B.Sc. IV SEM PHYSICS

PERESPECTIVES OF MODERN PHYSICS & BASIC ELECTRONICS

Relativity: Relativity is a theorem formulated by Albert Einstein, which states that space and time are relative, and all motion must be relative to a frame of reference. It is a notion that states' laws of physics are the same everywhere.

It states: There is no absolute reference frame. One can measure velocity if the object or momentum is only in relation to other objects .Albert Einstein's Theory of Relativity encompasses two theories: Special Relativity Theory and General Relativity Theory.

Special Theory of Relativity: Einstein first introduced this term in the year 1905. It is a theorem that deals with the structure of space-time. Einstein explained this theory based on two postulates –

- The laws of physics are the same for all, irrespective of the observer's velocity.
- The speed of light is always constant regardless of the motion of the light source or the motion of the observer.

There are other surprising consequences of this theory, such as –

- Relativity of simultaneity – two actions, simultaneous for one person, may not be simultaneous for another person in relative motion.
- Length Shrinking: Objects are measured and appear shorter in the direction they are moving with respect to the observer.
- Mass – Energy Equivalence: Study of relativity led to one of the greatest inventions, i.e., E = mc2 where E is Energy, m stands for mass and c for the velocity of light
  This equation is the answer to their problem, which explains that the increased relativistic weight of the object is equal to the kinetic energy divided by the square of the speed of light.

General Theory of Relativity: General Relativity theory, developed by Einstein in 1907-1915, states that being at rest in the gravitational field and accelerating are identical physically. For example, an observer can see the ball fall the same way on the rocket and on Earth. This is due to the rocket's acceleration, which equals 9.8 m/s2. This theory relates to Newton's gravitational theory and special relativity.

Some Consequences of General Relativity are :

- Gravitational Time Dilation: Gravity influences the passage of time. Clocks in the deeper gravitational wells run slower than in general gravitational levels.
- Light rays will bend in the gravitational field.
- The universe is expanding, and parts of it are moving away from Earth faster than the speed of light.

Frame of Reference: In physics, a frame of reference consists of an abstract coordinate system and the set of physical reference points that uniquely fix the coordinate system and standardize measurements within that frame.

Types of Frames of Reference: They can be of two types: Inertial Frame of Reference and Non-inertial Frame of Reference

Inertial Frame of Reference: An inertial frame of reference is a frame where Newton's law holds true. That means if no external force is acting on a body it will stay at rest or remain in uniform motion.

Non-inertial Frame of Reference: Non-inertial frame is defined as a frame that is accelerated with respect to the assumed inertial frame of reference. Newton's law will not hold true in these frames.

Galilean transformation: In Newtonian mechanics, a Galilean transformation is applied to convert the coordinates of two frames of reference, which vary only by constant relative motion within the constraints of classical physics.

Galilean invariance: Galilean invariance or relativity postulates that the laws governing all fundamental motions are the same in all inertial frames. Galileo derived these postulates using the case of a ship moving at a constant velocity on a calm sea.

Galilean Transformation Equations: These equations explain the connection under the Galilean transformation between the coordinates (x, y, z, t) and (x', y', z', t') of a single random event. It is calculated in two coordinate systems. S and S', in constant relative motion (velocity v) in their shared x and x' directions, with their coordinate origins meeting at time t = t' = 0.
x' = x = Vt, y' = y, z' = z & t' = t

Limitations of Galilean Transformations:

- Galilean Transformation cannot decipher the actual findings of the Michelson-Morley experiment.
- It breaches the rules of the Special theory of relativity.

Galilean and Lorentz Transformation: Galilean and Lorentz transformations are similar in some conditions.

- At lesser speeds than the light speed, the Galilean transformation of the wave equation is just a rough calculation of Lorentz transformations.
- Electromagnetic waves (propagate with the speed of light) work on the basis of Lorentz transformations.
- It is fundamentally applicable in the realms of special relativity. In contrast, Galilean transformations cannot produce accurate results when objects or systems travel at speeds near the speed of light.

- In the case of two observers, equations of the Lorentz transformation are

- $x' = y(x – vt)$, $y' = y$, $z' = z$, $t' = y(t – vx/c^2)$, & $y = 1/(1 – v^2/c^2)^{1/2}$

- As per these transformations, there is no universal time. Time changes according to the speed of the observer. Due to these weird results, effects of time and length vary at different speeds.
- Galilean transformations are estimations of Lorentz transformations for speeds far less than the speed of light
- Lorentz transformations are applicable for any speed. Galilean transformations are not relevant in the realms of special relativity and quantum mechanics.

Relative Mass in Mass Energy Equivalence: According to Classical Physics, the inertial mass of a body is independent of the velocity of light. It is regarded as a constant. However, the Special Theory of Relativityleads us to the concept of variation of mass with velocity. It follows from the special theory of relativity that the mass m of a body moving with relativistic velocity v relative to an observer is larger than its m0 when it is at rest. According to Einstein, the mass of the body in motion is different from the mass of the body at rest. $m=m_0/\sqrt{1-v^2/c^2}$

Mass Energy Equivalence: According to Einstein's theory, this relationship between mass and speed is often expressed as a relationship between mass and energy i.e., $E=mc^2$, where E is energy, m is mass and c is the speed of light.

Black Body Radiation: Black body radiation can be defined as the electromagnetic radiation emitted from or within an object to remain in thermodynamic equilibrium. It can also be defined as the electromagnetic radiation emitted by a black body at a constant uniform temperature using electromagnetic devices. **Example-** The Sun is a good example of a black body. It emits radiation across the entire electromagnetic spectrum, from radio waves to gamma rays. The peak of the Sun's black body spectrum is in the visible light region, which is why we see the Sun as white.

Wein's Displacement Law: The Wein's Displacement Lawstates that the black body radiation curve at different temperatures peaks at a wavelength inversely proportional to temperature. It is given by the equation:$\lambda_{max}=b / T$

Stefan-Boltzmann Law: The Stefan-Boltzmann Lawfor black body radiation explains the relationship between the total energy emitted and the absolute temperature. It is mathematically stated as- $E=kT^4$

Planck's Law: ThePlank's law for Black Body Radiation determines the spectral density for each wavelength at a particular temperature.

Properties of Black Body Radiation:

- The emissivity of black body radiation is 1.
- The radiation emitted by a black body is of different wavelengths lying in regions of ultraviolet, visible and infrared.
- The energy distribution is not uniform and at a particular temperature the energy peaks.

Applications of Black Body Radiation:

- Astronomy: Black body radiation is used to study the temperature of stars and other celestial objects.
- Materials science: Black body radiation is used to study the thermal properties of materials.

De Broglie Wavelength: According to Louis de Broglie, any particle which moves might very well behave like a wave.

- Clinton Davisson and Lester Germer demonstrated this experiment in 1927. Matter waves are waves that are related to the matter. De Broglie waves are another name for them.
- Except for photons, all particles have a different de Broglie wavelength formula. At non-relativistic speeds, a particle's momentum is equal to its rest mass m multiplied by its velocity v. The de Broglie wavelength is represented by λ.

De Broglie Wavelength Formula: According to de Broglie, the below equation is entirely general and applies to material particles as well. As a result, the wavelength of a particle of mass m travelling at speed is given by $\lambda=h / p$ or $\lambda=h / mv$

Applications of De Broglie Wavelength:

- Electron microscopy: One of the most significant applications of the de Broglie wavelength is in electron microscopy.
- Spectroscopy: Spectroscopy is the study of the interaction between matter and electromagnetic radiation.

Limitations of De Broglie Wavelength:

- Only applicable to particles with mass
- Only applicable to particles in motion
- Cannot predict exact position of particle

Group Velocity: Group Velocity is a concept that we discuss while studying the superposition principles of the waves.The velocity of a group of waves is referred to as group velocity. The group velocity of the wave can be expressed mathematically as, $V_g=d\omega / dk$

Phase Velocity: The rate at which the phase of a wave propagates through space is known as its phase velocity. When a wave train is modulated by an envelope, the group velocity represents the envelope's speed, while the phase velocity represents the wave's speed within the envelop. Phase velocity of wave can be calculated using the expression, $V_p = \lambda / T$ Here, λ= wavelength &T =Time period

PART- B BASIC ELECTRONICS

Transistor: Transistor is a semiconductor device that allows a weak signal to be transferred from a low-resistance circuit to a high-resistance circuit. The term 'trans' refers to transfer while 'istor' refers to the resistance properties provided by junctions. There are two kinds of transistor-NPN transistor and PNP transistor

NPN transistors: NPN transistors have two layers of N-type semiconductor material and one layer of P-type semiconductor material.

PNP transistor : PNP transistor has one layer of N-type material and two layers of P-type material.

Transistor Construction: A transistor has three terminals: emitter, base, and collector.

- **Emitter:** The part on one side of a transistor that transports electrons or holes. If there is a PNP-type transistor, the emitter is a p-type semiconductor diode with holes.
- **Base:** The base of a transistor is the central region that receives the majority of holes or electrons from an emitter. Because the base-emitter is driven forward, it has an extremely low resistance path. However, because base-collector junctions are short-circuited, they have a high resistive path.
- **Collector:** The collector is the part on one end of the other side. Because the collector-base junction is always in reverse bias, it has an extremely high resistance.

There are two types of Transistors: Bipolar junction transistor (BJT) **and** Field-effect transistor (FET)

Bipolar Junction Transistor (BJT): BJTs have three terminals: base, emitter, and collector. A relatively small current running between the base and the emitter terminal can influence a larger current flowing between the collector and the emitter terminal.

- **PNP Transistor:** A BJT in which one N-type semiconductor material is added or positioned between two P-type semiconductor materials. The device will control the flow of current in this setup. A PNP transistor is made up of two series-connected crystal diodes.
- **NPN Transistor:** This transistor has one P-type material sandwiched between two N-type materials. The NPN transistor is mostly used to convert weak signals into strong ones.

Field-Effect Transistor (FET): FETshave three terminals: Gate, Source, and Drain. A current between the source and drain may be controlled by the voltage at the gate contact. A FET is a unipolar transistor that uses either an N-channel FET or a P-channel FET for conduction.

Power Amplifier: A transistor amplifier which raises the power level of the signals that have audio frequency range is known as a transistor power amplifier. A power amplifier differs from a voltage amplifier. A transistor that is suitable for power amplification is generally called a power transistor.

Classification of Power Amplifiers: The power amplifiers can be classified in the following ways.

1.According to the Usage of Frequency Signals:

- Audio frequency power amplifiers
- Radio frequency power amplifiers
- Video frequency power amplifiers

2.According to the Period of Conduction

- Class A Power Amplifiers: The period of conduction is for a total 360°(full cycle).
- Class B Power Amplifiers: The period of conduction is for 180° only (half cycle)
- Class AB Power Amplifiers: The period of conduction is greater than180° but less than360°(in between class A and class B)
- Class C Power Amplifiers: The period of conduction is for less than 180°

3.According to the Configuration Used:

- Single-ended amplifier
- Push Pull amplifier
- Complementary symmetry push-pull amplifier

Applications of Power Amplifiers:

- They are used in RF applications to amplify the signal strength of wireless communication systems,
- These are included in cellular phones, wireless routers, and satellite communication systems.

Feedback Amplifier: Amplifiers generally work on the principle of increasing the voltage, current and power of an input signal. The concept of feeding the output signal back to its input circuit is known as feedback and that is why it is known as a feedback amplifier. It is dependent between the output and input with effective control. Feedback amplifiers are divided into two types: positive feedback and negative feedback.

Types of Feedback Amplifiers: There are two types of feedback amplifiers namely positive feedback amplifiers and negative feedback amplifiers.

1. **Positive Feedback Amplifiers:** In this feedback amplifier, the input voltage or the current is in phase with the input signal.
   - Both the input signal and feedback introduce a phase shift of 180° and makes a 360° resultant phase shift to be in phase with the input signal.
2. **Negative Feedback Amplifier :** In this feedback, the input voltage or current is out of phase with the input signal, opposing it.
   - In this type of circuit, a 180° phase shift is introduced, but the resultant phase shift is zero. Hence the feedback voltage would be 180° out of phase with respect to the input signal.

F**eedback Amplifier Topologies:** There are four types of feedback topology

1. Current series feedback amplifier
2. Voltage series feedback amplifier
3. Current shunt feedback amplifier
4. Voltage shunt feedback amplifier

Current series feedback amplifier

- In this feedback amplifier, both the input and output impedance are increased.
- The feedback circuit is placed in series with the input and output.
- Here a fraction of the output voltage is applied in series with the input voltage in the feedback circuit.

Voltage series feedback amplifier

- The feedback circuit is connected in shunt with the output in such a way that it decreases the output impedance and increases the input impedance.
- In this circuit, it is placed in a shunt with the output but in series with respect to the input signal.

Current shunt feedback amplifier

- It increases the output impedance and because of connecting the feedback circuit in parallel with the input, the input impedance is decreased.
- Here, the feedback circuit is placed in series with the output and in parallel with the input.

Voltage shunt feedback amplifier

- Here the feedback circuit is placed in a shunt with respect to output and input as well.
- It decreases the input and output impedance.

Advantages of feedback amplifier: 1. Improves stability gain of the circuit by negative feedback amplifiers. 2. Input resistance can be increased by selective configurations.

Disadvantages of feedback amplifier: 1. Increased noise and distortion in positive feedback. 2. Can reduce gain.

Application of Feedback Amplifier:

- They can be used in regulated power supplies.
- Generally used in electronic amplifiers.

Gain Stability Relation: The gain of a feedback amplifier is defined as the ratio of output voltage with respect to the input voltage of a circuit. The gain stability of a feedback amplifier refers to the ability of the amplifier to maintain a constant gain irrespective of the changes in the operating conditions. for a negative feedback amplifier, the loop gain margin can be mathematically expressed as, Loop gain margin=1 / Aβ

Optical Fibre: Optical fibre is the technology associated with data transmission using light pulses travelling along with a long fibre which is usually made of plastic or glass.

Types of Optical Fibres: The types of optical fibres depend on the refractive index, materials used, and mode of propagation of light.The classification based on the refractive index is as follows:

- **Step Index Fibres:** It consists of a core surrounded by the cladding, which has a single uniform index of refraction.
- **Graded Index Fibres:** The refractive index of the optical fibre decreases as the radial distance from the fibre axis increases.

The classification based on the materials used is as follows:

- **Plastic Optical Fibres:** The poly methyl methacrylate is used as a core material for the transmission of light.
- **Glass Fibres:** It consists of extremely fine glass fibres.

The classification based on the mode of propagation of light is as follows:

- **Single-Mode Fibres:** These fibres are used for long-distance transmission of signals.
- **Multimode Fibres:** These fibres are used for short-distance transmission of signals.

Advantages of Optical Fibre Communication:

- Less signal degradation
- Flexible and lightweight
- Economical and cost-effective