau = Fr \sin \theta$$

where r is the length of the lever arm and θ is the angle between the force vector and the lever arm.

21. State conservation of angular momentum

When applied to angular momentum, the law of conservation means that the momentum of a rotating object does not change unless some type of external torque is applied. Torque, in this sense, can refer to any outside force that acts upon the object to cause it to twist or rotate. Without the application of torque -- when net torque is zero -- the angular momentum remains constant; that is, the momentum remains conserved.

$$\frac{d\mathbf{L}}{dt} = 0$$

or $\mathbf{L} = \text{constant.}$

Thus, if the total external torque on a system of particles is zero, then the total angular momentum of the system is conserved, i.e. remains constant.

22. What is gyroscope?

A gyroscope is defined as the device has a spinning disc that is mounted on the base such that it can move freely in more than one direction so that the orientation is maintained irrespective of the movement in the base. 'Gyre' is a Greek word, meaning 'circular motion' and Gyration means the whirling motion.

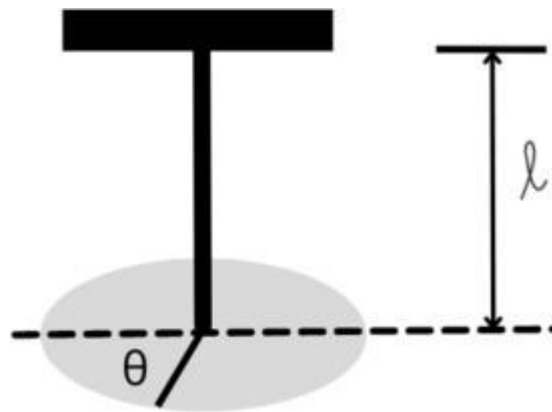
A gyroscope is a spatial mechanism which is generally employed for the study of precessional motion of a rotary body. Gyroscope is generally employed for the control of angular motion of a body. If we attempt to move some of its parts, it does not only resist this motion but even evades it. This resistance to change in the direction of rotational axis is called the gyroscopic effect.

23. What are the uses of gyroscope?

Gyroscope finds applications in gyrocompass, used in aircraft, naval ship, control system of missiles and space shuttle.

24. What is torsional pendulum

The torsional pendulum is the disc suspended to the thin bar which creates twisting oscillations around the axis of the bar. The restoring force developed by twisting or torsional action creates the oscillations in the disc. If the initial angular displacement θ is given to the disc by applying twisting torque, the thin rod generates the restoring torque, which causes the disc to revolve in the opposite direction.



This mechanism creates simple harmonic motion in the torsional pendulum.

$$\text{Period of torsional pendulum} = t = 2\pi\sqrt{\frac{I}{C}} \text{ --- (7)}$$

25. What are the uses of torsional pendulum?

Torsion pendulums are often used for time-keeping purposes. For instance, the balance wheel in a mechanical wristwatch is a torsion pendulum in which the restoring torque is provided by a coiled spring.

26. What is double pendulum?

A double pendulum is a pendulum with another pendulum attached to its end, forming a simple physical system that exhibits rich dynamic behavior with a strong sensitivity to initial conditions. The motion of a double pendulum is governed by a set of coupled ordinary differential equations and is chaotic.

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Question Bank

UNIT – II ELECTROMAGNETIC WAVES

PART A

1. Write Maxwell's equation – I from Gauss's law in electrostatics.

Maxwell's first equation is based on the Gauss law of electrostatic, which states that "when a closed surface integral of electric flux density is always equal to charge enclosed over that surface"

Gauss law for electricity

$$\vec{\nabla} \cdot \vec{D} = \rho$$

2. Write Maxwell's equation – II from Gauss's law in magnetostatics

Maxwell second equation is based on Gauss law on magnetostatics. Gauss law on magnetostatics states that "closed surface integral of magnetic flux density is always equal to total scalar magnetic flux enclosed within that surface of any shape or size lying in any medium."

Gauss law for magnetism

$$\vec{\nabla} \cdot \vec{B} = 0$$

3. Write Maxwell's equation –III from Faraday laws of electromagnetic induction.

Maxwell's 3rd equation is derived from Faraday's laws of Electromagnetic Induction. It states that "Whenever there are n-turns of conducting coil in a closed path placed in a time-varying magnetic field, an alternating electromotive force gets induced in each coil." Lenz's law gives this. Which states, "An induced electromotive force always opposes the time-varying magnetic flux."

Faraday's law of electromagnetic induction

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

4. Write Maxwell's equation –IV from Ampere's circuital law.

It is based on Ampere's circuit law. Ampere's circuit law states that "The closed line integral of magnetic field vector is always equal to the total amount of scalar electric field enclosed within the path of any shape".

Ampere's law

$$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

5. Give the Maxwell's equations in differential form.

The Maxwell's equations in differential form can be written as-

$$\vec{\nabla} \cdot \vec{D} = \rho$$

This is Maxwell's first equation in differential form.

$$\vec{\nabla} \cdot \vec{B} = 0$$

This is the Maxwell's second equation in differential form.

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

This is the Maxwell's third equation in differential form.

$$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

This is the Maxwell's fourth equation in differential form

6. Give the Maxwell's equations in integral form.

$$\oint_S \vec{D} \cdot d\vec{s} = \oint_V \rho \cdot dv$$

This is the Maxwell's first equation in integral form.

$$\oint_S \vec{B} \cdot d\vec{s} = 0$$

This is the Maxwell's second equation in integral form.

$$\oint_l \vec{E} \cdot d\vec{l} = -\oint_S \frac{d\vec{B}}{dt} \cdot d\vec{s}$$

This is the Maxwell's third equation in integral form.

$$\oint_l \vec{H} \cdot d\vec{l} = \oint_S \left(\vec{J} + \frac{\partial \vec{D}}{\partial t} \right) \cdot d\vec{s}$$

This is the Maxwell's fourth equation in integral form

7. Write the Maxwell's equations for free space.

If the electromagnetic wave field vector is constant over any plane perpendicular to the direction of wave propagation at any instant then this wave is called plane progressive wave.

Consider a plane electromagnetic wave vacuum or free space. Let permittivity ϵ_0 , permeability μ_0 are constants. And Conductivity, $\sigma = 0$

Maxwell's equations for free space can be written as

$$\vec{\nabla} \cdot \vec{E} = 0 \quad \text{----- (1)}$$

$$\vec{\nabla} \cdot \vec{B} = 0 \quad \text{----- (2)}$$

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad \text{----- (3)}$$

$$\vec{\nabla} \times \vec{B} = \epsilon_0 \mu_0 \frac{\partial \vec{E}}{\partial t} \quad \text{----- (4)}$$

8. Write the Maxwell's equations for conducting medium.

$$\vec{\nabla}^2 \vec{E} - \sigma \mu \frac{\partial \vec{E}}{\partial t} - \epsilon \mu \frac{\partial^2 \vec{E}}{\partial t^2} = 0$$

This is the wave equation in terms of electric field.

$$\vec{\nabla}^2 \vec{B} - \mu \sigma \frac{\partial \vec{B}}{\partial t} - \mu \epsilon \frac{\partial^2 \vec{B}}{\partial t^2} = 0$$

This is the wave equation in terms of magnetic field.

9. What are the characteristics of Maxwell's First equations?

The net quantity of the electric flux leaving a volume is proportional to the charge inside the

volume.

10. What are the characteristics Maxwell's second equations.

The second law states that there are no "magnetic charges (or monopoles)" analogous to electric charges, and that magnetic fields are instead generated by magnetic dipoles. Thus, the total magnetic flux through a surface surrounding a magnetic dipole is always zero.

11. What are the characteristics Maxwell's Third equations.

Whenever the magnetic flux associated with any closed loop changes an induced emf develops in the circuit and that sends current through the circuit which last so long as the change of flux lasts. He also showed that the induced emf produced is directly proportional to magnetic flux linked with the coil. Thus, the total magnetic flux through a surface surrounding a magnetic dipole is always zero.

12. What are the characteristics Maxwell's Fourth equations.

Ampere's law states that the line integral of the magnetic field $\vec{B}$ around any closed path or circuit is equal to the current enclosed by the path. Thus, magnetic field $\vec{B}$ around any closed path or circuit is equal to the conduction current plus the time derivative of electric displacement through any surface bounded by the path.

13. Write down general electromagnetic wave equation in terms of electric field vector for free space.

If the electromagnetic field vector is constant over any plane perpendicular to the direction of wave propagation at any instant then this wave is called plane progressive wave. The wave equations are:

$$\vec{\nabla} \cdot \vec{E} = 0 \quad \vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

14. Write down general electromagnetic wave equation in terms of magnetic field vector for free space.

If the electromagnetic field vector is constant over any plane perpendicular to the direction of wave propagation at any instant then this wave is called plane progressive wave. The wave equations are:

$$\vec{\nabla} \cdot \vec{B} = 0$$

15. Write down the expression for velocity of electromagnetic wave equation in terms of in free space.

Free space is a region where there is no matter and no gravitational or electromagnetic fields. The expression for velocity of the wave equation is

$$\frac{c}{\sqrt{\mu_r \epsilon_r}} = v$$

Where, μ_r – relative permeability and ϵ_r – Absolute permittivity

16. Write down the general solution of wave equation for plane polarized EM wave.

Polarization refers to the relationship between the orientation of electric and magnetic field Vectors and the direction of propagation of EM waves. If E_{ox} and E_{oy} are real numbers and if the electric and magnetic vectors are in phase, then it is plane polarized wave. The solution for the plane polarized wave is given by

$$\vec{E}(z, t) = [i\vec{E}_{ox} + j\vec{E}_{oy}]e^{i(K_z z - \omega t)}$$

17. Write down the relation between the electric field vector $\vec{E}$ and magnetic field vector.

The relation between the electric field vector $\vec{E}$ and magnetic field vector.

$$\begin{aligned}
\vec{\nabla} \times \vec{E} &= -\frac{\partial \vec{B}}{\partial t} & \vec{\nabla} \times \vec{B} &= \mu\epsilon \frac{\partial \vec{E}}{\partial t} \\
i\vec{k} \times \vec{E} &= -(-i\omega)\vec{B} & i\vec{k} \times \vec{B} &= \mu\epsilon(-i\omega)\vec{E} \\
i\vec{k} \times \vec{E} &= i\omega\vec{B} & i\vec{k} \times \vec{B} &= -i(\omega\mu\epsilon)\vec{E} \\
\vec{k} \times \vec{E} &= \omega\vec{B} & \vec{k} \times \vec{B} &= -(\omega\mu\epsilon)\vec{E}
\end{aligned}$$

and

Where, the wave vector k is perpendicular to both electric and magnetic fields respectively.

18. What is intrinsic or characteristic impedance of free space?

The characteristic impedance of free space, also called the Z_0 of free space, is an expression of the relationship between the electric-field and magnetic-field intensities in an electromagnetic field (EM field) propagating through a vacuum.

$$Z_0 = \frac{E}{H} = \sqrt{\frac{\mu_0}{\epsilon_0}}$$

Now substitute the value of μ_0 and ϵ_0 i.e.

$$\mu_0 = 4\pi \times 10^{-7}$$

$$\epsilon_0 = 8.854 \times 10^{-12}$$

$$Z_0 = \sqrt{\frac{4\pi \times 10^{-7}}{8.854 \times 10^{-12}}}$$

$$Z_0 = 376.73 \, \Omega$$

$$Z_0 = 120\pi \, \Omega$$

19. What is Poynting vector?

The Poynting vector represents the directional energy flux (the energy transfer per unit area per unit time) or power flow of an electromagnetic field. It is denoted by S . The SI unit of the Poynting vector is the watt per square metre (W/m^2); kg/s^3 in base SI units.

20. Write the general wave equation for the electric vector in an EM wave in conducting medium.

The general wave equation for the electric vector in an EM wave in conducting medium is

$$\vec{\nabla}^2 \vec{E} - \sigma\mu \frac{\partial \vec{E}}{\partial t} - \epsilon\mu \frac{\partial^2 \vec{E}}{\partial t^2} = 0$$

This is the wave equation in terms of electric field.

21. Write the general wave equation for the magnetic vector in an EM wave in conducting medium.

The general wave equation for the magnetic vector in an EM wave in conducting medium is

$$\vec{\nabla}^2 \vec{B} - \mu\sigma \frac{\partial \vec{B}}{\partial t} - \mu\epsilon \frac{\partial^2 \vec{B}}{\partial t^2} = 0$$

This is the wave equation in terms of magnetic field.

22. What is skin depth?

The skin depth is that distance below the surface of a conductor where the current density has diminished to $1/e$ of its value at the surface. The thickness of the conductor is assumed to be several (perhaps at least three) times the skin depth.

23. Define intensity of EM wave.

Intensity of electromagnetic wave is defined as the energy crossing per second per unit area

held perpendicular to the direction of propagation of electromagnetic waves. Intensity of electromagnetic wave, $I = 2\eta_0 c \epsilon_0 |E|^2$. The S.I unit of intensity is Watt per square meter (W/m^2) or (kg s^{-3})

24. Define radiation pressure.

Radiation pressure is the mechanical pressure exerted upon any surface due to the exchange of momentum between the object and the electromagnetic field. The radiation pressure is doubled if the radiation is reflected rather than absorbed. The radiation pressure P exerted on the surface is given by $P = \frac{2I}{c}$, where c is the speed of light.

The SI unit of pressure is Pascal (Pa), and pressure is a scalar quantity since it has only magnitude and no direction.

25. Give the properties of Electromagnetic waves.

1. In electromagnetic waves the electric field vector E and magnetic field vector B and propagation vector K are mutually perpendicular for a right-handed system. Hence electromagnetic waves are transverse in nature.
2. Electromagnetic waves travel with speed of light.
3. Electromagnetic waves doesn't need any medium to propagate.
4. Electromagnetic waves are not deflected by electric or magnetic field.

PART B

1. Derive Maxwell's equation in differential and integral form
2. Deduce Maxwell's equation for free space.
3. Write Maxwell's equation and explain the characteristics of each equation.
4. Give an account of Maxwell's equation for free space. Apply the equations to deduce the EM wave equation and determine the velocity of light in vacuum.
5. Deduce Maxwell's equation for free space and prove that electromagnetic waves are transverse.
6. Discuss production and propagation EM wave from vacuum to a non-conducting medium.

UNIT –III OSCILLATION, OPTICS AND LASER

Chapter 01- Oscillation PART A

1. Define simple harmonic motion.

Simple harmonic motion, is a repetitive movement back and forth through an equilibrium, or central, position, so that the maximum displacement on one side of this position is equal to the maximum displacement on the other side. The time interval of each complete vibration is the same. The force responsible for the motion is always directed toward the equilibrium position and is directly proportional to the distance from it.

That is, $F = -kx$, where F is the force, x is the displacement, and k is a constant. This relation is called Hooke's law.

2. What are the characteristics of simple harmonic motion?

Following are the main characteristics of simple harmonic motion:

- In simple harmonic motion, the acceleration of the particle is directly proportional to its displacement and directed towards its mean position.
- The total energy of the particle exhibiting simple harmonic motion is conserved.
- SHM is a periodic motion.
- SHM can be represented by a single harmonic function of sine or cosine.

3. What are examples of simple harmonic motions?

When an object moves to and fro or back and forth along the same line, it is called a simple harmonic motion (SHM). This motion is used to model many real life-situations in our daily life.

Let us look at a few of them:

- Swing

Swings that we see in the park is an example of simple harmonic motion. The back and forth, repetitive movements of the swing against the restoring force is the simple harmonic motion.

- Pendulum

The pendulum oscillating back and forth from the mean position is an example of simple harmonic motion.

4. What are types of oscillations?

There are three main types of oscillations.

(i) Free oscillations

When a body vibrates with its own natural frequency, it is said to execute free oscillations.

(ii) Damped oscillation

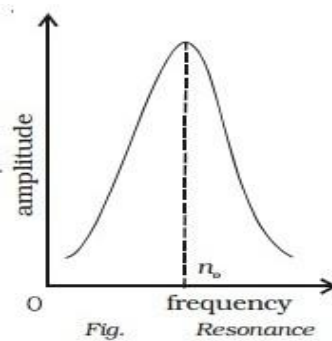
Most of the oscillations in air or in any medium are damped. When an oscillation occurs, some kind of damping force may arise due to friction or air resistance offered by the medium. So, a part of the energy is dissipated in overcoming the resistive force. Consequently, the amplitude of oscillation decreases with time and finally becomes zero. Such oscillations are called damped oscillations

(iii) Forced oscillations

When a vibrating body is maintained in the state of vibration by a periodic force of frequency (n) other than its natural frequency of the body, the vibrations are called forced vibrations.

5. What is resonance?

In the case of forced vibration, if the frequency difference is small, the amplitude will be large (Fig.). Ultimately when the two frequencies are same, amplitude becomes maximum. This is a special case of forced vibration.



If the frequency of the external periodic force is equal to the natural frequency of oscillation of the system, then the amplitude of oscillation will be large and this is known as resonance.

6. What is sharpness of resonance?

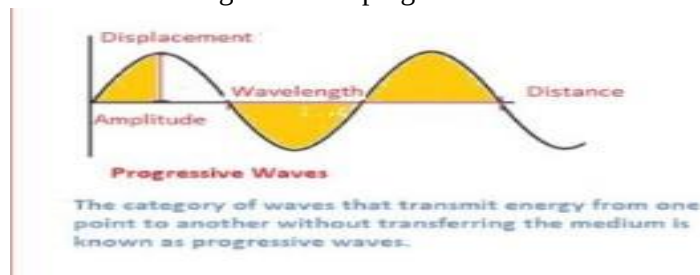
The sharpness of resonance is defined using the Q factor which explains how fast energy decay in an oscillating system. The sharpness of resonance depends upon: Damping: Effect due to which there is a reduction in amplitude of vibrations.

The Sharpness of Resonance is dependent on mainly two factors. These are:

- Amplitude
- Damping

7. Define progressive wave.

A wave which travels continuously in a medium in the same direction without a change in its amplitude is called a travelling wave or a progressive wave.

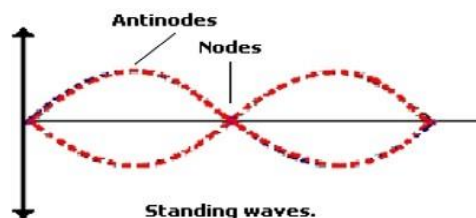


8. What are the characteristics of progressive wave?

1. A progressive wave is formed due to continuous vibration of the particles of the medium.
2. The wave travels with a certain velocity.
3. There is a flow of energy in the direction of the wave.
4. No particles in the medium are at rest.
5. The amplitude of all the particles is the same.
6. Phase changes continuously from particle to particle.

9. Define standing waves.

- **Standing wave**, also called **stationary wave**, combination of two waves moving in opposite directions, each having the same amplitude and frequency.
- The phenomenon is the result of interference; that is, when waves are superimposed, their energies are either added together or cancelled out.
- In the case of waves moving in the same direction, interference produces a traveling wave. For oppositely moving waves, interference produces an oscillating wave fixed in space.



10. What are the characteristics of standing waves?

When two identical waves moving in opposite directions interfere, it results in a standing wave. These waves are characterized by the zero displacement locations which are fixed and are called as nodes and locations of maximum displacements called as antinodes.

1. A stationary wave does not move in any direction.
2. There is no flow of energy.
3. All particles in a loop are in the same phase & they are in opposite phase with respect to the adjacent loop.
4. Amplitude is different for different particles.

11. What are differences between progressive waves and stationary waves?

Progressive wave	Stationary wave
1. The wave travel forward with a velocity called wave velocity.	1. The wave do not travel in any direction.
2. There is transfer of energy along the direction of propagation of wave.	2. There is no transfer of energy across any section of the medium.
3. No particle of the medium is permanently at rest.	3. Particles at nodes are always at rest. wave

12. State Doppler Effect.

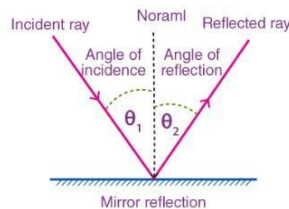
- Doppler effect or Doppler shift is a phenomenon that is observed whenever the source of waves is moving with respect to an observer. For example, an ambulance crossing you with its siren blaring is a common physical demonstration of the Doppler Effect.
- Doppler effect is an important phenomenon in various scientific disciplines, including planetary science.
- The Doppler effect or the Doppler shift describes the changes in the frequency of any sound or light wave produced by a moving source with respect to an observer.
- Doppler effect is defined as the increase (or decrease) in the frequency of sound, light, or other waves as the source and observer move towards (or away from) each other
- Waves emitted by a source travelling towards an observer get compressed. In contrast, waves emitted by a source travelling away from an observer get stretched out.

Chapter 02 – Optics

PART A

1. State laws of reflection

1. The law of reflection defines that upon reflection from a smooth surface, the angle of the reflected ray is equal to the angle of the incident ray, with respect to the normal to the surface that is to a line perpendicular to the surface at the point of contact.
2. The reflected ray is always in the plane defined by the incident ray and the normal to the surface at the point of contact of the incident ray.



2. State laws of refraction

1. The incident ray, the refracted ray and the normal at the point of incidence, all lie in the same plane.
2. The ratio of the sine of the angle of incidence i to the sine of the angle of refraction is constant for the pair of given media. This constant is called the refractive index of the second medium w.r.t. the first medium.

$${}_1\mu_2 = \sin i / \sin r$$

Note: When light ray is incident normally, only speed changes and direction of light remains the same. When light ray passes from rarer medium to denser medium, it bends towards the normal. When light ray passes from denser medium to rarer medium, it bends away from the normal.

3. Define refractive index of the medium

Refractive index of a medium is defined as ratio of speed of light in vacuum to that in the medium. It is a dimensionless quantity that describes how the light travels in the medium.

$$\mu = \frac{c}{v}$$

4. What is total internal reflection?

The phenomenon which occurs when the light rays travel from a more optically denser medium to a less optically denser medium. Consider the following situation. A ray of light passes from a medium of water to that of air. Light ray will be refracted at the junction separating the two media. Since it passes from a medium of a higher refractive index to that having a lower refractive index, the refracted light ray bends away from the normal. At a specific **angle of incidence**, the incident ray of light is refracted in such a way that it passes along the surface of the water. This particular angle of incidence is called the critical angle. Here the angle of refraction is 90 degrees. When the angle of incidence is greater than the critical angle, the incident ray is reflected back to the medium. We call this phenomenon total internal reflection.

5. Define critical angle.

Total internal reflection is a complete reflection of a ray of light within a medium such as water or glass from the surrounding surfaces back into the medium. It only occurs when both of the following two conditions are met: A light ray is in the more dense medium and approaching the less dense medium. The angle of incidence for the light ray is greater than the so-called critical angle.

The critical angle is the angle of incidence, for which the angle of refraction is 90° . If light enters a denser medium from a comparatively rarer medium, then the direction of light changes and the light ray bends towards the normal.

6. Give conditions of total internal reflection.

- The light ray moves from a more dense medium to a less dense medium.
- The angle of incidence must be greater than the critical angle.

7. Write expression for critical angle.

$n_1 \sin \theta_1 = n_2 \sin \theta_2$. Thus we have the following expression for the critical angle: $\sin \theta_c = n_2/n_1$.

8. Mention a few applications of total internal reflection.

- Total internal reflection is also used in optical fibres. An optical fibre consists of an inner core of high refractive index glass and surrounded by an outer cladding of lower refractive index.
- When light is introduced into the inner core at one end, it will propagate along the fibre in a zigzag path undergoing a series of total internal reflections.
- Optical fibres are useful for getting light to inaccessible places. They are used in many important practical applications. This includes fibre optic diagnostic tools in medicine and fibre optic cables in telecommunications.
- An endoscope is an instrument made of a fibre optic cable. It is used by doctors to see the inside of the human body such as the stomach and the duodenum.
- In telecommunications, copper cables are now replaced by fibre optic cables in the telephone system.
- Multiple signals can be sent at high speeds through bundles of fibres by using flashes of light from a laser.

9. What is interference?

Interference is what happens when two or more waves meet each other. Depending on the overlapping waves' alignment of peaks and troughs, they might add up, or they can partially or entirely cancel each other. As per the interference definition, it is defined as the phenomenon in which two or more waves superpose to form a resultant wave of greater, lower or the same amplitude.

10. What is air wedge?

An air wedge is a simple interferometer used to visualize the disturbance of the wave front after propagation through a test object.

11. What is the expression for the fringe width in air wedge experiment?

Light rays coming from slits S_1 and S_2 interfere at point P

$$\text{From figure, } S_1P = \sqrt{\left(y - \frac{d}{2}\right)^2 + D^2}$$

$$\text{Or } S_1P = \sqrt{y^2 + \frac{d^2}{4} - yd + D^2}$$

$$\text{Or } S_1P = D\sqrt{\frac{y^2}{D^2} + \frac{d^2}{4D^2} - \frac{yd}{D^2} + 1}$$

As $D \gg d$ and $y \ll D$, we neglect $d^2/4D^2$ and y^2/D^2 .

We get

$$\text{Or } S_1P = D\sqrt{1 - \frac{yd}{D^2}}$$

$$\text{Or } S_1P = D\left[1 - \frac{yd}{2D^2}\right]$$

$$\text{Or } S_1P = D - \frac{yd}{2D}$$

$$\text{Similarly we get } S_2P = D + \frac{yd}{2D}$$

$$\text{Path difference between two light rays } \Delta x = S_2P - S_1P$$

$$\text{Or } \Delta x = \left(D + \frac{yd}{2D}\right) - \left(D - \frac{yd}{2D}\right) = \frac{yd}{D}$$

For constructive interference, $\Delta x = n\lambda$.

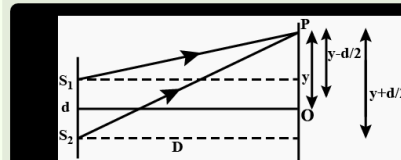
$$\therefore \frac{yd}{D} = n\lambda$$

$$\Rightarrow y = \frac{n\lambda D}{d}$$

$$\text{Fringe width } \beta = y_n - y_{n-1}$$

$$\therefore \beta = \frac{n\lambda D}{d} - (n-1)\frac{\lambda D}{d}$$

$$\Rightarrow \beta = \frac{\lambda D}{d}$$



12. What is the expression for the thickness of the wire in air wedge experiment? $d/\lambda = 2\mu\beta$ i.e $d = 2\lambda / \beta$

for an air film $\mu = 1$, β which is distance between two dark or bright/dark bands can be measured experimentally. Therefore, diameter can be determined.

13. What is Michelson interferometer?

The Michelson interferometer produces interference fringes by splitting a beam of light so that one beam strikes a fixed mirror and the other a movable mirror. When the reflected beams are brought back together, an interference pattern results.

14. What are the applications of Michelson interferometer?

- The detection of gravitational waves – LIGO is a massive interferometer with two lasers positioned thousands of kilometres apart
- In astronomical interferometry.
- In optical coherence tomography.
- In fibre optics.

1. What is stimulated emission?

An atom in the excited state is induced to return to the ground state, thereby resulting in two photons of same frequency and energy is called Stimulated emission.

The rate of stimulated emission is given by

$$R_{21}(St) = B_{21}\rho_\nu N_2$$

2. What is spontaneous emission?

The atom in the excited state returns to the ground state thereby emitting a photon, without any external inducement is called Spontaneous emission.

$$R_{21}(Sp) = A_{21}$$

Where A_{21} is a constant which gives the probability of spontaneous emission transitions per unit time.

3. What is stimulated absorption?

An atom in the lower energy level or ground state energy level E_1 absorbs the incident photon radiation of energy and goes to the higher energy level or excited level E_2 as shown in figure. This process is called absorption.

The rate of absorption (R_{12}) is proportional to the following $R_{12} \propto \rho_\nu N_1 = B_{12} \rho_\nu N_1$

4. What is laser?

LASER stands for Light Amplification by Stimulated Emission of Radiation. Laser is a device which emits a powerful, monochromatic collimated beam of light. The emitted light waves are coherent in nature.

5. What are the conditions necessary for stimulating emission of radiation?

Condition for Population inversion

1. There must be at least two energy levels $E_2 > E_1$.
2. There must be a source to supply the energy to the medium.
3. The atoms must be continuously raised to the excited state.

6. Write the difference between spontaneous emission and stimulated emission.

S. No.	Stimulated Emission	Spontaneous emission
1.	An atom in the excited state is induced to return to the ground state, thereby resulting in two photons of same frequency and energy is called Stimulated emission	The atom in the excited state returns to the ground state thereby emitting a photon, without any external inducement is called Spontaneous emission.
2	The emitted photons move in the same direction and is highly directional	The emitted photons move in all directions and are random
3	The radiation is highly monochromatic and coherent	The radiation is less intense and is incoherent
4	The photons are in phase, there is a constant phase difference	The photons are not in phase (i.e.) there is no phase relationship between them.
5	The rate of transition is given by $R_{12}(Sp) = A_{21} N_2$	The rate of transition is given by $R_{12}(Sp) = A_{21} N_2$

7. What is meant by population inversion and how is it achieved?

Population Inversion creates a situation in which the number of atoms in higher energy state is more than that in the lower energy state. The Phenomenon of making $N_2 > N_1$ is known as Population Inversion.

8. Explain the need for population inversion in the production of laser?

Usually at thermal equilibrium, the number of atoms N_2 i.e., the population of atoms at higher energy state is much lesser than the population of the atoms at lower energy state N_1 that is $N_1 > N_2$. The Phenomenon of making $N_2 > N_1$ is known as Population Inversion.

9. What is pumping action?

The process to achieve the population inversion in the medium is called Pumping action. It is essential requirement for producing a laser beam.

10. What are the methods commonly used for pumping action?

The methods commonly used for pumping action are:

1. Optical pumping (Excitation by Photons)
2. Electrical discharge method (Excitation by electrons)

3. Direct conversion
4. In elastic atom – atom collision between atoms.

11. What is optical pumping?

When the atoms are exposed to light radiations energy, atoms in the lower energy state absorb these radiations and they go to the excited state. This method is called Optical pumping. It is used in solid state lasers like ruby laser and Nd-YAG laser. In ruby laser, xenon flash lamp is used as pumping source.

12. What is meant by active material in laser?

A medium in which population inversion can be achieved is known as active medium.

13. What are the characteristics of the laser? (or) What are the properties of the laser beam?

Laser is basically a light source. Laser light has the following important characteristics

- High Directionality
- High Intensity
- Highly Monochromatic
- Highly Coherence

14. Under which conditions a set of laser beams is said to be coherent?

In lasers the wave trains of same frequency are in phase, the radiation given out is in mutual agreement not only in phase but also in the direction of emission and polarization. Thus, it is a coherent beam. Due to high coherence, it results in an extremely high power.

15. Compare the characteristics of laser with ordinary light.

S.No.	Ordinary light	Laser beams
1	In ordinary light the angular spread is more	In laser beam the angular spread is less.
2	They are not directional.	They are highly directional.
3	It is less intense	It is highly intense
4	It is not a coherent beam and is not in phase.	It is a coherent beam and is in phase
5	The radiation are polychromatic	The radiations are monochromatic
6	Example: Sun light, Mercury vapor lamp	He- Ne Laser, Co2 laser

16. What is optical resonant cavity?

An optical resonator consists of a pair of reflecting surfaces in which one is fully reflecting (R_1) and the other is partially reflecting (R_2). The active material is placed in between these two reflecting Surfaces. The photons generated due to transitions between the energy states of active material are bounced back and forth between two reflecting surfaces. This will induce more and more stimulated transition leading to laser action.

17. What is the function of resonator cavity in laser?

The photons generated due to transitions between the energy states of active material are bounced back and forth between two reflecting surfaces. This will induce more and more stimulated transition leading to laser action.

18. What is the principle of laser action?

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 the Radiation termed LASER.

19. What are the three important components of any laser device?

Active medium, Active center and Pumping mechanism.

20. What are the conditions required for laser action?

Condition for Population inversion

1. There must be at least two energy levels $E_2 > E_1$.
2. There must be a source to supply the energy to the medium.
3. The atoms must be continuously raised to the excited state.

21. What are Einstein's coefficients?

The constants A and B are called as Einstein Coefficients, which accounts for spontaneous and stimulated emission probabilities.

22. How lasers are classified? (or) Mention the various types of lasers.

There are several ways to classify the different types of lasers. What material or element is used as active medium. Mode of operation: CW or Pulsed. Lasers may be classified as Solid State Lasers – Ruby and Nd-YAG Laser – Gas Lasers – He-Ne and CO₂ lasers – semiconductor lasers – Heterojunction Lasers – Liquid Dye Lasers.

S.No	TYPES OF LASER	EXAMPLES
1.	Solid State laser Ruby Laser	Nd:YAG laser
2.	Gas laser He-Ne Laser,	CO ₂ Laser, Argon – ion laser
3.	Liquid Laser	SeOCL ₂ Laser, Europium Chelate Laser
4.	Dye laser	Rhodamine 6G laser, Coumarin dye laser
5	Semiconductor Laser	GaAs laser, GaAsP laser

23. What is Nd: YAG laser?

It is a solid state and 4 level system as it consists of 4 energy levels. Nd ion is rare earth metal and it is doped with solid state host. Due to doping, yttrium ions get replaced by the Nd³⁺ ions.

24. What are the applications of Nd: YAG laser?

Applications of Nd:YAG Laser

- Military applications to find the desired target.
- Application in medical field for the surgical purpose.
- Used in welding and cutting of steel and
- Used in communication system

25. What is CO₂ laser?

In a molecular gas laser, laser action is achieved by transitions between vibrational and rotational levels of molecules. Its construction is simple and the output of this laser is continuous. In CO₂ molecular gas laser, transition takes place between the vibrational states of Carbon dioxide molecules.

26. What is the active medium in CO₂ laser?

The active medium is a gas mixture of CO₂, N₂ and He. The laser transition takes place between the vibrational states of CO₂ molecules.

27. What are the applications of CO₂ laser?

Applications

1. High power CO₂ laser finds applications in material processing, welding, drilling, cutting soldering etc.
2. The low atmospheric attenuation (10.6 μm) makes CO₂ laser suitable for open air communication.

3. It is used for remote sensing
4. It is used for treatment of liver and lung diseases.
5. It is mostly used in neuro surgery and general surgery.
6. It is used to perform microsurgery and bloodless operations.

28. What is semiconductor laser?

It is specifically fabricated p-n junction diode. This diode emits laser light when it is forward biased.

29. What is homo-junction laser?

A PN junction diode made from single crystal of gallium arsenide is used as an active medium.

30. What are the drawbacks of homo junction laser diodes?

Disadvantages

1. It is difficult to control the mode pattern and mode structure of laser.
2. The output is usually from 5° to 15° i.e., laser beam has large divergence.
3. The purity and monochromaticity are poor than other types of lasers
4. Threshold current density is very large (400A/mm^2).
5. It has poor coherence and poor stability.

31. What are the applications of semiconductor laser?

Applications:

1. This type of laser is mostly used in optical applications
2. It is widely used in computers, especially on CD-ROMs.

32. What is laser material processing?

Laser material processing finds applications in industry. They are welding, cutting, drilling, machining etc.

33. Mention the applications of lasers in industry.

Laser material processing finds applications in industry. They are welding, cutting, drilling, machining etc.

34. What is laser welding?

Laser welding is a much more accurate manufacturing process and welds can be as small as one hundredths of a millimetre. Small pulses of heat are used to create the weld which leads to a higher quality finish which is stronger providing a better depth to width ratio.

35. What are the advantages of laser welding?

- Aesthetically better weld finishes
- More suited to high value items such as jewelry
- Ideal for solenoids and machined components
- Perfect for medical devices where weld quality is vital for hygiene and precision

36. What is heat treatment of laser?

37. What are advantages laser cutting?

PART B

1. For atomic transition, derive Einstein relations and hence deduce the expression for the ratio of spontaneous emission rate to stimulated emission rate.
2. Explain the principle, construction and working of Nd: YAG laser with neat diagram.
3. Explain the modes of vibrations of CO₂ molecule. Describe the principle, construction and working

- of CO₂ laser with necessary diagrams.
4. Describe the principle, construction and working of semiconductor laser with neat diagram.
 5. (a) What are different pumping mechanisms used in lasers? Give an example for each (b) List out the applications of laser beam in industries and in medical field.
 6. Explain the formation of interference fringes in an air-wedge shaped film.
How is the thickness of the wire determined by this method?
 7. How will you use Michelson's interferometer to determine the thickness of a thin transparent film or plate?
 8. Explain the construction, types of fringes and applications of Michelson's interferometer.
 9. (i) Describe the construction of a Michelson's interferometer and discuss the different types of interference fringes formed in it. (ii) How will you use it to determine the wavelength of a monochromatic source?

UNIT –IV

BASIC QUANTUM MECHANICS

PART A

1. State Compton effect

The Compton effect is defined as the effect that is observed when x-rays or gamma rays are scattered on a material with an increase in wavelength. It is dependent on the angle of scattering and on the wavelength of the incident beam.

2. What is Compton wavelength?

The Compton wavelength is the quantum mechanical property of a particle and is defined as the wavelength of the particle equal to the wavelength of the photon with same mass. It is well explained through the process called Compton scattering. The standard Compton wavelength is denoted by Greek letter λ (Lambda) measured using the SI unit of length angstrom (meter).

3. What are matter waves?

According to the De-Broglie concept, with each moving particle a wave is associated. These associated waves are called matter waves. That is, the wave–particle duality present in light must also occur in matter. So, starting from the momentum of a photon $p = h \nu / c = h/\lambda$, we can generalize this relation to any material particle with non zero rest mass. Each material particle of momentum behaves as a group of waves whose wavelength λ and wave vector are governed by the speed and mass of the particle.

$$\lambda = \frac{h}{p} \quad \& \quad \vec{k} = \frac{\vec{p}}{h}$$

Wave has wavelength λ here h is Planck's constant and p is the momentum of the moving particle.

4. How de – Broglie justified his concept?

de Broglie came up with an explanation for why the angular momentum might be quantized in the manner Bohr assumed it was. de Broglie realized that if you use the wavelength associated with the electron, and assume that an integral number of wavelengths must fit in the circumference of an orbit, you get the same.

5. Write an expression for the wavelength of matter waves?

de Broglie's wavelength of matter waves: de Broglie equated the energy equations of Planck(wave) and Einstein(particle).

For a wave of frequency ν , the energy associated with each photon is given by Planck's relation,

$$E = h\nu \quad \dots\dots\dots(1)$$

Where h is Planck's constant.

According to Einstein's mass energy relation, a mass m is equivalent to energy,

$$E = mc^2 \quad \dots\dots\dots(2)$$

where c is the velocity of light.

If, $h\nu = mc^2$

$$\therefore \frac{hc}{\lambda} = mc^2 \text{ (or) } \lambda = \frac{h}{mc} \quad \dots\dots\dots(3)$$

$$\text{(since } \nu = \frac{c}{\lambda} \text{)}$$

For a particle moving with a velocity v , if $c = v$ from equation (3)

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

Where $p = mv$, the momentum of the particle. These hypothetical matter

An electron of mass m is accelerated through a potential difference of V volt. The kinetic energy acquired by the electron is given by

$$\frac{1}{2} mv^2 = eV$$

Therefore, the speed v of the electron is

$$v = \sqrt{\frac{2eV}{m}}$$

Hence, the de Broglie wavelength of the electron is

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2emV}}$$

Substituting the known values in the above equation, we get

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2V \times 1.6 \times 10^{-19} \times 9.11 \times 10^{-31}}}$$

6. Write an expression for the de-Broglie wavelength associated with electrons?

$$\lambda = \frac{12.27 \times 10^{-10}}{\sqrt{V}} \text{ meter (or) } \lambda = \frac{12.27}{\sqrt{V}} \text{ \AA}$$

For example, if an electron is accelerated through a potential difference of 100 V, then its de Broglie wavelength is 1.227 \AA.

Since the kinetic energy of the electron, $K = eV$, then the de Broglie wavelength associated with electron can be also written as

$$\lambda = \frac{h}{\sqrt{2mK}}$$

7. State the properties of the matter waves.

1. Matter waves are not electromagnetic in nature
2. Matter-wave represents the probability of finding a particle in space.
3. Matter waves are independent of the charge on the material particle.
4. Electron microscope works on the basis of de-Broglie waves.
5. Matter waves can propagate in a vacuum, hence they are not mechanical wave.
6. The number of de-Broglie waves associated with n th orbital is n .
7. The phase velocity of matter waves can be greater than the speed of light.
8. The number of de-Broglie waves associated with the n th orbital electron is n .

8. Write down Schrodinger time independent and dependent wave equations.

1c Time Independent Schrödinger Equation.

$$\frac{-\hbar^2}{2m} \frac{\partial^2 u(x)}{\partial x^2} + V(x)u(x) = E u(x)$$

time dependent solution is.

$$\psi(x, t) = u(x)e^{-iEt/\hbar}$$

9. Mention some of the physical significance of the wave function.

The wave function ψ associated with a moving particle is not an observable quantity and does not have any direct physical meaning. It is a complex quantity. The complex wave function can be represented as $\psi(x, y, z, t) = a + ib$ and its complex conjugate as $\psi^*(x, y, z, t) = a - ib$. The product of wave function and its complex conjugate is $\psi(x, y, z, t)\psi^*(x, y, z, t) = (a + ib)(a - ib) = a^2 + b^2$ is a real quantity. However, this can represent the probability density of locating the particle at a place in a given instant of time. The positive square root of $\psi(x, y, z, t)\psi^*(x, y, z, t)$ is represented as $|\psi(x, y, z, t)|$, called the modulus of ψ . The quantity $|\psi(x, y, z, t)|^2$ is called the probability.

10. What are Eigen values and Eigen functions?

The solution to the Schrodinger equation for a given energy E_i involves also finding the specific function ψ_i which describes that energy state. The solution of the time independent Schrodinger equation takes the form

$$H_{op}\psi_i = E_i\psi_i$$

The eigenvalue concept is not limited to energy. When applied to a general operator Q, it can take the form

$$\underset{\text{operator}}{Q_{op}}\psi_i = q_i \underset{\text{eigenvalue}}{\psi_i}^{\text{eigenfunction}}$$

If the function ψ_i is an eigenfunction for that operator. The eigenvalues q_i may be discrete, and in such cases we can say that the physical variable is "quantized" and that the index i plays the role of a "quantum number" which characterizes that state.

11. What is Schrodinger wave equation?

Schrodinger wave equation is a mathematical expression describing the energy and position of the electron in space and time, taking into account the matter wave nature of the electron inside an atom. It is based on three considerations. They are;

- Classical plane wave equation,
- Broglie's Hypothesis of matter-wave, and
- Conservation of Energy.

Schrodinger equation gives us a detailed account of the form of the wave functions or probability waves that control the motion of some smaller particles. The equation also describes how these waves are influenced by external factors. Moreover, the equation makes use of the energy conservation concept that offers details about the behaviour of an electron that is attached to the nucleus.

12. What is wave function?

The wave function is an equation or a set of equations derived from Schrodinger's Equation. Schrodinger's Equation does not calculate the behavior of quantum particles directly. First it must be used to generate a wave function(s). It's the wave function that actually describes the behavior of quantum particles.

13. Define correspondence principle.

A principle of spectroscopy: the characteristics of spectral series are in approximate agreement with both the classical electromagnetic theory and the quantum theory of electron transitions, the correspondence becoming closer as the quantum numbers involved become greater.

14. Define degenerate and non-degenerate state.

The **key difference between degenerate and non-degenerate semiconductors** is that in degenerate semiconductors, the injection of electrons or holes is only possible from the Fermi energy level, whereas non-degenerate semiconductors can cause the formation of two types of contacts to organic material.

Semiconductors are materials having an electrical conductivity value that falls between the conductivity of conductors and insulators. Degenerate semiconductors are a type of semiconductors in which a high level of doping can be observed, making the semiconductor act as metal than a semiconductor.

PART B

1. What is Compton Effect? Derive an expression for the wavelength of the scattered photon
2. Explain the experimental verification of Compton shift in wavelength with neat diagram.
3. Derive the time independent Schrodinger equation for a one-dimensional case. Use it to prove that a particle enclosed in a one-dimensional box has quantized energy values.
4. Derive Schrodinger Time independent and Time dependent wave equation.
5. Derive Eigen value and Eigen function for two-dimension potential box.
6. Obtain Eigen value and Eigen function for three dimension potential box.

UNIT V – APPLIED QUANTUM MECHANICS

PART A – UNIT IV (2 Marks)

1. What is harmonic oscillator?
2. Give examples for harmonic oscillator.
3. What is the significance of zero point energy is a harmonic oscillator?
4. Define barrier penetration.
5. What is quantum tunneling?
6. What is the significance of tunneling effect?
7. Define magnification power.
8. Define resolving power.
9. What is scanning tunneling microscope?
10. What is the principle behind scanning tunneling microscope?
11. What is resonant diode?
12. Define resonant tunneling.
13. State Bloch's theorem.
14. What is energy band?
15. What is valance band?
16. What is conduction band?
17. What is forbidden gap?
18. What is an Electron Microscope
19. What are the types of Electron Microscope?
20. Draw the energy bands for conductor and insulator.

PART B – UNIT V (8 Marks)

1. Describe barrier penetration and quantum tunneling.
2. Explain the concept of resonant tunneling.
3. Explain Bloch's theorem for particles in a periodic potential.
4. Explain Band theory of solids.

PART C – UNIT V (16 Marks)

1. Obtain an expression for the energy levels of the harmonic oscillator by applying Schrodinger wave equation.
2. Explain the principle, construction and working of scanning tunneling microscope with suitable diagram and also mention the advantages, disadvantages and applications.
3. Explain the construction and working of resonant diode.
4. Discuss a particle in a finite potential well starting from schrodingerwave equation.
5. Discuss Kronig penny model.
6. Describe origin of energy bands in solids.
7. Explain the construction and working of resonant diode.