

## **Fundamentals of Heat and Thermodynamics**

### **Expected Learning Outcome**

- Fundamentals of heat
- Modes of heat transfer
- Types of heat involved in refrigeration
- Thermodynamic laws and Thermodynamic cycles

### **1.1.Heat**

Heat is a form of energy which gives the sensation of warmth or hotness.

When heat is added to a material or a substance, the following changes takes place.

- \* Increase in temperature
- \* The substance may melt or vaporize.
- \* Change in Radiation.

### **Importance of heat transfer**

In the modern technology heat transfer has gained importance in almost every field of Engineering. The laws which govern heat transmission are very important to the engineer in the design, construction, testing and operation of heat exchange apparatus. Electrical engineers apply their knowledge of heat transfer to the design of cooling systems of transformers, motors and generators. Chemical engineers are concerned with the evaporation, condensation, heating and cooling of fluids. The architect or civil engineers concerned mainly with the erection of structures, learned sufficient heat transfer theory to insulate the buildings properly. The power engineer in the design of ever more efficient central power stations sought understanding the action of steam generators and condensers and the means of preventing heat loss from the piping system. The Mechanical engineer deals with problems of heat transfer in the fields of internal combustion engines, refrigeration and air conditioning, nuclear reactors, rocket propulsion and space vehicles. Every engineer will be confronted from time to time with the question of how to transmit heat in the most effective way, or how to protect a construction most efficiently against heat losses or gains. In recent years, the facts and theories on heat transfer have become more unified and therefore more like a separate technology in its own right.

### **1.2.Modes of Heat transfer**

When energy is transferred from one body to another by virtue of a temperature difference existing between them, it is said that heat is transferred. The fundamental law governing this phenomenon is that heat may be transferred from a high temperature region to one of low temperature but never from a lower temperature region to one of higher temperature. Since the transfer of heat is in reality a transfer of energy, it necessarily follows the law of conservation that the heat emitted by the high temperature region must be exactly equal to the heat absorbed by the low temperature region. The study of heat transmission is therefore built upon these two fundamental axioms. The science of heat transfer concerns itself primarily with the determination of the quantity of heat transmitted from one region to another.

The flow of heat may occur in one or more of three basic modes. These three modes of heat transmission are, Conduction, Convection and Radiation.

### **Conduction**

The method of transferring heat from molecule to molecule is known as conduction.

### **Convection**

The method of transferring heat by upward currents caused by heat is known as convection.

### **Radiation**

The method of transmitting heat by waves is known as radiation.

### **1.3.Types of heat involved in Refrigeration**

The movement of molecules in a refrigeration is controlled by the heat energy which is either added or taken away. The sensible heat is valuable to the designer, craftsman and technician only if its effects are determined and there is some way to measure it. The more heat energy molecules receive, the faster they move. Such movement is accompanied by a change in temperature. The heat that is used to give the molecules movement and to raise the temperature is sensible heat because its effect can be determined by one of the senses—the sense of feeling.

The matter exists in any one of three states, depending on the energy in the molecules. This energy may be either kinetic (which is an energy of motion) or potential (an energy of position). The kinetic or potential energy of a material may be changed by adding heat. Heat can be added to a material under certain conditions without changing its temperature. Heat thus absorbed causes the molecules to move at the same rate of speed but with greater freedom. This results in an increase in potential energy results in a change in fluidity (freedom) which is a change of state. The heat which causes this change is latent heat. So these two heat plays an important role in refrigeration systems.

**Sensible heat:** when the temperature of a solid, liquid or gas is raised or lowered. The energy that causes temperature change is known as sensible heat.

- *Sensible heat of a solid:* The heat which causes changes in the temperature of a solid.
- *Sensible heat of a liquid:* The heat energy which is added to or removed from a liquid.
- *Sensible heat of a vapour:* The heat energy which is added to the vapour.

**Latent heat:** The heat which causes change of state without any change of temperature is called Latent heat.

- *Latent heat of fusion:* The amount of heat necessary to change one kg of solid to liquid, where the temperature and pressure remaining constant during the change.
- *Latent heat of vaporization:* The amount of heat required to change one kg of liquid to vapour at standard atmospheric pressure and at constant temperature.
- *Latent heat of sublimation:* The amount of heat required to change one kg of solid into the gaseous state at constant temperature.

### **1.4. Specific heat**

The specific heat of a substance is the amount of heat required to raise the temperature of a unit mass of any substance through 1°C. When a substance is heated it increases in volume thus pushing the surrounding atmosphere through a small distance. As a result some external mechanical work is done against the atmosphere pressure. In case of solids and liquids the change in volume is very small and hence the external work done during the change in temperature is negligible. However in case of gases the large changes in volume and pressure take place and a part of the heat energy supplied for heating the gas is utilized for doing external work.

In view of the above fact, the external conditions of the gas are important and should be stated when mentioning their specific heat. In case of solids and liquids the heating is done at

constant pressure while in case of gases the heating can be done either at constant pressure or at constant volume. As a result we have two types of specific heats of gases.

Specific heat at constant volume: It is the amount of heat required to raise the temperature of the unit mass of gas through 1°C, when it is heated at constant volume.

Specific heat at constant pressure: It is the amount of heat required to raise the temperature of unit mass of a gas through 1°C when it is heated at a constant pressure.

### **1.5. Temperature**

The degree of hotness or coldness of a body is known as its temperature. Thermometer is used to measure the temperature. Thermometer works on the principle of change in volume with change in temperature. The most common types of thermometers are mercury thermometer and alcohol thermometer. Two temperature scales are commonly used Centigrade Scale and Fahrenheit Scale. The freezing point and boiling point on centigrade scale is 0°C and 100°C respectively. The freezing point and boiling point on Fahrenheit scale is 32°F and 212°F respectively. The relation between centigrade and Fahrenheit scale to convert one into another is as follows,

$$^{\circ}\text{F} = 9/5 [^{\circ}\text{C} + 32]$$

$$^{\circ}\text{C} = 5/9 [^{\circ}\text{F} - 32]$$

### **Absolute Temperature**

The temperature below which the temperature of any substance cannot fall is known as absolute zero temperature. The absolute zero temperature for all sorts of calculations is taken as -273°C in Celsius scale and -460°F in Fahrenheit scale. The temperature measured from this zero are called absolute temperature.

### **1.6. Pressure**

Scientifically pressure is a force per unit area. The pressure exerted by the atmosphere is called atmospheric pressure. The difference between actual pressure and atmospheric pressure is known as gauge pressure. The sum of atmospheric pressure and gauge pressure is known as absolute pressure.

The pressure of a space below atmospheric pressure is known as vacuum pressure.

### **Volume**

Occupied space by substance is known as volume. Change in temperature affects the volume of solids and liquids.

### **1.7. Enthalpy**

Enthalpy means heat content. It is denoted by the letter H. Enthalpy is a function of states and like the internal energy, it also depends on the initial and final states of the systems (anything that is under observation for experimental work is called a system. A gas placed in a cylinder for experimental work forms a system). The enthalpy of a refrigerant at a given temperature is the amount of heat that must be added to one pound of the refrigerant to bring it up to the required temperature of a liquid or vapour from the reference temperature. The total heat of the vapour includes the sensible heat of the liquid plus the latent heat needed to form the vapour at that same temperature.

### **Entropy**

Entropy is the quantitative measure of disorder in a system. The concept comes out of thermodynamics which deals with the transfer of heat energy within a system. It is an important thermodynamic property of a working substance, which increases with the addition

of heat and decreases with its removal over a small range of temperature, the increase or decrease of entropy, when multiplied by the absolute temperature gives the heat absorbed or rejected by the working substance.

### **1.8. Thermodynamics and Thermodynamics Laws**

Thermodynamics is the science that deals with the relations between heat, work and properties of systems. General laws of energy transformation concerning all types of systems, mechanical, electrical and chemical may fall within the purview of this science. It is a science based on a number of empirical law formed by experimentation from which all predictions concerning the physical behaviour of the system may be deduced by logical reasoning.

#### **Zeroth law of Thermodynamics**

If two systems are both in thermal equilibrium with a third system, they are in thermal equilibrium with each other.

#### **First law of Thermodynamics**

Whenever a system undergoes a cyclic change the algebraic sum of work transfer is proportional to the algebraic sum of heat transfer or Heat and work are mutually convertible one into the other.

#### **Second law of Thermodynamics**

There is a definite limit to the amount of mechanical energy which can be obtained from a given quantity of heat energy.

#### **Clausius statement of second law of Thermodynamics**

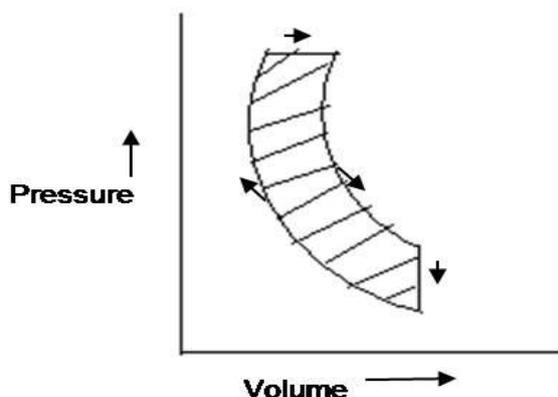
It is impossible for a self acting machine working in a cyclic process, unaided by an external energy, to convey heat from a body at a lower temperature to a body at higher temperature.

#### **Kelvin plank statement of second law of Thermodynamics**

It is impossible to construct an engine, which while operating in a cycle produces no other effect except to extract heat from a single reservoir and do equivalent amount of work.

### **1.9. Thermodynamic cycles**

A Thermodynamic cycle or a cyclic process consists of a series of thermodynamic operations (processes) which take place in a certain order and the initial conditions are restored at the end of the processes. When the operations or processes are plotted on P.V. diagram they form a closed figure, each operation being represented by its own curve. Since the area under each curve gives the work done to scale, during each operation, it therefore follows that the network done during one cycle will be given by the enclosed area of the diagram as shown in.



## **Types of Thermodynamic cycles**

### ***Reversible cycle***

A process in which some change in the reverse direction, reverse the process completely, is known as reversible process. In a reversible process there should not be any loss of heat due to friction, radiation or conduction etc. A cycle will be reversible if all the processes constituting the cycle are reversible. Thus in a reversible cycle, the initial conditions are restored at the end of the cycle. A little consideration will show that, when the operations are performed in the reversed order, they cycle draws heat from the cold body and rejects it to the hot body. This operation requires an external power to drive the mechanism according to second law of thermodynamics. A machine which operates on a reversed cycle is regarded as "Heat pump" such as "Refrigerator" because it pumps heat from the cold body to the hot body.

### ***Irreversible cycle***

Whenever some changes in the reverse direction reverses the process completely, it is known as reversible process. But if the change does not reverse the process it is called an Irreversible process. In an irreversible process there is a loss of heat due to friction, conduction or radiation. Thus in an irreversible process the initial conditions are not restored at the end of the process