B.Sc. II SEMESTER PHYSICS

THERMAL PHYSICS AND SEMICONDUCTOR DEVICES

PART-A Thermodynamics & kinetic theory of gases

Thermodynamics :Thermodynamics is the branch of physics that deals with the concepts of heat flow and temperature change in a system and the inter-conversion of heat and other forms of energy.

The Thermodynamic System: A thermodynamics system is a study of the behavior of gases, it is a macroscopic science. It deals with bulk systems and does not go into the molecular constitution of matter.

1. System: A specified part of the universe that is under observation is called the system. Types of system:

1. **Open system: A** system that can exchange matter as well as energy with the surroundings is called an open system.
2. **Closed System:** A system that can exchange energy but not matter with its surroundings is called a closed system.
3. **Isolated System:** A system that can neither exchange matter nor energy with the surroundings is called an isolated system.

2. Surroundings: The remaining portion of the universe which is not a part of the system is called the surroundings.

3. Macroscopic Properties of a System: These are the properties of any system which arise from the bulk behavior of matter. These properties can be classified into two types: 1. **Extensive Properties:** The properties of the system whose value depends upon the amount or size of substance present in the system. For example, mass, volume, molar properties Force, etc. 2. **Intensive Properties:** The properties of the system whose value is independent of the amount or size of substance present in the system. For example temperature, pressure, viscosity, vapor pressure, etc.

4. State Variable: The measurable properties required to describe the state of the system are the state variables. For example temperature, pressure, volume, composition, etc.

5. State Functions: It is a property of the system whose value depends only upon the state of the system and is independent of the path or manner by which the state is reached.

6. Isothermal Process: It is defined as a process where a change in pressure or volume does not affect temperature. Hence, the temperature in this process remains constant.

7. Adiabatic Process: A process in which the system does not exchange any heat with the surroundings. This implies that no heat leaves or enters the system.

8. Isobaric Process: It is defined as a process where the pressure of the system remains constant.

9. Isochoric Process: When the volume of a system remains constant regardless of the change in pressure or temperature then that process is known as the isochoric process.

10. Reversible Process: A process in which the direction may be reversed at any stage by merely a small change in a variable like a temperature, pressure, etc.

11. Irreversible processA process that is not reversible is called an irreversible process. All-natural processes are irreversible.

12. Cyclic Process: A process in which the system undergoes a series of changes and ultimately returns to its original state.

Laws of Thermodynamics: Now to understand the heat flow and mechanics of thermodynamics there are four laws which had been proposed and it is termed as laws of thermodynamics, which can be given as

Zeroth Law of Thermodynamics: This law was first proposed in 1931 by RH Fowler. It states that if two thermodynamic systems are each in thermal equilibrium with a third, then they are in thermal equilibrium with each other.

First Law of Thermodynamics:: The first law of thermodynamics is a restatement of the law of conservation of energy. It states that energy cannot be created or destroyed in an isolated system; energy can only be transferred or changed from one form to another.According to the first law of Thermodynamics: $\mathbf{\delta Q = \delta W + \Delta U}$

Entropy: The degree of randomness of the system is called the entropy of the system. i.e., the Entropy of the system can be expressed as$\Delta S=\Delta Q\Delta T$. So, for adiabatic processes $\Delta Q = 0$ hence Entropy of the given system will also be zero.

Carnot Engine: The Carnot engine is a thermodynamic cycle that gives the maximum efficiency of a heat engine while working between two temperatures in reversible thermal and adiabatic expansion and compression processes. It works between two temperatures T1 and T2 with a hot and a cold reservoir.

Carnot's Theorem: Carnot's theorem can be stated as An engine working between two temperatures T1 and T2 of hot and cold reservoirs cannot have efficiency more than that of Carnot's engine.The efficiency of the Carnot engine is independent of the nature of the working substance.The efficiency of Carnot Engine is given as$\eta=1-T2\ /T1$.

Applications of Carnot Engine: 1. Used for comparing efficiencies of thermal devices like, heat pumps, ac and refrigerators (to yield cooling). 2. Used to compare efficiencies of petrol and diesel engines.

Second law of Thermodynamics: According to the Second Law of thermodynamics, for natural systems heat always flows in one direction (higher temperature to lower temperature body) unless it is aided by an external factor. For e.g., If ice is melting heat will always flow from ice to the hot atmosphere of the surroundings unless it is kept back in the freezer.

Third Law of Thermodynamics: The third law of Thermodynamics states that: At absolute zero degree temperature, the entropy of an ideal and perfectly crystalline solid is zero.

Joule-Thomson Effect: It is defined as that gas can experience temperature changes due to a sudden tension change at a valve. This phenomenon is known as the Joule-Thomson Effect. It is important in the advancement of refrigeration frameworks such as hotness syphons, climate control systems, liquefiers, and climate control systems.

Applications of Joule-Thomson Effect: It has been a valuable tool in refrigeration because of the cooling it produces in the Joule-Thomson expansion.This effect can also be used for liquefying helium.

Kinetic Theory of Gases: A vast number of submicroscopic particles, such as atoms and molecules, are used in the kinetic theory of gases to represent the molecular makeup of a gas. The kinetic theory of gases also defines mass diffusivity, viscosity, thermal conductivity, and pressure in addition to temperature, volume, and pressure. In essence, it covers every facet of the tiny phenomenon.

Mean Free Path: In between the two successive collisions, the gas molecule travels a straight path with constant velocity. This is called a free path. It is very small and measured in Armstrong meters. For N number of collisions, the mean free path is given as $\lambda=\underline{\lambda1+\lambda2+\lambda3+\ldots+\Lambda n}/\ _{N}$

Mean Velocity: For N number of gas molecules in a container with individual velocity denoted by C1,C2,C3,…CN. The Mean Velocity is given by,C=C1+C2+C3+…+CN/ N

Mean Square Velocity: The average value of the squares of the velocity of each molecule is called mean square velocity.

Root Mean Square Velocity: It is the Square root of mean square velocity.

Pressure of a Gas:pressure of the gas is given by $P=1/3\rho C^2_{RMS}$

Kinetic Theory of Gases: Gas Law: For our earlier discussion, we had understood that gas quantities like temperature, Pressure, volume and mass are interconnected with each other. And the law that interconnects this quantity is known as Gas laws, these gas laws are given as

- **Boyle's Law:** According to Boyle's Law, the Volume of any given mass of gas is inversely proportional to its pressure as long as the temperature is kept constanti.e., PV= constant
- **Charles' Law:** According to Charles' law, the volume (V) of given mass of gas will be directly proportional to its temperature (T) at that given instant as long as the system is at constant pressure$V \propto T$.
- **Pressure Law or Gay Lussac's Law:** According to Gay Lussac's Law or Pressure Law, at some constant volume (V) both pressure and temperature will be directly proportional to each other. **Ideal and Perfect Gas Equations:**A gas that obeys all gas laws (such asboyle's law, Charles law, Gay Lussac's Law, etc.,) are known as ideal gas or perfect gas.

Ideal Gas Equation: The equation which relates pressure (P), volume (V) and temperature (T) of the given state for an ideal gas is known as the ideal gas equation or equation of states. And for 1 mol of gas, it is represented as PV/ T=R (constant) $\Longrightarrow$PV=RT**.** For 1 mole of gas,(P+a / V2)(V−b)=RT. Similarly, for n mol of gas,(P+an2 / V2)(V−nb)=nRT

Planck's Quantum Theory: Planck's quantum theory of radiation is a scientific theory that explains the energy and the behaviour of matter on the atomic and subatomic levels. It is based on the idea that energy is not continuous or persistent, yet rather comprises tiny, discrete packets called quanta.

Electromagnetic Radiation: Electromagnetic Radiation is just a form of energy with both wave as well as particle-like properties; visible light is a good example. According to the wave perspective, all forms of electromagnetic radiation might be described in terms of their frequency and wavelength.

Blackbody Radiation: Different materials emit different quantities of radiant energy even when they are at a similar temperature. A body that radiates the most amount of heat for its absolute temperature is known as a blackbody. It can also be stated as a body that absorbs or retains all the radiation falling on it is called a blackbody.

Planck's Quantum Formula:P lanck's Quantum Formula, also sometimes referred to as plank's equation provides a quantitative description of the amount of spectral radiance at a specific frequency radiated by Black body in the equilibrium state. As per the given postulates, the energy, E of a particle of light or photon is directly proportional to its frequency ν. That is, $E \propto \nu$Or, $E=h\nu$ Clearly, we also know that $c=\nu\lambda$or, $\nu=c / \lambda$, On substituting the value of ν in the Planck's equation we obtained,$E=hc / \lambda$

Applications of Planck's Quantum Theory: 1. The theory explained the spectra of blackbody radiation. 2. It led to the development of photon concept.

Wien's Displacement Law: Wien's Displacement Law statement is, "black body radiation has a number of temperature peaks at wavelengths that are inversely proportional to temperatures". Wien's Displacement law is expressed mathematically as follows:$\lambda maxT = b$.

Wien's Constant: Wien's constant is a physical constant that defines the relationship between the thermodynamic temperature of the blackbody and the wavelength. It is a product of the blackbody's temperature and wavelength, which grows shorter as the wavelength increases with temperature.

Limitations of Wien's Displacement Law: 1. The limitation of Wien's Displacement law indicates that it fails in the case of longer wavelength blackbody radiations. 2. A continuous Wein curve cannot be obtained when the body's temperature is reduced.

PART-B Circuit Fundamentals & Semiconductor Devices

Electrical Circuit:A grouping of two or more electrical components connected by conducting channels is known as electrical circuits. It's possible for the electrical components to be either active or inactive, or a combination of the two.

DC Current: The unidirectional transmission of electric charge is referred to as direct current. It is frequently utilized in solar and battery cells. Thomas Edison made various sophisticated electrical systems possible by creating DC current.

DC Circuit:A DC circuit, like any other circuit, is a closed path for current to flow. The only thing different in this circuit is that the circuit uses a direct current which flows in only one direction. DC circuits are mostly used for simple applications.

AC Circuit: The quantity that changes continuously in magnitude between zero and a maximum value with alternating directions at regular time intervals is known as an alternating quantity such as current (I) or voltage (V)

Semiconductor: A semiconductor is a material that has its conductivity somewhere between the insulator and conductor. A diode is a special type of conductor which uses semiconductors for conducting the electric current. Due to the use of semiconductors, the diodes give additional functionality like controlling the flow of current or emitting light. **Types of semiconductor:** Intrinsic Semiconductor and Extrinsic Semiconductor

Intrinsic Semiconductor: An intrinsic type of semiconductor material is made to be very pure chemically. It is

made up of only a single type of element.

Extrinsic Semiconductor: The process of adding impurity atoms to the pure semiconductor is called extrinsic

semiconductor . It can be further classified into types:N-type Semiconductor and P-type Semiconductor..

Diode:A diode is a two-terminal semiconductor which allows the flow of current exclusively in one direction. It's one end is of high resistance while the other is low resistance. Thus, if electricity tries to flow in the opposite direction it faces a high resistance. Generally, diodes are made up of Selenium or Germanium..

Applications of Diodes: Isolating signals from the supply and Used in rectifier circuits

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**.** NPN transistor and PNP transistor are the two kinds of transistors.

Transistor Biasing: Transistors can be studied and analyzed with proper biasing. With the right biasing techniques, transistors can be studied and evaluated. This approach makes us understand that a transistor amplifier works within the specified linear range just by adjusting the DC operating point, This is also known as the bias point.

Need for Transistor Biasing: ForWorks inefficiently and to produce distortion in the output.

Essentials of Transistor Biasing: The biasing is required for faithful amplification. The biasing network associated with the transistor should meet the following requirements:It should ensure proper zero signal collector current.Make the operating point independent of the transistor parameters.

Types of Transistor Biasing: The most commonly preferred transistor biasing methods are:Fixed bias (or) Base resistor bias, Collect-to-base bias (or) Biasing with collector feedback resistor and Potential divider bias (or) self bias (or) Voltage divider bias (or) Universal bias.

Stability Factor: It is desirable and necessary to keep IC constant in the face of variations of ICBO(sometimes represented as ICO. The extent to which a biasing circuit is successful in achieving this goal is measured by stability factor **S**.Stability factor, $S=d_{Ic} / d_{ICO}$

Multimeter:A multimeter is a type of device that is used to measure the voltage, electric current, and resistance present in an electric machine**.**

Advantages of Digital Multimeters: 1. Accurate readings. 2. Easy to read. 3. Faster response time

Disadvantages of Digita lMultimeters: 1. High cost. 2. Digital multimeters require batteries or a power source to operate. 3. Sensitivity to electrical noise

Advantages of Analog Multimeter: 1. Analog multimeters have a simple design and operation 2. They provide immediate and continuous readings.

DisadvantagesofAnalogMultimeter:1. Less accuracy. 2. Limited resolution 3. Lack of additional features

Applications of Multimeters: It is used to measure AC and DC voltage and current and also used to check the diodes.

Cathode Ray Oscilloscope(CRO): Full form of CRO is Cathode Ray Oscilloscope. A cathode ray oscilloscope is an electrical test device used to produce waveforms in response to several input signals. It was originally known as an oscillograph. The general block diagram of CRO consists of the major blocks namely: The Vertical Amplifier, Delay line, Trigger circuit, Time base generator, Horizontal Amplifier and Cathode Ray Tube (CRT)

Applications: 1. The application of CRO are in radio stations to observe the signal's sending and receiving characteristics. **2.** The voltage, current, frequency, inductance, admittance, resistance, and power factor are all measured with the Cathode Ray Oscilloscope.

Advantages: 1. Cost and Schedule**. 2.** requirements for training**. 3.** Consistency and excellence

Limitations: 1. Comparing the cost of these oscilloscopes to other measurement tools like multimeters, they are costly. **2.** Once damaged or had trouble, they are difficult to repair.