

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

1

Heat

Chapter 11

HEAT

Q.1. Define heat and gives its unit.

Ans. Different scientists defines heat in different ways from them the following theories are popular.

Classical theory: -

According to classical theory heat is a weightless fluid known as caloric and is present in each substance. The material having more heat has more caloric. If two bodies are in contact to each other then caloric is transfer from a body having high caloric to a body having low caloric.

Mechanical theory: -

Count Rumfort in 1798 challenge classical theory and said that heat is a form of energy and is able to do mechanical work

Joule also says that transfer of heat is not as a flow of caloric but is transfer of energy.

Modern theory: -

It states that heat is a form of energy associated with the motion of molecules

In a substance molecules have three types of K.E.

1. Rotational Kinetic energy.
2. Vibrational Kinetic energy.
3. Translational Kinetic energy

The average K.E. of molecules in a substance is the sum of all three kinds of energies.

The molecules having different kinetic energies when collides with each other elastically, energy is transfer from molecule of high energy to molecule of low energy.

Units of Energy: -

Calorie: -

It is the amount of heat energy required to increase the temperature of one gram of water from 14.5°C to 15.5°C.

British thermal unit (BTU):-

It is the amount of heat energy required to increase the temperature of $\frac{1}{32}$ Slug of water from 63°F to 64°F.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Modern unit (Joule): -

As heat is form of energy therefore unit of energy is taken as Joule which is also unit of work.

$$1 \text{ Calorie} = 4.1868 \text{ Joule} = \frac{1}{800} \text{ Watt-hour.}$$

$$1 \text{ BTU} = 251.996 \text{ Calorie} = 1254.87 \text{ Joules.}$$

Q.2. Define temperature.

Ans. Temperature: -

Temperature is the quantitative determination of degree of hotness or coldness of a body and it determines the direction of flow of heat from one body to other in contact. "Or,

Temperature is the average translational kinetic energy of molecules.

Thermal Equilibrium: -

If two bodies of different masses and temperature are taken in thermal contact to each other then after some time the thing, which is common to both, is known as temperature, at this time bodies are in thermal equilibrium.

Q.3. What is a thermometer? On what principle it is constructed?

Ans. Thermometer: -

It is a device by which temperature is measured correctly.

Principle: -

The thermometer is based on thermometric property of substance. Commonly thermometers are based on the expansion of liquid.

Construction: -

Common thermometer is consisting of a long capillary tube having uniform and narrow bore. One end of tube is closed and second end is fitted with mercury or any liquid filled bulb.

Q.4. What do you mean by thermometric properties of matter? Why mercury is consider best for it.

Ans. Thermometric properties of matter: -

The physical properties of matter, which changes uniformly with change of temperature, are known as thermometric properties.

The thermometric properties of a matter are as under

1. Change of colour of substance.
2. Change of resistance.
3. Thermal expansion
4. Change of viscosity.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

5. Other physical properties.

Mercury is best because: -

1. It is not clear solution.
2. It has uniform linear expansion.
3. Its melting point is -30°C and boiling point is 357°C i.e. has wide range.
4. It does not wet the tube.
5. It is good conductor of heat.
6. Its specific heat is low.

- Q.5. What do you mean by fixed points of thermometer?

Ans. **Fixed points of thermometer: -**

There is two fixed point of thermometer.

A lower fixed point:-

It is the melting point of water at standard atmospheric pressure of 760mm of Hg.

Higher fixed point: -

It is the boiling point of water at standard atmospheric pressure of 760mm of Hg.

- Q.6. Describe various scales for the measurement of temperature.

Ans. **Scale of thermometer: -**

There is three scale of temperature commonly used.

1. Celsius or Centigrade scale.
2. Fahrenheit scale.
3. Kelvin or Absolute scale.

Celsius scale or centigrade scale: -

In it melting point of ice is denoted by 0°C and boiling point of water as 100°C . The distance between the two points is divided in 100 parts and each part is known as one degree centigrade.

Fahrenheit scale: -

In it melting point of ice is denoted by 32°F and boiling point of water as 212°F . The distance between the two points is divided in 180 parts and each part is known as one degree Fahrenheit.

Kelvin Scale: -

In it melting point of ice is denoted by 273 K and boiling point of water as 373K. The distance between the two points is divided in 100 parts and each part is denoted as one degree Kelvin.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Comparison of scales: -

	Scale	Melting point	boiling point	parts
1	Celsius	0°C	100°C	100
2	Fahrenheit	32°F	212°F	180
3	Kelvin	273K	373K	100

Conversion of C° and k: -

In centigrade and Kelvin scale parts are similar that is the size of one degree is same, the difference is only that of melting point of ice there fore we can write as

$$K = C^{\circ} + 273$$

and $C^{\circ} = K - 273$

Conversion of C° and F°: -

It is clear that $100^{\circ}C = 180^{\circ}F$

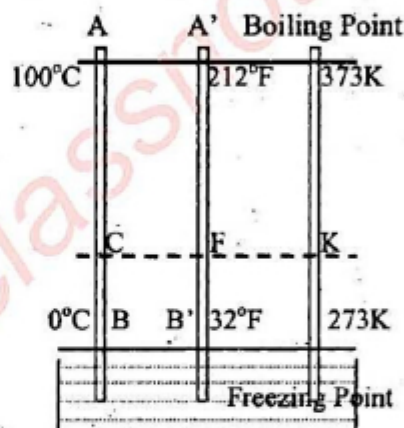
$$\frac{CB}{AB} = \frac{F - 32}{212 - 32} = \frac{C - 0}{100}$$

$$= \frac{F - 32}{180} = \frac{C}{100}$$

$$= \frac{F - 32}{9} = \frac{C}{5}$$

that is $C^{\circ} = \frac{5}{9}(F - 32)$

and $F^{\circ} = \frac{9}{5}C + 32$



Q.7. What do you mean by thermal expansion?

Explain the term coefficient of linear expansion and coefficient of volume expansion. Also drive the expression for final length.

Give the mathematical relation between coefficient of linear expansion and coefficient of volume expansion

Ans. Thermal expansion: -

The increase of size of a sample as solid, liquid or gas due to change of its temperature is known as thermal expansion.

Cause of expansion: -

The size is increases because due to increase of temperature the kinetic energy of molecules of sample is increases i.e. the molecules vibrates with more amplitude, therefore they require more space, which increase its size.

There are three types of thermal expansion.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

5

Heat

1. Linear expansion.
2. Superficial expansion.
3. Volume expansion.

Q. Define and explain Linear expansion in Solid.

Ans. **Linear expansion:** -

The unidirectional increase in the size of a sample due to heat energy is known as linear expansion. Or

The increase in length of a solid bar due to change of its temperature is known as linear expansion.

Derivation of formula: -

Let a rod of length L_0 is heated from temperature T_1 to T_2 due to which its length is increases by ΔL then increase in length is directly proportional to

1. Initial length ($\Delta L \propto L$).
2. Difference of temperature ($\Delta L \propto \Delta T$) where $\Delta T = (T_2 - T_1)$

Comparing the two relations we get

$$\Delta L \propto L_0 \Delta T$$

Or
$$\Delta L = \alpha L_0 \Delta T$$

Where α is proportionality constant and is known as coefficient of linear expansion.

Coefficient of linear expansion: -

It can be defined as friction change in length per unit length per degree rise of temperature.

Unit of α : -

The unit of α is $^{\circ}\text{C}^{-1}$ or $1/^{\circ}\text{C}$ or $^{\circ}\text{K}^{-1}$ or $1/^{\circ}\text{K}$

Final length: -

Let if L is the initial length of rod and ΔL is increase due to heat energy then final length

$$\begin{aligned} L' &= L_0 + \Delta L \\ \text{Or} \quad &= L_0 + \alpha L \Delta T \\ &= L_0 (1 + \alpha \Delta T) \end{aligned}$$

This gives the length of rod after heating.

Q. Define and explain Superficial expansion.

Ans. **Superficial expansion:** -

The expansion in two dimensions (length and width) of a body due to heat energy is known as superficial expansion.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Derivation of formula: -

Consider a plate of length 'L' and width 'b' as figure, then its initial area will be $A_0 = L b$. If its temperature is raises from t_1 to t_2 due to which its area become A' then

$$\text{Increase in area} = \Delta A = A' - A_0$$

$$\text{and increase in temperature} = \Delta T = t_2 - t_1$$

The increase in area ΔA is directly proportional to the initial area as well as to the difference of temperature

$$\text{i.e.} \quad \Delta A \propto A_0 \quad \text{and}$$

$$\Delta A \propto \Delta t$$

Comparing the two relations we get

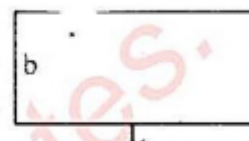
$$\Delta A \propto A_0 \Delta t$$

$$\text{or} \quad \Delta A \propto A_0 \Delta t$$

$$\text{or} \quad \Delta A = \gamma A_0 \Delta t$$

$$\text{or} \quad \gamma = \frac{\Delta A}{A_0 \Delta t}$$

Where γ is coefficient of superficial expansion.



Definition of γ :-

It is define as the change in area per unit area per degree rise of temperature, and its unit is $^{\circ}\text{C}^{-1}$ or $^{\circ}\text{C}^{-1}$ or $^{\circ}\text{K}^{-1}$ or $^{\circ}\text{K}^{-1}$.

Q. Define and explain Volume expansion in Solid.

Ans. **Volume expansion: -**

The expansions in three dimensional (length, width and height) of a body due to heat energy is known as Volume expansion.

Derivation of formula: -

Consider a rectangular block of length L, Width W and height h as figure, then its initial volume will be $V_0 = L w h$. If its temperature is raises from t_1 to t_2 due to which its volume become V' then

$$\text{Increase in volume} = \Delta V = V' - V_0$$

$$\text{and increase in temperature} = \Delta T = t_2 - t_1$$

The increase in volume ΔV is directly proportional to the initial Volume as well as to the difference of temperature

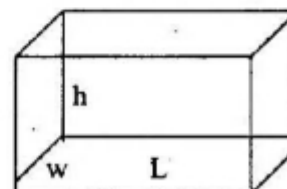
$$\text{i.e.} \quad \Delta V \propto V_0 \quad \text{and}$$

$$\Delta V \propto \Delta t$$

Comparing the two relations we get

$$\Delta V \propto V_0 \Delta t$$

$$\text{or} \quad \Delta V \propto V_0 \Delta t$$



PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

$$\text{or } \Delta V = \beta V_0 \Delta t$$

$$\text{or } \beta = \frac{\Delta V}{V_0 \Delta t}$$

Where β is coefficient of volume expansion.

Definition of β :-

It is define as the change in volume per unit volume per degree rise of temperature, and its unit is $^{\circ}\text{C}^{-1}$ or $1/^{\circ}\text{C}$ or $^{\circ}\text{K}^{-1}$ or $1/^{\circ}\text{K}$.

Final Volume:-

Let if V is the initial volume of rod and ΔV is increase due to heat energy then final volume

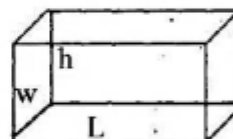
$$\begin{aligned} V' &= V_0 + \Delta V \\ \text{Or } &= V_0 + \beta V \Delta T \\ &= V_0 (1 + \beta \Delta T) \end{aligned}$$

This gives the Volume after heating.

Q.8. Give the mathematical relation between coefficient of linear expansion (α) and coefficient of volume expansion (β)

Ans. Consider a rectangular block of length 'L' width 'W' and height 'h' then its volume will be

$$V = L W h$$



If it is heated from temperature t_1 to t_2 then its volume is increases from V_1 to V_2 then $\Delta V = V_2 - V_1$
 therefore its final volume becomes $V + \Delta V$ which may be written as

$$\begin{aligned} V + \Delta V &= [L(1+\alpha\Delta T)][W(1+\alpha\Delta T)][h(1+\alpha\Delta T)] \\ &= L W h (1+\alpha\Delta T)^3 \end{aligned} \quad \text{but } L W h = V$$

$$\text{therefore } V + \Delta V = V(1+3\alpha\Delta T+3\alpha^2\Delta T^2+\alpha^3\Delta T^3)$$

but α is very small so its higher powers may be neglected that is $(\alpha^2 \rightarrow 0, \alpha^3 \rightarrow 0)$ therefore

$$\begin{aligned} V + \Delta V &= V(1+3\alpha\Delta T) \\ &= V + 3V\alpha\Delta T \end{aligned}$$

$$\Delta V = 3V\alpha\Delta T$$

$$\frac{\Delta V}{V \Delta t} = 3\alpha \quad \text{but} \quad \frac{\Delta V}{V \Delta t} = \beta$$

$$\beta = 3\alpha$$

The relation shows that the coefficient of volume expansion (β) is three times to the coefficient of linear expansion (α).

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Q.9. What do you mean by bimetallic strips, How they work and write its uses.

Ans. **Bimetallic strip: -**

When two strips of different metals i.e. different coefficient of linear expansion are attached rigidly side by side to one another then the arrangement is called bimetallic strip.

Principle:-

It works on the principle of thermal expansion.

Bimetallic strip as thermostat: -

To use bimetallic strip as thermostat, its one end is fixed while the open end is touches by a screw. An Electric circuit connects the both ends through heater as figure.



When current flows heater become hot and temperature of strips is increases. Due to different coefficient of linear expansion length of one-strip increases more then other and the strips bent and the circuit is broken. As the temperature again decrease, the strip becomes straight and circuit becomes on. With the help of it temperature of any body may be maintain.

Bimetallic strip as thermometer: -

To use as thermometer bimetallic strip is taken in the form of coil whose one end is connected by a needle, which can move on calibrated scale. When temperature is increases then due to change of length spring is stretched and needle moves on scale from where temperature is noted.

Use: -

It is used in many devices to maintain temperature as thermometer, thermostat, fire alarm, etc.

Q.10. What do you mean by a gas law? State and explain Boyle's Law, Charles's Law and General gas equation.

Ans. **Gas laws:-**

The relation between mass, volume, pressures and temperature of a gas is known as gas law.

Boyle's law: -

Robert Boyle's developed it in 1660.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Definition: -

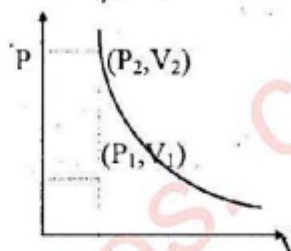
It states that the volume of given mass of a gas is inversely proportional to the pressure if temperature is kept constant.

Formula: -

Let V is the volume of a gas at pressure P then

$$V \propto 1/P$$

$$\text{or } PV = \text{Constant.}$$



This law also may be stated that the product of pressure and volume of a given mass of a gas at constant temperature.

Graph: -

The graph between P and V is a curve and for any two points A and B of it we can write

$$P_1 V_1 = P_2 V_2$$

Defect of Law: -

The graph shows that if pressure is increases to infinity the volume become zero, which is impossible because

1. Gas is consisting of molecules and molecule occupies space.
2. When molecules comes near to each other inter atomic Coulomb repulsive forces are create.

Conclusion: -

There fore it is conclude that this law fails at very high or low pressure but it agrees at normal pressure.

Q. State and explain Charles's Law.

Ans. **Charles law: - (1746-1823)**

Definition: -

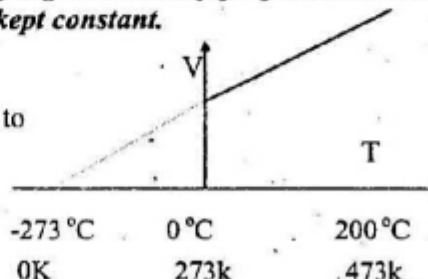
It states that volume of a given mass of a gas is directly proportional to its absolute temperature if the pressure on gas is kept constant.

Formula: -

Let V is volume of gas, which is heated to then temperature difference of $T^\circ \text{K}$

$$V \propto T$$

$$\text{or } V/T = \text{Constant}$$



Graph: -

The graph between V and T is a straight line which shows that at -273 k the

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

10

Heat

volume of gas become zero and negative volume is impossible therefore this temperature is consider as absolute zero (0k). As zero volume is impossible because

1. Gas is consists of molecules and molecules occupies space.
2. When molecules comes near to each other inter atomic Coulomb repulsive forces are create

Conclusion: -

There fore it is conclude that this law is valid above the freezing point of gas or for higher temperature.

Q.10. Drive General gas equation.

Ans. General gas equation: -

From Boyle's law $V \propto 1/p$

From Charles law $V \propto T$

Comparing the two relations we get

$$V \propto T/p$$

OR

$$PV/T = \text{Constant.}$$

For one mole of gas constant is denoted by R ie.

$$PV/T = R$$

$$PV = R_m T$$

The value of R_m for same mass of different gases is different because in same mass of different gases the number of molecules is different.

If mass of gas is 'n' mole, which is enclosed in container then R, will be constant and in S.I. system its value is $8.314 \text{ J.mole}^{-1} \text{ K}^{-1}$.

$$PV = n RT$$

This equation is known as general gas equation.

Q.10. Drive Universal Gas Law.

A. Universal gas Law: -

The value of gas constant for single molecule is known as Boltzman constant denoted by 'K' therefore

$$K = \frac{R}{N_A} = \frac{8.314}{6.025 \times 10^{23}} = 1.38 \times 10^{-23} \text{ Joule/moleculeK}$$

$$R = K N_A$$

Putting this value we get

$$PV = n K N_A T$$

$$P = n \frac{N_A}{V} K T \quad \text{if} \quad n \frac{N_A}{V} = N$$

$$\text{Therefore} \quad P = N K T$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Defect: -

This law agrees at normal pressure and temperature but at very low temperature and very high pressure it fails because

1. Gas is consisting of molecules and a molecule occupies space.
2. When molecules comes near to each other inter atomic Coulomb repulsive forces are create

Q.11. What are the basic assumptions of kinetic molecular theory of gases?

Ans. **Basic Assumptions of kinetic interpretation of gas laws: -**

Kinetic theory of gases explains the behavior of a gas in term of the interaction of molecules and the energy they possess. The fundamental assumptions of theory are as under.

1. Shape and size of molecule: -

Every gas consists of a large numbers of molecules which are identical and similar having diameter of $3\text{\AA}$ which is negligible as compare the volume of gas. For example there are 3×10^{25} molecules of a gas are present in one cubic meter at S.T.P.

2. Distance between molecules: -

The molecules are at large distance as compare to their size.

3. Velocities of molecules: -

The molecule moves with different velocities.

4. Random motion: -

The molecules have Brownian (random) motion.

5. Collision between molecules: -

The molecule collides with each other and with the walls of container elastically.

6. Forces between molecules: -

The attractive forces between molecules are very small.

7. Newton's Mechanics: -

The molecule obeys the laws of mechanics.

Q.11. Show that the pressure of an ideal gas is $P = \frac{1}{3}\rho V^2$ Where ρ is density of gas.

Ans. **Pressure of gas: -**

Consider a cube having length 'l'. Let mass of a molecule is 'm' and has velocity 'V' at any point, there fore it may be written as

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

12

Heat

$$V = V_x + V_y + V_z$$

The magnitude of velocity is given as

$$V^2 = V_x^2 + V_y^2 + V_z^2$$

Let

$$V_x = V_y = V_z \text{ then}$$

$$V^2 = 3V_x^2$$

or

$$V_x^2 = \frac{1}{3} V^2$$

let us consider motion along X-axis only

Then momentum of body before collision = $m V_x$

And momentum of body after collision = $-m V_x$

Therefore total momentum = $m V_x - (-m V_x) = m V_x + m V_x = 2m V_x$

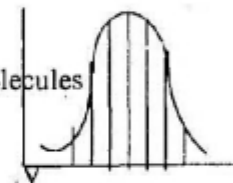
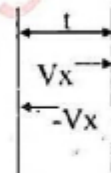
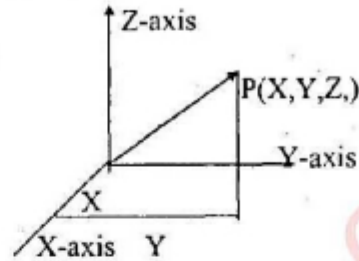
The distance covered by the body in one collision is '2l' which is covered in time 't' then $t = \frac{2l}{V_x}$

The rate of change of momentum is called force therefore

$$F = \frac{\text{Change in momentum}}{\text{time}} = \frac{2m V_x}{\frac{2l}{V_x}} = 2m V_x \frac{V_x}{2l}$$

$$F = \frac{m V_x^2}{l}$$

Maxwell gave the idea of distribution of velocities among molecules graphically.



If velocities of molecules are $V_{1x}, V_{2x}, V_{3x}, \dots, V_{nx}$ then

$$\text{Total force from them} = F = \frac{m v_1^2 x}{l} + \frac{m v_2^2 x}{l} + \frac{m v_3^2 x}{l} + \dots + \frac{m v_n^2 x}{l}$$

But $P = F/A$ and $A = l^2$ therefore

$$P = \frac{F}{l^2} = \frac{1}{l^2} \left(\frac{m v_1^2 x}{l} + \frac{m v_2^2 x}{l} + \frac{m v_3^2 x}{l} + \dots + \frac{m v_n^2 x}{l} \right)$$

$$P = \frac{m}{l^3} (v_1^2 x + v_2^2 x + v_3^2 x + \dots + v_n^2 x)$$

As number of molecules in container is N therefore the number in unit volume is $n_v = N/V = N/l^3$ or $l^3 = N/n_v$

$$P = \frac{m}{N/n_v} (v_1^2 x + v_2^2 x + v_3^2 x + \dots + v_n^2 x)$$

$$P = \frac{m n_v}{N} (v_1^2 x + v_2^2 x + v_3^2 x + \dots + v_n^2 x)$$

but $m n_v$ = mass of molecules x number of molecules per unit volume = density = ρ

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

13

Heat

$$P = \frac{\rho}{N} (v_1^2 x + v_2^2 x + v_3^2 x + \dots + v_n^2 x)$$

$$P = \rho \frac{(v_1^2 x + v_2^2 x + v_3^2 x + \dots + v_n^2 x)}{N}$$

Or $P = \rho V_x^2$, Where V_x^2 is the average velocity of molecules moving along X-axis and $V_x^2 = \frac{1}{3} V^2$.

Substituting we get $P = \frac{1}{3} \rho V^2$

Note: Here $V_{rms} = \sqrt{V_x^2}$

Q. Starting from $P = \frac{1}{3} \rho V^2$ Prove that $T \propto$ Translational K.E., Also prove Boyle's and Charle's Law.

Ans. Prove that $T \propto$ Translational K.E.

From kinetic theory $P = \frac{1}{3} \rho V^2$ where $\rho = m n_v$

Substituting we get $P = \frac{1}{3} m n_v V^2$ but $N/V = n_v$

or $P = \frac{1}{3} m N/V V^2$

or $PV = \frac{1}{3} m N V^2 \dots \dots \dots (1)$

For gas laws $PV = n R T$ but $n = N/N_a$

therefore $PV = N/N_a R T$

Comparing the two relations we get

$$\frac{N}{N_a} R T = \frac{1}{3} m N V^2 \quad \frac{2}{3} \cdot \frac{1}{2} m N V^2$$

$$N \frac{R}{N_a} T = \frac{2}{3} \cdot \frac{1}{2} m N V^2 \quad \text{but} \quad K = R/N_a$$

therefore $NKT = \frac{2}{3} \cdot \frac{1}{2} m N V^2$

or $KT = \frac{2}{3} \cdot \frac{1}{2} m V^2$

or $T = \frac{2}{3K} \left(\frac{1}{2} m V^2 \right)$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

or $T = \frac{2}{3K} (\text{Translational K.E.})$

as $\frac{2}{3}K = \text{constant}$

therefore $T \propto (\text{Translational Kinetic energy})$

i.e. (Translational Kinetic energy of molecules of gas is directly proportional to the absolute temperature.

Boyles' Law: -

As $PV = \frac{1}{3} mNV^2 = \frac{2}{3} \cdot \frac{1}{2} mNV^2$

$PV = \frac{2}{3} N \left(\frac{1}{2} mV^2 \right)$ but $T \propto \left(\frac{1}{2} mV^2 \right)$

For Boyle's law T is constant therefore $\left(\frac{1}{2} mV^2 \right) = \text{Constant}$

or $PV = \frac{2}{3} N (\text{Constant})$

or $PV = \text{Constant}$

Which is **Boyle's law**.

Charles law: -

As $PV = \frac{2}{3} N \left(\frac{1}{2} mV^2 \right)$

or $V = \frac{2}{3P} N \left(\frac{1}{2} mV^2 \right)$

For Charles law pressure of system is kept constant therefore

$V = \text{Constant} \left(\frac{1}{2} mV^2 \right)$

or $V \propto \left(\frac{1}{2} mV^2 \right)$ but

$T \propto \left(\frac{1}{2} mV^2 \right)$

Comparing we get

$V \propto T$

Which is **Charles law**.

Q12. Define and explain the term heat capacity, Specific heat and molar specific heat, write its formula and unit. Establish the relation between molar and common specific heat.

Ans. Heat capacity: -

It is define as the rate of change of heat absorbs by a body.

If ΔQ is heat required to rise the temperature of one mole of substance

through $\Delta T^\circ \text{C}$ then Specific heat capacity = $C = \frac{\Delta Q}{\Delta T}$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Specific heat: -

The heat energy required to rise the temperature of unit mass of a substance through one-degree Celsius is known as specific heat capacity.

Formula: -

If ΔQ is heat required to rise the temperature of unit mass "m" of substance through $\Delta T^\circ \text{C}$ then

$$\text{Specific heat} = c = \frac{\Delta Q}{m \Delta T}$$

or $\Delta Q = m c \Delta T$

From experiments it is observed that the value of 'C' for same mass of different substance is different because the same mass of different substance have different numbers of molecules this problem may be solved by taking the mass in moles because in one mole of any substance number of molecules is same may solve this problem.

Unit: -

The unit of specific heat is Joule/Kg^oC

Molar Specific heat: -

The heat energy required rising the temperature of one-gram mole of a substance through one-degree Celsius or Kelvin is known as molar specific heat capacity.

If 'n' moles of a substance required ΔQ joules of energy to rise the temperature through ΔT degree Kelvin then

$$\Delta Q = n c \Delta T$$

Unit: -

The unit of molar specific heat is Joule/mole^oC

Relation between molar and common specific heat: -

$$\text{Specific heat}_{\text{common}} = c_{\text{Common}} = \frac{\Delta Q}{m \Delta T}$$

$$\text{Specific heat}_{\text{Molar}} = c_{\text{Molar}} = \frac{\Delta Q}{n \Delta T}$$

But "n" one mole is define as quantity of matter m in gram is equal to molecular weight M then $n = m/M$

$$m = nM$$

$$\text{Putting this value } c_{\text{Common}} = \frac{\Delta Q}{nM \Delta T} = \frac{1}{M} \cdot \frac{\Delta Q}{n \Delta T} = \frac{1}{M} \cdot c_{\text{Molar}}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

$$\text{or } c_{\text{Common}} = \frac{c_{\text{Molar}}}{M}$$

$$\text{or } c_{\text{Molar}} = M \cdot c_{\text{Common}}$$

Q. Define molar specific for gases. Why gases have two types of specific heat?

Drive an expression, which shows the difference of two specific heat of gases is equal to gas constant R i.e. ($C_p - C_v = R$).

Ans. **Molar Specific heat of gases: -**

The gases may be heated under two conditions

1. At constant volume.
2. At constant Pressure.

In both cases heat energy required to rise its temperature through same temperature is different, therefore the gases have two types of specific heat.

1. Molar specific heat at constant volume (C_v).
2. Molar specific heat at constant pressure (C_p).

1. **Molar specific heat at constant volume (C_v):-**

It is the amount of heat energy required to rise the temperature of one mole of a gas through one degree Kelvin at constant volume is known as molar specific heat of gas at constant volume.

If ΔQ_v is the amount of heat energy required to increase the temperature of 'n' moles of a gas at constant volume through ΔT K then

$$\Delta Q_v = n C_v \Delta T$$

2. **Molar specific heat at constant pressure (C_p): -**

It is the amount of heat energy required to rise the temperature of one mole of a gas through one degree Kelvin at constant pressure is known as molar specific heat of gas at constant pressure.

If ΔQ_p is the amount of heat energy required increasing the temperature of 'n' moles of a gas at constant pressure through ΔT K then

$$\Delta Q_p = n C_p \Delta T$$

Prove that $C_p - C_v = R$:-

Consider a system consist of a cylinder whose walls are perfectly insulator and conducting base and ideal gas is enclosed in it by means of a friction less and insulating piston.

Let the system is heated to difference temperature T and $T + \Delta T$ under isothermal process, then we get two curves which are parallel to each other as figure.

For point A and B of curves the temperature is increases under isobaric process i.e. pressure remain constant therefore

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

$$\Delta Q_p = n C_p \Delta T$$

In this case piston moves outward there fore work done will be $P\Delta V$, but according to gas laws $P\Delta V = n R \Delta T$,

Putting this value in equation of first law of thermodynamics we get

$$\begin{aligned} \Delta U &= \Delta Q - \Delta W \\ &= n C_p \Delta T - n R \Delta T \dots \dots \dots (1) \end{aligned}$$

For point A and C of curves temperature is

increases under isochoric process i.e. volume remain constant, therefore for the case specific heat may be

as $\Delta Q_v = n C_v \Delta T$

In this case volume remain constant there fore piston does not moves outward and work done will be zero

Putting this value in equation of first law of thermodynamics we get

$$\begin{aligned} \Delta U &= \Delta Q - \Delta W \\ &= n C_v \Delta T - 0 = n C_v \Delta T \dots \dots \dots (2) \end{aligned}$$

The values are taken for same temperature therefore ΔU is same there fore

$$\begin{aligned} n C_v \Delta T &= n C_p \Delta T - n R \Delta T \\ &= n \Delta T (C_p - R) \end{aligned}$$

$$C_v = C_p - R$$

or $C_p - C_v = R$

It means that the difference of C_p and C_v is equal to universal gas constant and C_p is greater then C_v .

Values of C_p and C_v :

Consider a monoatomic gas having temperature T then the kinetic energy of one molecule of gas may be written as

$$T = \frac{2}{3K} \left(\frac{1}{2} m V^2 \right)$$

or $\frac{3}{2} K T = \left(\frac{1}{2} m V^2 \right) \quad \text{as } K = R/N_a$

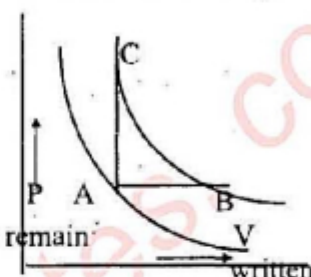
or $\frac{3}{2} \frac{R}{N_a} T = \left(\frac{1}{2} m V^2 \right)$

or $\frac{3}{2} R T = \left(\frac{1}{2} m V^2 \right) N_a$

Where $(\frac{1}{2} m V^2) \cdot N_a$ is kinetic energy of one mole of molecules

therefore $K.E. = \frac{3}{2} R T \quad \text{If } T = T_2 - T_1 = 1k \quad \text{then}$

$$K.E. = \frac{3}{2} R$$



PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

But at constant volume the rise of temperature through 1k is known as molar specific heat at constant volume therefore

$$K.E. = \frac{3}{2} R = C_v$$

or $C_v = \frac{3}{2} R = \frac{3}{2} \times 8.314 = 12.46 \text{ J.mole}^{-1}\text{K}^{-1}$

As $C_p - C_v = R$

or $C_p = C_v + R = 12.46 + 8.314$

$$C_p = 20.774 \text{ J.mole}^{-1}\text{K}^{-1}$$

Q13. Define thermodynamics, a system, an isolated system, and find work done in thermodynamics.

Ans. **Thermodynamics: -**

The branch of physics, which deals with the transformation of heat energy into mechanical energy, is known as thermodynamics.

System: -

The collection of matter with distinct boundary is called a system.

There is two type of system

1. Closed system. 2. Open system.

Closed System: -

The system in which there is no transfer of mass across boundary is called closed system.

Open System: -

The System in which mass and energy both can transfer from its boundary is called open system.

Isolated System: -

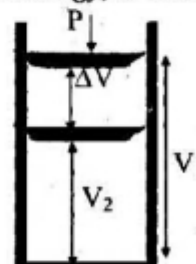
The system in which there is no transfer of mass and energy across boundary is called isolated system.

Heat Engine: -

The device, which converts heat energy in to mechanical energy, is called heat engine.

Work in thermodynamics: -

Consider a system consist of a cylinder whose walls are perfectly insulator and conducting base and ideal gas is enclosed in it by means of a friction less and insulating moveable piston.



PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Let the 'A' is area of cylinder and 'P' is the pressure per unit area then force on piston will be "PA"

When heat is supplied to the system then temperature of gas is increases and piston is pushed outward through a distance Δy , then work done on it may be written as

$$\Delta W = F \cdot d$$

$$= PA \cdot \Delta y$$

But $A\Delta y = \Delta V$ therefore $\Delta W = P\Delta V$ but $\Delta V = V_2 - V_1$

therefore $\Delta W = P(V_2 - V_1)$

This gives the work done in thermodynamics.

Q.14. What is thermodynamics? State and explain the first law of thermodynamics.
Explain the following process

- | | |
|------------------------|------------------------|
| (1) Isobaric process | (2) Isochoric process |
| (3) Isothermal process | (4) Adiabatic process. |

Ans. **Thermodynamics: -**

The branch of physics, which deals with the transformation of heat energy into mechanical energy, is known as thermodynamics.

First Law of Thermodynamics: -

It is a second form of law of conservation of energy written by Helum Hold in 1847. *It states that when heat energy is transformed into any other form of energy or when other forms of energy into heat energy then total amount of energy always remain constant.*

Explanation: -

When ever heat is supplied to a system, the system

1. Absorb heat (ΔQ).
2. Do some mechanical work (ΔW).
3. Its internal energy is increases by (ΔU)

There fore according to law

$$\Delta Q = \Delta U + \Delta W$$

or $\Delta Q - \Delta W = \Delta U$

Internal Energy: -

We know that all the matters are consist of molecules, which moves in it and have kinetic energy. *The sum of kinetic energies of molecules is known as its internal energy and it never be zero.* If heat energy is given to the system kinetic energies of molecules are increases i.e. the internal energy is increases.

If U_i is initial internal energy before heating and U_f is internal energy after heating then the difference of two is known as change in internal energy

$$\Delta U = U_f - U_i$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Then according to 1st law $\Delta Q - \Delta W = \Delta U = U_f - U_i$.

If in a system change in internal energy is zero then according to first law of thermodynamics

$$\Delta Q = \Delta U + \Delta W$$

$$\Delta Q = 0 + \Delta W$$

$$\Delta Q = \Delta W$$

That is if all the energy is converted into work or maximum work may be equal to supplied energy but can not exceed from it. Due to friction between various part of an engine we can not construct an engine which convert all the energy in work.

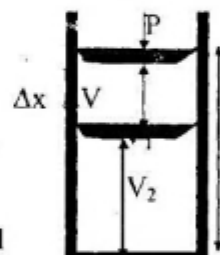
An engine, which converts all the energy in to work, is known as perpetual motion machine of first kind.

The first law of thermodynamics therefore may be stated that the perpetual motion machine of first kind is impossible.

Sign. Conversion: -

In the equation $\Delta Q = \Delta U + \Delta W$ the sign. Are as under.

1. ΔQ is positive if heat flows toward system.
2. ΔQ is negative if heat comes out of system.
3. ΔU is positive if internal energy is increases.
4. ΔU is negative if internal energy is decreases.
5. ΔW is Positive if work is done by the system.
6. ΔW is negative if work is done on the system.



Application of 1st. Law:-

The first law of thermodynamics can be explain in detail by the following four process.

Isobaric Process: -

It is the process in which pressure of system remains constant.

Explanation: -

Consider a system consist of a cylinder whose walls are perfectly insulator and conducting base and ideal gas is enclosed in it by means of a friction less and insulating move able piston.

Let ΔQ heat energy is given to the system due to which piston moves outward through a distance ΔX . If P is the pressure per unit area of cylinder then force on it will be PA . The work done by gas may be written as

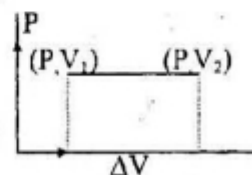
$$\Delta W = F \cdot d$$

$$= PA \cdot \Delta X \quad \text{But } A\Delta X = \Delta V = V_2 - V_1$$

$$\Delta W = P(V_2 - V_1) = P\Delta V$$

Substituting in equation of first law of thermodynamics we get

$$\Delta Q = \Delta U + P\Delta V$$



PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

The graph between P and ΔV is a horizontal line and shows that at constant pressure volume is increases.

Isochoric Process: -

It is the process in which volume of the system remains constant.

Explanation: -

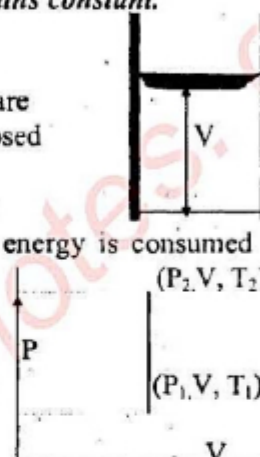
Consider a system consist of a cylinder whose walls are perfectly insulator and conducting base and ideal gas is enclosed in it by means of a fixed and insulating piston.

Let ΔQ heat energy is given to the system, but due to fixed piston there will be no work ($\Delta W = 0$) i.e. all the energy is consumed to increase the internal energy, Substituting we get

$$\Delta Q = \Delta U + \Delta W = \Delta U + 0$$

$$\text{or } \Delta Q = \Delta U$$

The graph between P and V is vertical straight line and shows that pressure on the walls of container and temperature is increases when volume remain constant.



Isothermal Process: -

It is the process in which temperature of the system remains constant.

Explanation: -

Consider a system consist of a cylinder whose walls are perfectly insulator and conducting base and ideal gas is enclosed in it by means of a friction less moveable and insulating piston.

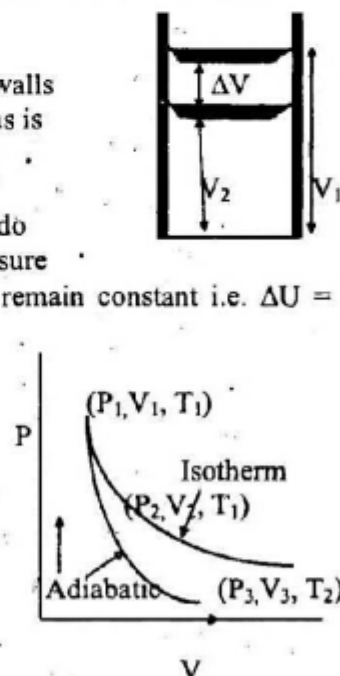
Let ΔQ heat energy is given to the system, due to which temperature start to rise but by reducing the pressure gas is allowed to expand due to which temperature remain constant i.e. $\Delta U = 0$ substituting in equation of first law we get

$$\Delta Q = \Delta U + \Delta W = 0 + \Delta W$$

$$\text{or } \Delta Q = \Delta W$$

The equation shows that all the energy is converted into work. It is example of Boyle's law in which gas is allowed to expand at constant temperature.

Similarly the process may be explained for isothermal compression.



Graph: -

The graph between P and V is a curve like hyperbola.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Adiabatic Process: -

It is the process in which no heat flows into or out of system

Explanation: -

Consider a system consist of a cylinder whose walls and base are perfectly insulator and ideal gas is enclosed in it by means of a friction less moveable and insulating piston.

In the process no heat flows into the system i.e. $\Delta Q = 0$ therefore to take work pressure from piston is decreases due to which gas expand with out energy. Substituting we get

$$\Delta Q = \Delta U + \Delta W$$

$$\text{or } 0 = \Delta U + \Delta W$$

$$\text{or } \Delta W = - \Delta U$$

The equation shows that work is done on the basis of internal energy, which is a decrease.

If pressure is increases the work is done on the system and ΔU will be positive

Graph: -

The graph between P and V is a curve but this curve is deeper then isotherm and shows that with the change of pressure, volume and temperature both are changes.

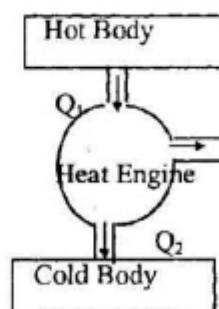
Q.15. State and explain second law of thermodynamics. Prove that Kelvin and Clausius statements are equivalent.

Ans. A machine which convert heat energy into mechanical energy is known as heat engine.

There are three parts of an engine

1. A hot body (Furnace or source of energy)
2. The working part (engine)
3. A cold body (Sink).

The heat flows from hot body toward cold body, Work between them engine convert a part of heat energy into work i.e. for an heat engine two different temperature are necessary there fore the second law is defined by different scientist in different ways all of which are equivalent from which two are popular.



Kelvin Statement: -

Kelvin stated the second law of thermodynamics as "no heat engine operating in a cycle can extract heat from a hot reservoir and convert it into work with out a heat sink to which heat flows".

Or

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

"It is impossible to drive a continuous supply of work by cooling a body to a temperature lower than that of the coldest of its surrounding".

Lord Clauses Statement: -

"It is impossible to cause heat to flow from a cold body to a hot body without the expenditure of energy."

It is the example of refrigerator in which heat flows from cold body to hot body with the help of compressor to which energy from outside is given.

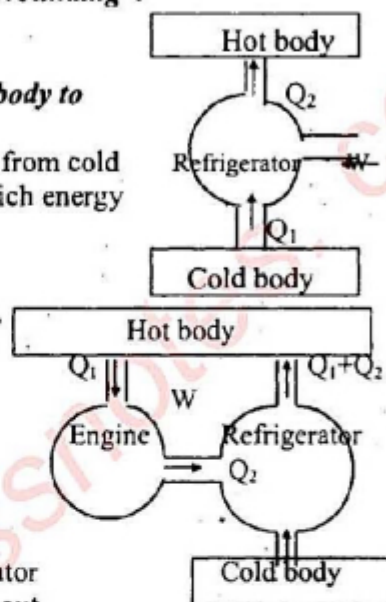
Two statements are similar: -

To prove that the two statements of 2nd law of thermodynamics are identical,

consider that one from two is false.

Let suppose that Kelvin statement is false and we can construct an engine which do nothing except it take heat from hot body and convert it completely into work. If this engine is connected to a refrigerator then this work operates the refrigerator which convert heat from cold body to hot body without external (expenditure) of work which is against the Clausius statement.

The result is that If one is consider wrong 2nd also become wrong therefore we conclude that two statements are equivalent.



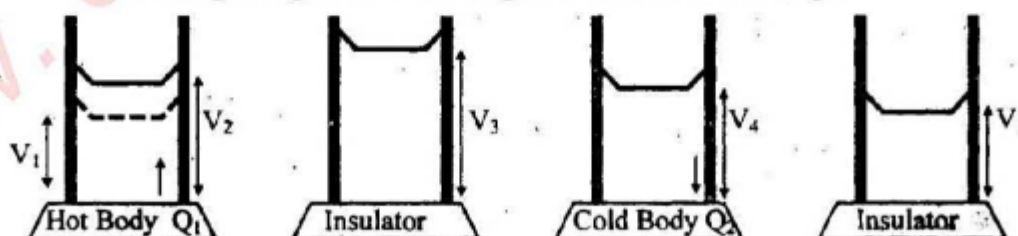
Q What is Carnot engine, describe its cycle and derive body expression for its efficiency.

Ans. The Carnot engine: -

It is an imaginary engine having 100% efficiency. It is based on the principle that efficiency of an engine never be increases from 100%. A French scientist Sadi Carnot gave the theory.

The Carnot engine is consist of a cylinder whose walls is perfectly insulator and conducting base and ideal gas is enclosed in it by means of a friction less and insulating moveable piston.

One complete cycle of Carnot engine is consists of four steps.



1. The engine is placed on a hot reservoir and gas is allowed to expand under isothermal expansion. Let Q_1 is the energy absorbed by the system due to which

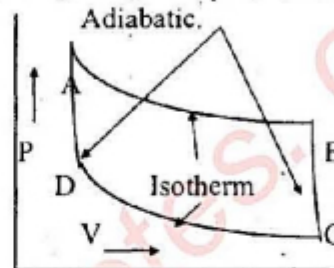
PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

volume of gas is increases from V_1 to V_2 . The process can be represent by curve AB as graph.

2. The engine is placed on insulator and gas is allowed to expand under adiabatic expansion then volume of gas is increases from V_2 to V_3 . The process can be represented by curve BC as graph

3. The engine is placed on a cold body at temperature T_2 which absorb heat Q_2 due to which volume of gas is decreases from V_3 to V_4 . This process is isothermal compression, represented by curve CD. as in graph.

4. The engine is again placed on insulator and gas is pressed such that its volume and temperature become as initial volume and temperature. The work is done on the system under adiabatic compression, represented by curve DA as in graph.



Efficiency: -

As Q_1 is heat absorb by system and Q_2 is heat rejected to cold body then the work done in the cycle may be written as

$$\text{Work} = \text{Output} = Q_1 - Q_2$$

and

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{Q_1 - Q_2}{Q_1}$$

Or

$$\text{Efficiency} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

This equation shows that as the ratio $\frac{Q_2}{Q_1}$ is decreases the efficiency is increases and If $Q_2 = 0$ then efficiency will be 100% but this condition disobey the laws of thermodynamics i.e. the efficiency of an engine is never be 100% even of a Carnot engine.

As Q depends upon the temperature and $Q \propto T$ i.e. $Q = KT$

There fore $Q_1 = KT_1$ and $Q_2 = KT_2$

$$\text{Therefore } \frac{Q_2}{Q_1} = \frac{KT_2}{KT_1}$$

$$\text{Or } \frac{Q_2}{Q_1} = \frac{T_2}{T_1}$$

$$\text{Efficiency} = \left(1 - \frac{T_2}{T_1} \right)$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

$$\text{Percentage Efficiency} = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

Q. State and explain the term entropy. Explain entropy of a system on the bases of 2nd Law of thermodynamics.

Ans. Entropy means the disability or disorder of a system. *The law of entropy states that during any process the entropy of system is increases or remains constant, i.e. it is never be decreases.*

For example consider a box containing white and red balls placed side by side, then a red or black ball may be pick out easily. If the box is shacked well then the ball will be mixed and it will be difficult to pick out a ball of correct color. It is because the disorder or entropy is increases.

According to second law of thermodynamics, If a system undergoes spontaneous change, it will change in such a way that its entropy will increases or at least remain constant.

Explanation: -

According to second law of thermodynamics engine operate in a cycle when heat is transfer from a hot body to cold body. We also know that as the difference of temperature between hot and cold body is increases its efficiency is increases.

We also know that when heat is transfer from a hot body to cold body the difference of temperature is decreases as a result of which efficiency is decreases or the entropy is increases.

Formula: -

If ΔQ is the transfer of energy at constant absolute temperature T then change in entropy is the ratio of ΔQ and T i.e.

$$\text{Entropy} = \Delta S = \frac{\Delta Q}{T}$$

Unit: -

The unit of entropy in S.I. system is JK^{-1} .

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

26

Heat

SHORT ANSWER QUESTIONS (Scientific Reasons)

Q. Explain why the column of mercury first descends and then rises when a mercury-in-glass thermometer is put in a flame?

Ans. When a thermometer is put in a flame, its bulb absorbs the heat first and expands, which causes the descent in the column of mercury, after some time mercury in bulb start absorbing heat and it rises in the tube of thermometer.

Q. According to molecular picture of matter distinguish between heat and temperature.

Ans. According to molecular theory every substance is consist of molecules having continuous motion with different velocities, The average translational K.E. of molecules is known as temperature, while some of all types of K.E.s (Translational + Rotational + Vibrational) is known as heat.

Q. Explain Absolute Zero temperature.

Ans. If Graph is drawn between Volume and Temperature of a gas keeping constant volume a straight line is obtain

which shows that at -273 K the volume of gas become zero and negative volume is impossible therefore this temperature is consider as absolute zero (0K). As zero volume is impossible because

1. Gas is consists of molecules and molecules occupies space.
2. When molecules comes near to each other inter atomic Coulomb repulsive forces are create

Q. What is kinetic theory of gases? Give the experimental evidence for it.

Ans. According to the theory, all matters are consists of molecules which moves randomly in the matter. Experimentally it is proved in Diffusion of gases and Brownian motion.

Q. Why is the average velocity of the molecules in a gas zero but the average of square of velocity is not zero?

Ans. The molecules of a gas moves randomly in the container, and the number of molecules moving from one side to other is equal to the number of molecules from opposite side to that side therefore average velocity of the molecules in a gas zero. On the other hand the square of negative or positive is positive therefore the average of square of velocity is not zero.

Q. Why does the pressure of a gas in a car tyre increases when it is driven through some distance?

Ans. The pressure is directly proportional to average translational kinetic energy of molecules. When car moves, the average translational K.E. of air molecules in the car tyre is increased, so pressure of a gas, in a car tyre increases.

Q. Why is the specific heat at constant pressure (C_p) is greater then specific heat at constant volume (C_v)?

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Ans. When heat is supplied to a gas at constant volume then all the energy is consumed to increase its translational K.E. i.e. to increase temperature while when heat is supplied to a gas at constant pressure, the piston is pushed up i.e. some energy is consumed to do work therefore more energy is required to get same temperature as in case of constant volume, therefore $C_p > C_v$.

Q. Is it possible to convert internal energy into mechanical energy? If so give example.

Ans. Yes, it is possible to convert internal energy into mechanical energy, for example in case of adiabatic expansion work is done on the basis of internal energy.

Q. Is it possible to construct a heat engine that will not expel heat into the atmosphere?

Ans. No, it is impossible to construct a heat engine that will not expel heat into the atmosphere; if it is constructed then it is against the second law of thermodynamics.

Q. A thermo flask containing milk as a system is shaken rapidly, does the temperature of milk rise?

Ans. Thermo flask maintains its temperature when it is at rest. When it is shaken rapidly kinetic energy of milk molecules will be increased which causes to rise of temperature of milk.

Q. If air conditioner is left running on a table in the center of a room, is temperature of room is changes?

Ans. If air conditioner is left running on a table in the center of a room its temperature will not change because air conditioner in the room will absorb heat from room and reject back at same time.

Q. Give an example in which no heat is transferred to or from the system but the temperature of the system changes?

Ans. A Thermo flask maintains its temperature when it is at rest. When it is shaken rapidly kinetic energy of milk molecules will be increased which causes to rise of temperature of milk.

Q. Explain the process in which no heat is transferred to or from the system but temperature of the system changes?

Ans. The process in which no heat is transferred to or from the system but temperature of the system changes is adiabatic process, in which work is done on the basis of internal energy of the system and temperature of system is decreased.

Q. Define Second law of thermodynamics in terms of entropy.

Ans. According to second law of thermodynamics engine operates in a cycle when heat is transferred from a hot body to cold body. We also know that as the difference of temperature between hot and cold body is increased its efficiency is increased.

We also know that when heat is transferred from a hot body to cold body the difference of temperature is decreased as a result of which efficiency is decreased or the entropy is increased.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

28

Heat

Chapter 11 [MCQ's]

1. Heat is a form of energy associated with motion of:
(a) electrons (b) protons (c) atoms (d) **molecules**
2. The S.I. unit of heat is
(a) **Joule** (b) Calorie (c) Centigrade (d) Fahrenheit
3. The quantity of heat required to rise the temperature of 1gm of water from 14.5°C to 15.5°C is known as
(a) Specific heat (b) Latent heat (c) **Calorie** (d) Joule
4. The degree of hotness or coldness is called:
(a) Heat (b) **temperature** (c) energy (d) none of these
5. The temperature which centigrade and Fahrenheit scales are equal is
(a) 0 (b) **-40** (c) -32 (d) -273 (e) 100
6. 273 Kelvin corresponds to
(a) 273°C (b) **-32°F** (c) 0°C (d) -273°C
7. On Fahrenheit scale, the temperature of 50°C responds to
(a) 40°F (b) 101 (c) **122°F** (d) 105°F
8. One cubic meter is equal to
(a) **10⁶ cm³** (b) 10² cm³ (c) 10³ cm³ (d) 10⁻³ cm³
9. The frictional change in length per unit length per degree rise of temperature is called:
(a) linear expansion (b) **coefficient of linear expansion**
(c) Volume expansion (d) coefficient of volume expansion
10. Coefficient of volume expansion is ____ of coefficient of linear expansion:
(a) One third (b) half (c) doubled (d) **three times**
11. A thermometer works on the principle of:
(a) linear expansion (b) volume expansion
(c) **both linear and volume expansion** (d) none of these
12. Bimetallic strip work on the principle of:
(a) **linear expansion** (b) volume expansion
(c) both linear and volume expansion (d) none of these
13. The internal energy of a system depends upon
(a) Pressure (b) Volume (c) **Temperature** (d) Entropy
14. RMS velocity of a gas molecule at absolute zero temperature is
(a) 9×10⁶ m/sec (b) 3×10³ m/sec (c) 273m/sec (d) **zero**

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

29

Heat

15. If the pressure of a gas is doubled, keeping the temperature constant, the volume of the gas is
 (a) Reduce to one forth. (b) Doubled
 (b) **Reduce to one half of the original volume.**
 (c) Increases four times.
16. Universal gas constant for one molecule of a gas is known as:
 (a) Avogadro's number (b) **Boltzman constant**
 (c) molar gas constant (d) molecular constant
17. According to Charles law
 (a) $PV = \text{constant}$ (b) $\frac{V}{T} = \text{constant}$ (c) $VT = \text{constant}$ (d) $\frac{P}{V} = \text{constant}$
18. The pressure and volume relation for a gas undergoing an isothermal change is
 (a) $PV = \text{Constant}$ (b) **$PV^{\gamma} = \text{Constant}$** (c) $(P V^{\gamma}) = \text{Constant}$ (d) $P/V = \text{Constant}$
19. According to kinetic theory of gases, the root mean square speed of gas molecules is directly proportional to
 (a) $\sqrt{T}$ (b) $\sqrt{T^2}$ (c) T (d) T^2
20. The value of Boltzman constant is equal to
 (a) $R N_A$ (b) $\frac{R}{N_A}$ (c) $\frac{N_A}{R}$ (d) $\frac{1}{N_A}$
21. The value of Boltzman constant is equal to
 (a) 3.85×10^{-23} (b) $2.185 \times 10^{-12} \text{JK}^{-1}$ (c) $1.62 \times 10^{-22} \text{JK}^{-1}$ (d) **$1.38 \times 10^{-23} \text{JK}^{-1}$**
22. If the pressure of a gas is doubled, keeping the temperature constant, the volume of gas
 (a) Reduces to one-fourth (b) doubled
 (c) Reduces to one-half of the original volume (d) Increased four time
23. The pressure and volume formula of a gas undergoes an adiabatic change is
 (a) $PV = \text{const.}$ (b) **$PV^{\gamma} = \text{const.}$** (c) $(PV^{\gamma} = \text{const.}$ (d) $P^{\gamma}V = \text{const.}$
24. The pressure exerted by the gas molecules on the walls of a vessel increases if the
 (a) temperature of the gas is decreases
 (b) velocity of molecules of gas is decreases
 (c) Collision of the molecules of the gas with the walls is increases.
 (d) None of the above.
25. The K.E. of the molecules of a ideal gas at absolute zero temperature will be:
 (a) infinity (b) **zero** (c) very high (d) very low
26. The volume of a gas is doubled without changing its temperature, the pressure of the gas is
 (a) Reduced to half of the original value (b) Doubled
 (c) Reduced to one-quarter of the original value (d) Quadrupled

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

30

Heat

27. The heat required to produce a unit change in the temperature of a unit mass of a substance is called:
 (a) **Heat capacity** (b) Molar heat (c) Specific heat (d) Latent heat
28. The S.I. unit of molar specific heat is:
 (a) J/kg-k (b) calorie /gm- °C (c) **J/mole-k** (d) J/mole-°C
29. The quantity of heat required to rise the temperature of 1gm of a substance through 1°C is known as
 (a) **Specific heat** (b) Latent heat (c) Calorie (d) Joule
30. The difference of molar specific heat at constant pressure and at constant volume per mole is called:
 (a) Molar heat (b) Heat constant (c) Boltzman constant (d) **Gas constant**
31. Amount of heat energy absorb during the change of state without rise of temperature is known as
 (a) Specific heat (b) **Latent heat**
 (c) thermal conductivity (d) vaporization
32. For a mono atomic gas value of C_p is:
 (a) $\frac{3}{2}R$ (b) $\frac{5}{2}R$ (c) $\frac{7}{2}R$ (d) $\frac{1}{2}R$
33. The system in which there is no transfer of mass and energy across the boundary is called :
 (a) Open system (b) Closed system (c) **Isolated system** (d) heat engine
34. For adiabatic process:
 (a) $\Delta W = 0$ (b) $\Delta U = 0$ (c) $\Delta Q = 0$ (d) none of these
35. The internal energy of an isothermal process
 (a) Decreases (b) increases (c) Zero (d) **remain the same**
36. If the volume of system remain constant during the process, it is called
 (a) Isobaric (b) Isothermal (c) **Isochoric** (d) Adiabatic
37. The process during which no external work is perform is:
 (a) Isobaric (b) **Isochoric** (c) Isothermal (d) Adiabatic
38. Graph of adiabatic process is _____ then isothermal process:
 (a) **lower** (b) higher (c) same (d) none of there
39. The maximum efficiency of a heat engine is obtain by
 (a) Increasing the temperature of hot and cold body simultaneously, keeping other factors constant.
 (b) **Decreasing the temperature of the sink and increasing the temperature of source, keeping other factors constant.**
 (c) Decreasing the temperature simultaneously (d) None of these

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

31

Heat

40. The efficiency of Carnot engine is 100% if temperature of sink is:
 (a) 0° C (b) 0° F (c) 0 K (d) 100° C
41. The efficiency of Carnot engine is given by:
 (a) $E = \left(1 - \frac{T_2}{T_1}\right)$ (b) $E = \left(1 - \frac{T_1}{T_2}\right)$ (c) $E = \left(1 + \frac{T_2}{T_1}\right)$ (d) $E = \left(\frac{T_2}{T_1} - 1\right)$
42. The change of entropy is given by
 (a) $\Delta S = \frac{\Delta Q}{T}$ (b) $\frac{T}{\Delta Q}$ (c) $\Delta Q = \frac{\Delta S}{T}$ (d) $\Delta S = \frac{\Delta Q}{T}$
43. The entropy of universe
 (a) Always remain constant (b) Always decreases
 (c) Either remain constant or increases (d) Always increases
44. The net change in entropy of a system in a natural process is:
 (a) Positive (b) negative (c) zero (d) infinity
45. The change in disorder of a system is equal to
 (a) $\frac{\Delta Q}{T}$ (b) $\frac{T}{\Delta Q}$ (c) $(\Delta Q \times T)$ (d) $(\Delta Q + T)$

IMPORTANT FORMULAS OF CHAPTER

1. $C = \frac{5}{9}(F - 32)$
2. $\frac{P_1 V_1}{m_1 T_1} = \frac{P_2 V_2}{m_2 T_2}$
3. $L' = L_0(1 + \alpha \Delta T)$
4. $\beta = \frac{\Delta V}{V_0 \Delta T}$
5. $\beta = 3\alpha$
6. $T = \frac{2}{3K} \left(\frac{1}{2} m V^2 \right)$
7. $C_p - C_v = R$
8. $E = \left(1 - \frac{T_2}{T_1}\right) \times 100$
9. $\Delta S = \frac{\Delta Q}{T}$
10. $\Delta Q = m c \Delta T$
11. $\Delta Q = m c \Delta T$
12. $\Delta Q = m c \Delta T$
13. $\Delta Q = m c \Delta T$
14. $\Delta Q = m c \Delta T$
15. $\Delta Q = m c \Delta T$
16. $\Delta Q = m c \Delta T$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

PROBLEMS

- 11.1 (i) The normal body temperature is 98.4°F. What is this temperature on Celsius scale?
 (ii) At what temperature do the Fahrenheit and Celsius scales coincide?

Data: -

$$^{\circ}\text{F} = 98.4^{\circ}\text{F}$$

$$^{\circ}\text{C} = ?$$

Solution: -

$$(i) \quad C = \frac{5}{9}(F - 32)$$

$$C = \frac{5}{9}(98.4 - 32)$$

$$C = \frac{5}{9}(66.4) = 36.89^{\circ}\text{C} \quad \text{Ans.}$$

- (ii) Let the two scale coincide at $x^{\circ}\text{C}$, then

$$x^{\circ}\text{C} = x^{\circ}\text{F}$$

$$C = \frac{5}{9}(F - 32)$$

$$x = \frac{5}{9}(x - 32)$$

$$9x = 5(x - 32) = 5x - 160$$

$$9x - 5x = -160$$

$$4x = -160$$

$$x = \frac{-160}{4} = -40^{\circ}$$

$$-40^{\circ}\text{C} = -40^{\circ}\text{F}$$

- 11.2 A steel rod has a length of exactly 0.2 cm at 30°C, what will be its length at 60°C?

Data: -

$$L_0 = 0.2 \text{ cm}$$

$$T_1 = 30^{\circ}\text{C}$$

Solution: -

$$L_1 = L_0(1 + \alpha \Delta t)$$

$$L_1 = 0.2 \{1 + 11 \times 10^{-6} \times (60 - 30)\}$$

$$L_1 = 0.200066 \text{ cm.} \quad \text{Ans.}$$

- 11.3 Find the change in volume of an Aluminum sphere of 4m radius when it is heated from 0°C to 100°C?

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Data: -

$$R = 0.4\text{m}$$

$$T_1 = 0^\circ\text{C}$$

$$T_2 = 100^\circ\text{C}$$

$$\Delta V = ?$$

$$\alpha = 24 \times 10^{-6} ^\circ\text{C}^{-1}$$

Solution: -

$$\beta = 3\alpha = 3 \times 24 \times 10^{-6} = 72 \times 10^{-6} ^\circ\text{C}^{-1}$$

$$\Delta T = T_2 - T_1 = 100 - 0 = 100^\circ\text{C}$$

$$V_0 = \frac{4}{3} \pi r^3 = \frac{4}{3} \times 3.14 \times (0.4)^3 = 0.268\text{m}^3$$

Putting values in formula

$$\Delta V = V_0 \beta \Delta T$$

$$\Delta V = 0.268 \times 72 \times 10^{-6} \times 100$$

$$= 0.0019\text{m}^3$$

- 11.4 Calculate the root mean square speed of Hydrogen atoms at 800°K.

Data: -

$$V_{r.m.s.} = ?$$

$$T = 800\text{K}$$

$$K = 1.38 \times 10^{-23} \text{JK}^{-1}$$

Solution: -

$$T = \frac{2}{3K} \left(\frac{1}{2} m v^2 \right)$$

$$v^2 = \frac{3KT}{m}$$

$$V_{r.m.s.} = \sqrt{v^2} = \sqrt{\frac{3KT}{m}}$$

In air Hydrogen is found in molecular form therefore

Mass of one mole of Hydrogen molecules = 2gm = 0.002 Kg.

$$\text{Mass of one mole of Hydrogen} = m = \frac{0.002}{6.025 \times 10^{23}} = 3.32 \times 10^{-27} \text{Kg}$$

$$V_{r.m.s.} = \sqrt{\frac{3KT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 800}{3.32 \times 10^{-27}}}$$

$$= \sqrt{9975903.6} = 3158.5\text{ms}^{-1} \quad \text{Ans.}$$

- 11.5 (i) Calculate the average value of kinetic energy of the particles of an ideal gas at 0°C and at 50°C.
 (ii) What is the kinetic energy per mole at these temperatures?

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Data: -

$$T_1 = 0^\circ\text{C} = 0 + 273 = 273 \text{ K}$$

$$T_2 = 50^\circ\text{C} = 50 + 273 = 323 \text{ K}$$

- (a) K.E.₁ = ?
 K.E.₂ = ?
 (b) K.E.₁/mole = ?
 K.E.₂/mole = ?

Solution: -

$$T = \frac{2}{3K} \left(\frac{1}{2} m v_{\text{rms}}^2 \right) = \frac{2}{3K} (K.E.)$$

$$K.E. = \frac{3KT}{2}$$

(a) $K.E._1 = \frac{3KT_1}{2} = \frac{3 \times 1.38 \times 10^{-23} \times 273}{2} = 5.65 \times 10^{-21} \text{ J}$ Ans.

$K.E._2 = \frac{3KT_2}{2} = \frac{3 \times 1.38 \times 10^{-23} \times 323}{2} = 6.686 \times 10^{-21} \text{ J}$ Ans.

(b) $K.E./\text{mole} = \frac{3KNaT}{2} = \frac{3RT}{2}$

$K.E._1/\text{mole} = \frac{3RT_1}{2} = \frac{3 \times 8.314 \times 273}{2} = 3404.5 \text{ J/mole}$ Ans.

$K.E._2/\text{mole} = \frac{3RT_2}{2} = \frac{3 \times 8.314 \times 323}{2} = 4028.13 \text{ J/mole}$ Ans.

- 11.6 A two-Kg iron block is taken from a furnace where its temperature was 650°C and placed on a large block of ice at 0°C . Assuming that all the heat given up by the iron is used to melt the ice, how much ice is melted?

Data: -

$m = 2 \text{ Kg}$ Mass of the ice melted = $M \text{ Kg}$
 $t_1 = 0^\circ\text{C}$ H_f of ice = 336000 J/Kg
 $t_2 = 650^\circ\text{C}$ C for iron = $499.8 \text{ J/Kg}^\circ\text{C}$

Solution: -

Heat lost by iron = $m C \Delta t$
 $= 2 \times 499.8 \times 650$
 $= 649740 \text{ J}$

Heat gained by $M \text{ Kg}$ of ice to melt at 0°C

$= M \times H_f = 336000 M$ (i)

Heat gained = Heat lost

$336000 M = 649740$ (ii)

$M = 1.93 \text{ Kg}$ Ans.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

- 11.7 In a certain process 400J of heat are supplied to a system and at the same time 150J of work are done on the system. What is the increase in the internal energy of the system?

Data: -

$$\Delta Q = 400\text{J}$$

$$\Delta W = 150\text{J}$$

$$\Delta U = ?$$

Solution: -

From the relation

$$\Delta Q = \Delta W + \Delta U$$

or

$$\Delta U = \Delta Q - \Delta W$$

$$\Delta U = 400 - 150$$

$$= 250\text{J}$$

Ans.

- 11.8 There is an increase of internal energy by 400J when the 800J of work is done by the system. What is the amount of heat supplied during this process.

Data: -

$$\Delta Q = ?$$

$$\Delta U = 400\text{J}$$

$$\Delta W = 800\text{J}$$

Solution: -

From the relation

$$\Delta Q = \Delta U + \Delta W$$

$$= 400 + 800 = 1200\text{J}$$

Ans.

- 11.9 A heat engine performs 200J of work in each cycle and its efficiency 20%. For each cycle of operation,

(a) How much heat is absorbed? (b) How much heat is expelled?

Data: -

$$\Delta W = 200\text{J}$$

$$\text{Efficiency } E = 20\% = 0.2$$

$$\Delta Q = ?$$

$$\Delta U = ?$$

Solution: -

$$\text{Efficiency} = \frac{\Delta W}{\Delta Q}$$

$$\Delta Q = \frac{\Delta W}{E} = \frac{200}{0.2} = 1000\text{J}$$

Ans.

$$\Delta Q = \Delta U + \Delta W$$

$$\Delta U = \Delta Q - \Delta W$$

$$= 1000 - 200 = 800\text{J}$$

Ans.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

- 11.10 A heat engine operates between two reservoirs at temperatures of 25°C and 300°C. What is the maximum efficiency for this engine?

Data: -

$$t_2 = 25^\circ\text{C}$$

$$t_1 = 300^\circ\text{C}$$

$$T_2 = 25 + 273 = 298^\circ\text{K}$$

$$T_1 = 300 + 273 = 573^\circ\text{K}$$

Solution: -

$$\text{Efficiency} = E = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

$$E = \left(1 - \frac{298}{573}\right) \times 100 = 48\% \quad \text{Ans.}$$

- 11.11 The low temperature reservoir of a Carnot engine is at 7°C and has the efficiency of 40%. It is desired to increase the efficiency to 50%. By how much degrees must the temperature of high temperature reservoir be increased?

Data: -

$$E_1 = 40\%$$

$$T_2 = 7^\circ\text{C}$$

$$E_2 = 50\%$$

$$T_1 = ?$$

$$T_2 = 7 + 273 = 280 \text{ K}$$

$$T_2 = 280 \text{ K} \quad T'_1 = ?$$

Solution: -

For 40% efficiency

$$(i) \quad E_1 = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

$$\frac{40}{100} = \left(1 - \frac{280}{T_1}\right)$$

$$\frac{280}{T_1} = 1 - 0.4 = 0.6$$

$$T_1 = \frac{280}{0.6} = 466.6 \text{ K}$$

For 50% efficiency

$$E_2 = \left(1 - \frac{T_2}{T'_1}\right) \times 100$$

$$\frac{50}{100} = \left(1 - \frac{280}{T'_1}\right)$$

$$\frac{280}{T'_1} = 1 - 0.5 = 0.5$$

$$T'_1 = \frac{280}{0.5} = 560 \text{ K}$$

$$\therefore \text{Increase in temperature of hot reservoir} = T'_1 - T_1 = \Delta T$$

$$\Delta T = 560 - 466.6 = 93.4^\circ\text{K}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

EXAMPLE

Example 11.1

A steel rod has a length of 10m at a temperature of 25°C. What will be the increase in length if the temperature is raised to 35°C? Given

$$\alpha = 1.1 \times 10^{-5} \text{K}^{-1}$$

Data:

$$L_0 = 10 \text{ m}$$

$$T_1 = 25^\circ \text{C}$$

$$\Delta L = ?$$

$$T_2 = 35^\circ \text{C}$$

$$\Delta T = T_2 - T_1 = 35 - 25 = 10^\circ \text{C}$$

Solution: -

$$\Delta L = L_0 \alpha \Delta T.$$

$$= (10) (1.1 \times 10^{-5} \times 10)$$

$$= 1.1 \times 10^{-3} \text{ m Ans.}$$

Example 11.2

An air-storage tank whose volume is 112 liters contains 3kg of air at a pressure of 18 atmospheres. How much air would have to be forced into the tank to increase the pressure to 21 atmospheres assuming no change in temperature.

Data: -

$$V_1 = 112 \text{ liters}$$

$$m_1 = 3 \text{ Kg}$$

$$P_1 = 18 \text{ atm}$$

$$m_2 = ?$$

$$P_2 = 21 \text{ atm.}$$

$$V_2 = V_1$$

Solution: -

$$\frac{P_1 V_1}{m_1} = \frac{P_2 V_2}{m_2}$$

$$m_2 = \frac{P_2 V_2 m_1}{P_1 V_1} = \frac{21 \times 112 \times 3}{18 \times 112} = 3.5 \text{ Kg}$$

The mass of air which must be forced into the tank = $(3.5 - 3.0) = 0.5 \text{ kg.}$ Ans.

Example 11.3

Calculate the volume occupied by a gram-mole of a gas at 0°C and a pressure of 1 atmosphere.

Data: -

$$V = ?$$

$$P = 1 \text{ atm.} = 1.01 \times 10^5 \text{ N m}^{-2}$$

$$T = 0^\circ \text{C} + 273 = 273 \text{ K}$$

$$n = 1 \text{ mole}$$

$$R = 8.314 \text{ J/mole K.}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Solution: -

$$PV = nRT$$

$$V = \frac{nRT}{P} = \frac{1 \times 8.134 \times 273}{1.01 \times 10^5} = 0.0224 \text{ m}^3/\text{mole} \quad \text{as } 1 \text{ m}^3 = 1 \times 10^3 \text{ liters}$$

$$= 22.4 \text{ liters/mole} \quad \text{Ans.}$$

Example 11.4

Calculate the v_{rms} of hydrogen molecules at 0 °C and 1.00 atm. pressure, assuming hydrogen to be an ideal gas. Under these conditions hydrogen has a density ρ of $8.99 \times 10^{-2} \text{ kg/m}^3$.

Data: -

$$V_{r.m.s.} = ?$$

$$T = 0^\circ\text{C} = 0 + 273 = 273^\circ\text{K}$$

$$p = 1.00 \text{ atm} = 1.01 \times 10^5 \text{ Nm}^{-2}$$

$$\rho = 8.99 \times 10^{-2} \text{ kg/m}^3.$$

Solution: -

$$V_{r.m.s.} = \sqrt{\frac{3P}{\rho}}$$

$$V_{r.m.s.} = \sqrt{\frac{3 \times 1.01 \times 10^5}{8.99 \times 10^{-2}}}$$

$$V_{r.m.s.} = 1835.86 \text{ ms}^{-1} \quad \text{Ans.}$$

Example 11.5

A 50 gram piece of metal is heated to 100°C and then dropped into a copper calorimeter of mass 400 gram containing 400 gram of water initially at 20°C. If the final equilibrium temperature of the system is 22.4°C, find the specific heat of the metal. Specific heat of copper is $386 \text{ J kg}^{-1}\text{K}^{-1}$

Data: -

$$M_M = \text{mass of metal} = m_M = 50\text{g} = 0.05\text{kg}$$

$$C = \text{Specific heat of the metal} = c = ?$$

$$T_M = \text{Temperature of the metal piece} = T_M = 100^\circ\text{C}$$

$$T_F = \text{Final temperature} = T_F = 22.4^\circ\text{C}$$

$$M_W = \text{Mass of water} = m_W = 400\text{g} = 0.4\text{kg}$$

$$M_c = \text{Mass of Calorimeter} = m_c = 400\text{g} = 0.4 \text{ kg}$$

$$C_W = \text{Specific Heat of water} = C_W = 4200 \text{ Jkg}^{-1}\text{K}^{-1}$$

$$C_C = \text{Specific heat of Copper} = 386 \text{ J kg}^{-1}\text{K}^{-1}$$

Solution: -

From the law of heat exchange.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Heat lost by metal = Heat gained by water + Heat gained by Calorimeter.

$$M_m \times C_m \times (T_m - T_F) = m_w \times C_w \times (T_F - T_w) + m_c \times C_c \times (T_F - T_w)$$

$$0.5 \times C_m \times (100 - 22.4) = 0.4 \times 4200 \times (22.4 - 20) + 0.4 \times 386 (22.4 - 20)$$

$$C = 1134.68 \text{ J kg}^{-1} \text{K}^{-1}$$

Example 11.6

A system absorbs 1000 Joules of heat and delivers 600 joules of work while losing 100 Joules of heat by conduction to the atmosphere. Calculate the change in the internal energy of the system.

Data: -

$$Q_1 = 1000 \text{ J}$$

$$\Delta W = 600 \text{ J}$$

$$Q_2 = 100 \text{ J}$$

$$\Delta U = ?$$

Solution

$$\Delta Q = 1000 - 100 = 900 \text{ J}$$

$$\Delta U = \Delta Q - \Delta W = 900 - 600 = 300 \text{ J Ans.}$$

Example 11.7

A thermodynamic system undergoes a process in which its internal energy decreases by 300 J. If at the same time, 120 J of work is done on the system find the heat transferred to or from the system.

Data: -

$$\Delta U = 300 \text{ J}$$

$$\Delta W = 120 \text{ J}$$

$$\Delta Q = ?$$

$$\text{Solution: - } \Delta Q = \Delta U + \Delta W$$

$$\Delta Q = 300 + 120$$

$$\Delta Q = 420 \text{ J Ans.}$$

Example 11.8

Find the efficiency of the carnot's engine working between 150°C and 50°C.

Data: -

$$T_1 = 150^\circ \text{C} = 150 + 273 = 423 \text{ K}$$

$$T_2 = 50^\circ \text{C} = 50 + 273 = 323 \text{ K}$$

$$E = ?$$

Solution: -

$$E = \left(1 - \frac{T_2}{T_1} \right) \times 100$$

$$E = \left(1 - \frac{323}{423} \right) \times 100 = 23.6\% \text{ Ans.}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

40

Heat

SOLVED NUMERICALS FROM PAPERS

Example: 1.

A meter bar of steel is correct at 0°C and another at -2.5 °C. What will be the difference between their lengths at 30°C. $\alpha = 11 \times 10^{-6} \text{ K}^{-1}$.

Data: -

1st. rod

$$L_0 = 1 \text{ m}$$

$$T_1 = 0^\circ\text{C}$$

$$T_2 = 30^\circ\text{C}$$

$$L_2 = ?$$

$$\Delta T = T_2 - T_1 = 30 - 0 = 30^\circ\text{C}$$

$$\Delta L = ?$$

2nd. rod

$$L_0 = 1 \text{ m}$$

$$T_1 = -2.5^\circ\text{C}$$

$$T_2 = 30^\circ\text{C}$$

$$L_2 = ?$$

$$\Delta T = T_2 - T_1 = 30 - (-2.5) = 32.5^\circ\text{C}$$

Solution: -

1st. rod

$$L_2 = L_1(1 + \alpha \Delta T)$$

$$= (1)(1 + 11 \times 10^{-6} \times 30)$$

$$= 1.00033 \text{ m}$$

$$\Delta L = L_2 - L_1 = 1.0003575 - 1.00033 = 2.75 \times 10^{-5} \text{ Ans.}$$

2nd. rod

$$L_2 = L_1(1 + \alpha \Delta T)$$

$$= (1)(1 + 11 \times 10^{-6} \times 32.5)$$

$$= 1.0003575 \text{ m}$$

Example: 2.

A cylinder of diameter 1.00-cm at 30°C is to be slid into a hole in a steel plate. The hole has a diameter of 0.99970 cm at 30°C. To what temperature must the plate be heated. (α for steel = $1.1 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$).

Data: -

$$L_1 = 1.00 \text{ cm}$$

$$T_2 = 30^\circ\text{C}$$

$$L_2 = 0.99970 \text{ cm}$$

$$T_1 = ?$$

Solution: -

$$\Delta L = \alpha L_1 \Delta T$$

$$L_2 - L_1 = \alpha L_1(T_2 - T_1) = \alpha L_1 T_2 - \alpha L_1 T_1$$

$$(L_2 - L_1) + \alpha L_1 T_1 = \alpha L_1 T_2$$

$$T_2 = \frac{(L_2 - L_1) + \alpha L_1 T_1}{\alpha L_1}$$

$$T_2 = \frac{(1 - 0.99970) + 1.1 \times 10^{-5} \times 0.99970 \times 30}{1.1 \times 10^{-5} \times 0.99970}$$

$$T_2 = 57.19^\circ\text{C} \quad \text{Ans.}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Example: 3.

An air-storage tank whose volume is 110 liters contains 2kg of air at a pressure of 15 atmospheres. How much air would have to be forced into the tank to increase the pressure to 18 atmospheres' assuming no change in temperature?

Data: -

$$V_1 = V_2 = 110 \text{ liters}$$

$$m_1 = 2 \text{ kg}$$

$$P_1 = 15 \text{ atm.}$$

$$m_2 = ?$$

$$P_2 = 18 \text{ atm.}$$

Solution: -

$$\frac{P_1 V_1}{m_1} = \frac{P_2 V_2}{m_2}$$

$$m_2 = \frac{P_2 V_2 m_1}{P_1 V_1} = \frac{18 \times 110 \times 2}{15 \times 110} = 2.4 \text{ kg} \quad \text{Ans.}$$

Example: 4.

Calculate the volume occupied by a gram-mole of a gas at 10 °C and pressure of one atmosphere.

Given $R = 8.313 \text{ J/mole-K}$ and one atmosphere $1.01 \times 10^5 \text{ N/m}^2$.

Data: -

$$n = 1 \text{ mole}$$

$$T = 10^\circ\text{C} = 10 + 273 = 283\text{K}$$

$$P = 1.01 \times 10^5 \text{ N/m}^2$$

$$R = 8.313 \text{ J/mole-K}$$

$$V = ?$$

Solution: -

$$PV = nRT$$

$$V = \frac{nRT}{P} = \frac{1 \times 8.314 \times 283}{1.01 \times 10^5} = 2.33 \times 10^{-2} \text{ liters.}$$

Example: 5.

Find the r.m.s. Speed of the nitrogen molecules at 27°C. Given the mass of nitrogen molecule to be $4.67 \times 10^{-26} \text{ Kg}$; $K = 1.38 \times 10^{-23} \text{ Joules/K}$

Data:

$$V_{r.m.s.} = ?$$

$$T = 27^\circ\text{C} = 27 + 273 = 300\text{K}$$

$$m = 4.67 \times 10^{-26} \text{ Kg}$$

$$K = 1.38 \times 10^{-23} \text{ Joules/K}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

42

Heat

Solution:

$$T = \frac{2}{3K} \left(\frac{1}{2} m \bar{V}^2 \right)$$

$$V_{r.m.s.} = \sqrt{\frac{3KT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 300}{4.67 \times 10^{-26}}}$$

$$V_{r.m.s.} = 515.706 \text{ m/s} \quad \text{Ans.}$$

Example: 6.

Find the root mean square of a hydrogen molecule at 7°C. Take the mass of hydrogen molecule to be 3.32×10^{-27} Kg and Boltzman's constant $= 1.38 \times 10^{-23}$ Joules/K.

Data:

$$V_{r.m.s.} = ?$$

$$T = 7^\circ\text{C} = 7 + 273 = 280\text{K}$$

$$m = 3.32 \times 10^{-27} \text{ Kg}$$

$$K = 1.38 \times 10^{-23} \text{ Joules/K}$$

Solution:

$$T = \frac{2}{3K} \left(\frac{1}{2} m \bar{V}^2 \right)$$

$$\sqrt{\bar{V}^2} = V_{r.m.s.} = \sqrt{\frac{3KT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 280}{3.32 \times 10^{-27}}}$$

$$V_{r.m.s.} = 1868.57 \text{ m/s} \quad \text{Ans.}$$

Example: 7.

Determine the average value of kinetic energy of a gas at 300K. The value of $K = 1.38 \times 10^{-23}$ Joules/K

Data: -

$$T_1 = 300 \text{ K}$$

$$\text{K.E.} = ?$$

Solution: -

$$T = \frac{2}{3K} \left(\frac{1}{2} m v^2 \right) = \frac{2}{3K} (\text{K.E.})$$

$$\text{K.E.} = \frac{3KT}{2}$$

$$\text{K.E.} = \frac{3KT_1}{2} = \frac{3 \times 1.38 \times 10^{-23} \times 300}{2} = 6.21 \times 10^{-21} \text{ J} \quad \text{Ans.}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Example: 8.

At a certain temperature the average kinetic energy of hydrogen molecule is 6.2×10^{-21} Joules. If the mass of hydrogen molecule is 3.31×10^{-27} Kg; find (i) the temperature and (ii) root mean square velocity of the hydrogen molecule. (Given $K = 1.38 \times 10^{-23}$ Joules/ K.)

Data: -

$$K.E. = 6.2 \times 10^{-21} \text{ Joules}$$

$$m = 3.31 \times 10^{-27} \text{ Kg}$$

$$T = ?$$

$$V_{rms} = ?$$

$$K = 1.38 \times 10^{-23} \text{ Joules/ K.}$$

Solution: -

$$T = \frac{2}{3K} \left(\frac{1}{2} mv^2 \right) = \frac{2}{3K} (K.E.)$$

$$T = \frac{2}{3K} (K.E.) = \frac{2}{3 \times 1.38 \times 10^{-23}} (6.2 \times 10^{-21})$$

$$T = 299.5$$

$$\begin{aligned} \sqrt{V^2} = V_{rms} &= \sqrt{\frac{3KT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 299.5}{3.32 \times 10^{-27}}} \\ &= 1932.5 \text{ m/s} \end{aligned}$$

Example: 9.

The molar specific heat of a given gas at constant volume is 12.45 J/mole K ; find its molar specific heat at constant pressure and the ratio of the two molar specific heat of the gas. ($R = 8.3 \text{ J/mole K}$)

Data: -

$$C_v = 12.45 \text{ J/mole K}$$

$$C_p = ?$$

$$\frac{C_p}{C_v} = ?$$

$$R = 8.3 \text{ J/mole K}$$

Solution:

$$C_p - C_v = R$$

$$C_p = C_v + R$$

$$C_p = 12.45 + 8.3 = 20.75 \text{ J/mole K} \quad \text{Ans}$$

$$\frac{C_p}{C_v} = \frac{20.75}{12.45} = 1.67 \quad \text{Ans.}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Example: 10.

If one mole of a monatomic gas is heated at constant pressure from -30°C to 20°C , find the change in its internal energy and the work done during the process. $C_p = 20.8 \text{ J/mole-K}$ $C_v = 12.5 \text{ J/mole-K}$

Data:

$$\begin{aligned} n &= 1 \text{ mole} \\ T_1 &= -30^{\circ}\text{C} + 273 = 243 \text{ K} \\ T_2 &= 20^{\circ}\text{C} + 273 = 293 \text{ K} \\ \text{(a)} \quad \Delta U &= ? \\ \text{(b)} \quad \Delta W &= ? \end{aligned}$$

Solution:

$$\Delta T = T_2 - T_1 = 293 - 243 = 50 \text{ K}$$

$$\text{(a)} \quad \Delta U = \Delta Q_v = n C_v \Delta T = 1 \times 12.5 \times 50 = 625 \text{ J} \quad \text{Ans.}$$

$$\text{(b)} \quad \Delta Q_p = n C_p \Delta T = 1 \times 20.8 \times 50 = 1040 \text{ J}$$

$$\text{But} \quad \Delta Q_p = \Delta U + \Delta W$$

$$\begin{aligned} \text{Or} \quad \Delta W &= \Delta Q_p - \Delta U \\ &= 1040 - 625 = 415 \text{ J} \quad \text{Ans.} \end{aligned}$$

Example: 11.

A heat engine performs 1000 joules of work and at same time rejects 5000 joules of heat energy to the cold reservoir. What is the efficiency of the heat engine?

Data:

$$\begin{aligned} \Delta W &= 1000 \text{ J} \\ \Delta U &= 5000 \text{ J} \\ E &= ? \end{aligned}$$

Solution:

$$\Delta Q = \Delta U + \Delta W$$

$$\Delta Q = 5000 + 1000 = 6000 \text{ J}$$

$$E = \frac{\text{Output}}{\text{Input}} \times 100 = \frac{\Delta W}{\Delta Q} \times 100$$

$$E = \frac{1000}{6000} \times 100 = 16.67\% \quad \text{Ans.}$$

Example: 12.

A heat engine performs 1000 joules of work and at same time rejects 4000 joules of heat energy to the cold reservoir. What is the efficiency of the heat engine? If the difference of temperature between the sink and the source of the engine is 75°C , find the temperature of its source.

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Data:

$$\Delta W = 1000 \text{ J}$$

$$\Delta U = 4000 \text{ J}$$

(a) $E = ?$

$$\Delta T = 75^\circ\text{C} + 273 = 348 \text{ K}$$

(b) $T_1 = ?$

Solution:

$$\Delta Q = \Delta U + \Delta W$$

$$\Delta Q = 4000 + 1000 = 5000 \text{ J}$$

$$E = \frac{\text{Output}}{\text{Input}} \times 100 = \frac{\Delta W}{\Delta Q} \times 100$$

$$E = \frac{1000}{5000} \times 100 = 20\% \text{ Ans.}$$

$$E = \left(1 - \frac{T_2}{T_1}\right) \times 100 = \left(1 - \frac{T_1 - 348}{T_1}\right) \times 100$$

$$20 = \left(\frac{T_1 - T_1 + 348}{T_1}\right) \times 100$$

$$20 = \frac{348}{T_1} \times 100$$

$$T_1 = \frac{348}{20} \times 100 = 1740 \text{ K} \quad \text{Ans.}$$

Example: 13.

In an Isobaric process, when 2000 J of heat energy is supplied to a gas in a cylinder, the piston moves through 0.5m under a constant pressure of $1.01 \times 10^5 \text{ N/m}^2$. If the area of the piston is $2 \times 10^{-2} \text{ m}^2$, calculate the work done and the increase in the internal energy of the system.

Data:

$$\Delta Q = 2000 \text{ J}$$

$$\Delta x = 0.5 \text{ m}$$

$$P = 1.01 \times 10^5 \text{ N/m}^2$$

$$A = 2 \times 10^{-2} \text{ m}^2$$

(a) $\Delta W = ?$

(b) $\Delta U = ?$

Solution:

$$\Delta W = P A \Delta x$$

$$= 1.01 \times 10^5 \times 2 \times 10^{-2} \times 0.5$$

$$= 1.01 \times 10^3 = 1010 \text{ J} \quad \text{Ans.}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

46

Heat

$$\begin{aligned}\Delta U &= \Delta Q - \Delta W \\ &= 2000 - 1010 = 990\text{J} \quad \text{Ans.}\end{aligned}$$

Example: 14.

1200 joules of heat energy are supplied to the system at constant pressure. The internal energy of system is increases by 750 joules and the volume by 4.5 cubic meters; find the work done against piston and the pressure on the piston.

Data:

$$\Delta Q = 1200\text{ J}$$

$$\Delta U = 750\text{ J}$$

$$\Delta V = 4.5\text{ m}^3$$

$$\Delta W = ?$$

$$P = ?$$

Solution:

$$\Delta Q = \Delta U + \Delta W$$

$$1200 = \Delta W + 750$$

$$\Delta W = 1200 - 750 = 450\text{ J} \quad \text{Ans.}$$

$$\Delta W = P \Delta V$$

$$P = \frac{\Delta W}{\Delta V} = \frac{450}{4.5} = 100\text{N/m}^2 \quad \text{Ans.}$$

Example: 15.

A heat engine performs work at the rate of 500 K.W. The efficiency of the engine is 30%; calculate the loss of heat per hour.

Data:

$$P = 500\text{ KW} = 500 \times 1000 = 5 \times 10^5\text{ W}$$

$$E = 30\%$$

$$Q_2 = ?$$

$$T = 1\text{ hour} = 3600\text{ Sec.}$$

Solution:

$$\Delta W = P \times t = 5 \times 10^5 \times 3600 = 1.8 \times 10^9\text{ J}$$

$$E = \frac{\Delta W}{Q_1} \times 100$$

$$Q_1 = \frac{\Delta W}{E} \times 100 = \frac{1.8 \times 10^9}{30} \times 100 = 6 \times 10^9\text{ J}$$

$$\begin{aligned}\text{heat lost per hour} &= Q_2 = Q_1 - \Delta W \\ &= 6 \times 10^9 - 1.8 \times 10^9 = 4.2 \times 10^9\text{ J} \quad \text{Ans.}\end{aligned}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Example: 16.

In an Isobaric process, when 2000 J of heat energy is supplied to a gas in a cylinder, the piston moves through 0.1m under a constant pressure of $2 \times 1.01 \times 10^5 \text{ N/m}^2$. If the area of the piston is $5 \times 10^{-2} \text{ m}^2$, calculate the work done and the increase in the internal energy of the system.

Data:

$$\begin{aligned}\Delta Q &= 2000 \text{ J} \\ \Delta X &= 0.1 \text{ m} \\ P &= 2 \times 1.01 \times 10^5 \text{ N/m}^2 \\ A &= 5 \times 10^{-2} \text{ m}^2 \\ \Delta W &= ? \\ \Delta U &= ?\end{aligned}$$

Solution:

$$\begin{aligned}\Delta W &= P \Delta V = P A \Delta X \\ &= 2 \times 1.01 \times 10^5 \times 5 \times 10^{-2} \times 0.1 \\ &= 505 \text{ J Ans.}\end{aligned}$$

$$\begin{aligned}\Delta Q &= \Delta U + \Delta W \\ \Delta U &= \Delta Q - \Delta W \\ &= 2000 - 505 = 1495 \text{ J Ans.}\end{aligned}$$

Example: 17.

920 J of energy is supplied to the system in a certain process. At the same time 380J of work is done by the system. Calculate the increase in the internal energy of the system.

Data:

$$\begin{aligned}\Delta Q &= 920 \text{ J} \\ \Delta W &= 380 \text{ J} \\ \Delta U &= ?\end{aligned}$$

Solution:

$$\begin{aligned}\Delta U &= \Delta Q - \Delta W \\ &= 920 - 380 = 540 \text{ J Ans.}\end{aligned}$$

Example: 18.

A heat engine performs 200 J of work in each cycle and has an efficiency of 20%; find for each cycle of operation:

(i) how much heat is absorbed. (ii) how much heat is expelled

Data:

$$\begin{aligned}\Delta W &= 200 \text{ J} \\ E &= 20\%\end{aligned}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

$$\Delta Q = ?$$

$$\Delta U = ?$$

Solution:

$$E = \frac{\text{Output}}{\text{Input}} \times 100 = \frac{\Delta W}{\Delta Q} \times 100$$

$$\Delta Q = \frac{\Delta W}{E} \times 100 = \frac{200}{20} \times 100 = 1000 \text{ J} \quad \text{Ans.}$$

$$\Delta U = \Delta Q - \Delta W$$

$$= 1000 - 200 = 800 \text{ J} \quad \text{Ans.}$$

Example: 19.

Find the efficiency of a Carnot engine working between 100 °C and 50 °C

Data:

$$T_1 = 100^\circ\text{C} + 273 = 373 \text{ K}$$

$$T_2 = 50^\circ\text{C} + 273 = 323 \text{ K}$$

$$E = ?$$

Solution:

$$E = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

$$E = \left(1 - \frac{323}{373}\right) \times 100 = 13.4\% \quad \text{Ans.}$$

Example: 20.

A Carnot engine whose low temperature reservoir is 200 K has an efficiency of 50%. If is desired to increases this to 75%. By how many degrees must the temperature be decreased, if higher temperature of the reservoir remains constant

Data:

$$T_2 = 200 \text{ K}$$

$$E_1 = 50\%$$

$$E_2 = 75\%$$

$$\Delta T = ?$$

Solution:

If temperature of hot reservoir is T_1 then

For 50% efficiency

$$E_1 = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

$$50 = \left(1 - \frac{200}{T_1}\right) \times 100$$

$$\frac{50}{100} = \left(1 - \frac{200}{T_1}\right)$$

$$\frac{200}{T_1} = 1 - \frac{50}{100} = \left(1 - \frac{1}{2}\right) = \frac{1}{2}$$

$$T_1 = 400 \text{ K}$$

For 75% efficiency

$$E_1 = \left(1 - \frac{T_2'}{T_1}\right) \times 100$$

$$75 = \left(1 - \frac{T_2'}{400}\right) \times 100$$

$$\frac{75}{100} = 1 - \frac{T_2'}{400}$$

$$\frac{T_2'}{400} = 1 - \frac{75}{100} = \left(1 - \frac{3}{4}\right) = \frac{1}{4}$$

$$T_2' = 100 \text{ K}$$

$$\Delta T = T_2 - T_2' = 200 - 100 = 100 \text{ K} \quad \text{Ans.}$$

Example: 21.

An ideal heat engine operates in Carnot's cycle between temperature 227°C and 127°C and it absorbs 600 joules of heat energy; find the

- (i) Work done per cycle
- (ii) efficiency of the engine

Data:

$$T_1 = 227^\circ\text{C} + 273 = 500 \text{ K}$$

$$T_2 = 127^\circ\text{C} + 273 = 400 \text{ K}$$

$$\Delta Q = 600 \text{ J}$$

$$\Delta W = ?$$

$$E = ?$$

Solution:

$$E = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

$$E = \left(1 - \frac{400}{500}\right) \times 100 = 20\% \quad \text{Ans.}$$

PHYSICS NOTES FOR 2ND YEAR (FOR SINDH)

Chapter 11

50

Heat

$$E = \frac{\Delta W}{Q_1} \times 100$$

$$\Delta W = \frac{E \times Q_1}{100} = \frac{20 \times 600}{100} = 120 \text{ J} \quad \text{Ans.}$$

Example: 22.

1200 joules of heat energy are supplied to the system at constant pressure. The internal energy of the system is increased by 750 joules and the volume by 4.5 m³. Find the work done against the piston and the pressure on the piston.

Data:

$$\Delta Q = 1200 \text{ J}$$

$$\Delta U = 750 \text{ J}$$

$$\Delta V = 4.5 \text{ m}^3$$

$$\Delta W = ?$$

$$P = ?$$

Solution:

$$\begin{aligned} \Delta W &= \Delta Q - \Delta U \\ &= 1200 - 750 = 450 \text{ J} \quad \text{Ans.} \end{aligned}$$

$$\Delta W = P \Delta V$$

$$P = \frac{\Delta W}{\Delta V} = \frac{450}{4.5} = 100 \text{ N/m}^2 \quad \text{Ans.}$$

Example: 23.

540 calories of heat is required to vaporize 1 gm of water at 100 °C. Determine the entropy change involved in vaporizing 5 gm of water. (one calorie = 4.2J)

Data:

$$H_v = 540 \text{ calories} = 540 \times 4.2 = 2268 \text{ J}$$

$$m_1 = 1 \text{ gm} = 0.001 \text{ kg}$$

$$T = 100^\circ\text{C} + 273 = 373 \text{ K}$$

$$m_2 = 5 \text{ gm} = 0.005 \text{ kg}$$

$$\eta = ?$$

Solution:

$$\begin{aligned} \text{Heat required for 5gm of water} &= \Delta Q = H_v \times m \\ &= 2268 \times 0.005 = 11.34 \text{ J} \end{aligned}$$

$$\Delta S = \frac{\Delta Q}{T}$$

$$\Delta S = \frac{11.34}{373} = 0.03 \text{ JK}^{-1} \quad \text{Ans.}$$

