VINAYAKAR MATRICULATION HIGHER SECONDARY SCHOOL, SIVAKASI.

11th Standard - PHYSICS

DATE : 05-DEC-2021 **P– 50** **No.of Pages: 07**

UNIT 8 HEAT AND THERMODYNAMICS

Warm greetings:

The previous notes and videos uploaded are very useful to you. Now we are going to discuss about

- Heat and temperature
- Thermal properties of matter
- Heat capacity and specific heat capacity

HEAT AND TEMPERATURE:

Introduction:

- Temperature and heat play very important role in everyday life.
- All species can function properly only if its body is maintained at a particular temperature.
- In fact life on Earth is possible because the Sun maintains its temperature. Understanding the meaning of temperature and heat are very crucial to understand the nature.
- Thermodynamics is a branch of physics which explains the phenomena of temperature, heat etc.
- The concepts presented in this chapter will help us to understand the terms ‘hot’ and ‘cold’ and also differentiate heat from temperature.
- In thermodynamics, heat and temperature are two different but closely related parameters. **Meaning of heat** When an object at higher temperature is placed in contact with another object at lower temperature, there will be a spontaneous flow of energy from the object at higher temperature to the one at lower temperature. This energy is called heat.
- This process of energy transfer from higher temperature object to lower temperature object is called heating.

☞ Due to flow of heat sometimes the temperature of the body will increase or sometimes may not increase.

Note There is a misconception that heat is a quantity of energy. People often talk 'this water has more heat or less heat'. These words are meaningless. Heat is not a quantity. Heat is an energy in transit which flows from higher temperature object to lower temperature object. Once the heating process is stopped we cannot use the word heat. When we use the word 'heat', it is the energy in transit but not energy stored in the body.

Meaning of work:

- When you rub your hands against each other the temperature of the hands increases. You have done some work on your hands by rubbing.
- The temperature of the hands increases due to this work. Now if you place your hands on the chin, the temperature of the chin increases.
- This is because the hands are at higher temperature than the chin.
- In the above example, the temperature of hands is increased due to work and temperature of the chin is increased due to heat transfer from the hands to the chin.
- t is shown in the Figure 8.1 By doing work on the system, the temperature in the system will increase and sometimes may not.
- Like heat, work is also not a quantity and through the work energy is transferred to the system . So we cannot use the word 'the object contains more work' or 'less work'.
- Either the system can transfer energy to the surrounding by doing work on surrounding or the surrounding may transfer energy to the system by doing work on the system.

- For the transfer of energy from one body to another body through the process of work, they need not be at different temperatures.

Meaning of temperature:

- Temperature is the degree of hotness or coolness of a body. Hotter the body higher is its temperature.
- The temperature will determine the direction of heat flow when two bodies are in thermal contact.
- The SI unit of temperature is ***kelvin* (K)**. In our day to day applications, ***Celsius*** (˚C) and ***Fahrenheit*** (°F) scales are used.
- Temperature is measured with a thermometer. The conversion of temperature from one scale to other scale is given in Table 8.1

Table 8.1 Temperature conversion

Scale	To Kelvin	From Kelvin
Celsius	K=°C + 273.15	°C = K – 273.15
Fahrenheit	K=(°F + 459.67)÷1.8	°F=(K × 1.8)-459.67

Scale	To Fahrenheit	From Fahrenheit
Celsius	°F=(1.8 × °C) + 32	°C = (°F – 32)÷1.8

Scale	To Celsius	From Celsius
Fahrenheit	°C=(°F – 32)÷1.8	°F = (1.8 × °C) + 32

THERMAL PROPERTIES OF MATTER:

Boyle's law, Charles' law and ideal gas law:

- For a given gas at low pressure (density) kept in a container of volume V, experiments revealed the following information.

1. When the gas is kept at constant temperature, the pressure of the gas is inversely proportional to the volume. $P \alpha 1/V$. It was discovered by Robert Boyle (1627-1691) and is known as Boyle's law.

2. When the gas is kept at constant pressure, the volume of the gas is directly proportional to absolute temperature. *V α T.* It was discovered by Jacques Charles (1743-1823) and is known as Charles' law.

3. By combining these two equations we have *PV = CT.* Here C is a positive constant. We can infer that C is proportional to the number of particles in the gas container by considering the following argument.

If we take two containers of same type of gas with same volume V, same pressure P and same temperature T, then the gas in each container obeys the above equation. *PV =CT.* If the two containers of gas is considered as a single system, then the pressure and temperature of this combined system will be same but volume will be twice and number of particles will also be double as shown in Figure 8.2

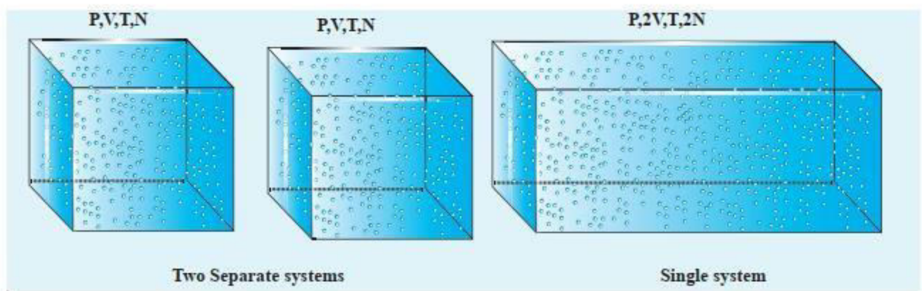

Figure 8.2 Ideal gas law

- For this combined system, V becomes 2V, so C should also double to match with the ideal gas equation (P 2V) / T = 2C .
- It implies that C must depend on the number of particles in the gas and also should have the dimension of { *PV / T*}=JK^{-1}.
- So we can write the constant C as k times the number of particles N.

  Here k is the Boltzmann constant ($1.381\times10^{-23}\ JK^{-1}$) and it is found to be a universal constant. So the ideal gas law can be stated as follows:

$$PV = NkT \qquad (8.1)$$

The equation (8.1) can also be expressed in terms of mole.

Mole is the practical unit to express the amount of gas. One mole of any substance is the amount of that substance which contains Avogadro number (N_A) of particles (such as atoms or molecules). The Avogadro's number N_A is defined as the number of carbon atoms contained in exactly 12 g of ^{12}C.

Suppose if a gas contains μ mole of particles then the total number of particles can be written as

$$N = \mu N_A \quad (8.2)$$

where N_A is Avogadro number ($6.023 \times 10^{23} mol^{-1}$) Substituting for N from equation (8.2), the equation (8.1) becomes

$PV = \mu N_A kT$.

Here $N_A k = R$ called universal gas constant and its value is 8.314 J /mol. K.

So the ideal gas law can be written for μ mole of gas as

$$PV = \mu RT \quad (8.3)$$

This is called the equation of state for an ideal gas. It relates the pressure, volume and temperature of thermodynamic system at equilibrium.

Heat capacity and specific heat capacity:

- Take equal amount of water and oil at temperature 27°C and heat both of them till they reach the temperature 50°C. Note down the time taken by the water and oil to reach the temperature 50°C.
- Obviously these times are not same. We can see that water takes more time to reach 50°C than oil.
- It implies that water requires more heat energy to raise its temperature than oil.
- Now take twice the amount of water at 27°C and heat it up to 50°C , note the time taken for this rise in temperature.
- The time taken by the water is now twice compared to the previous case.
- We can define 'heat capacity' as the amount of heat energy required to raise the temperature of the given body from T to T + ΔT .

Heat capacity $S = \Delta Q / \Delta T$

- *Specific heat capacity of a substance is defined as the amount of heat energy required to raise the temperature of 1kg of a substance by 1 Kelvin or 1°C.*

$$\Delta Q = m\,s\Delta T$$

Therefore,

$$s = \frac{1}{m}\left(\frac{\Delta Q}{\Delta T}\right)$$

Where s is known as *specific heat capacity* of a substance and its value depends only on the nature of the substance not amount of substance

ΔQ = Amount of heat energy

ΔT = Change in temperature

m = Mass of the substance

The SI unit for specific heat capacity is J $kg^{-1} K^{-1}$. Heat capacity and specific heat capacity are always positive quantities.

Table 8.2 Specific heat capacity of some common substances at 1 atm (20°C)

Material	Specific heat capacity ($Jkg^{-1}K^{-1}$)
Air	1005
Lead	130
Copper	390
Iron (steel)	450
Glass	840
Aluminium	900
Human body	3470
Water	4186

From the table 8.2 it is clear that water has the highest value of specific heat capacity. For this reason it is used as a coolant in power stations and reactors.

Note The term heat capacity or specific heat capacity does not mean that object contains a certain amount of heat. Heat is energy transfer from the object at higher temperature to the object at lower temperature. The correct usage is 'internal energy capacity'. But for historical reason the term 'heat capacity' or 'specific heat capacity' are retained.

DO YOU KNOW?

When two objects of same mass are *heated* at equal rates, the object with *smaller specific heat capacity* will have a *faster temperature increase*.

When two objects of same mass are *left to cool down*, the temperature of the object with *smaller specific heat capacity* will *drop faster*.

When we study properties of gases, it is more practical to use molar specific heat capacity. Molar specific heat capacity is defined as heat energy required to increase the temperature of one mole of substance by 1K or 1°C. It can be written as follows

$$C = \frac{1}{\mu}\left(\frac{\Delta Q}{\Delta T}\right)$$

Here C is known as *molar specific heat capacity* of a substance and μ is number of moles in the substance. The SI unit for molar specific heat capacity is J mol^{-1} K^{-1} . It is also a positive quantity.

For reference:

https://youtu.be/F97E1WwGamI?t=1

https://youtu.be/4Z4h7CdjN_o?t=1