

Chapter	6 Heat and Thermodynamics	Class	1 st Year	Subject	Physics
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Give Short Answers of the Following Questions

1. Write down the main postulates of kinetic theory of gases.

Ans. • A finite volume of gas consists of very large number of molecules.

- The size of the molecules is much smaller than the separation between molecules.
- The gas molecules are in random motion and may change their direction of motion after every collision.
- Collisions between gas molecules themselves and with walls of container are assumed to be perfectly elastic.

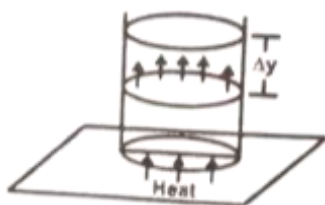
2. Prove that $W = P\Delta V$.

Ans. Let θ heat is added into the system at constant pressure, so the piston will move upward through distance Δy . So

$$W = F \Delta y$$

$$W = PA \Delta y \quad \because P \frac{F}{A} \Rightarrow F = PA$$

$$W = P\Delta V \quad \because \Delta V = A\Delta y$$



3. What would be the heat lost if internal energy decreases by 10 J and 20 J of work is done on the system simultaneously?

Ans. According to first law of thermodynamics,

$$Q = \Delta U + W$$

$$Q = -10 + (-20)$$

$$Q = -30 \text{ J}$$

So the heat lost is of 30 J.

4. What are reversible and irreversible processes?

Ans. A process in which succession of events brings the system back to its initial condition (i.e. which all the changes can be reversed), is called reversible process.

Although no actual change is completely reversible but the processes of liquefaction and evaporation of a substance, performed slowly are practically reversible.

The process which cannot be retraced in backward direction by reversing the controlling factors is called irreversible process.

An example of highly reversible process is an explosion.

5. State Carnot's theorem.

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Ans. Statement:

No heat engine can be more efficient than a Carnot engine operating between the same two temperatures.

Extended Statement:

All Carnot's engines operating between the same two temperatures have the same efficiency, irrespective of the nature of working substance.

Note:

All real heat engines are less efficient than Carnot engine due to friction & heat losses.

6. How can we increase the internal energy? Explain.

Ans. 1. By Heating:

When we heat a substance, energy associated with its atoms or molecules is increased. i.e., heat is converted to internal energy.

2. By doing mechanical work:

When two objects are rubbed together, their internal energy increases because of mechanical work. The increase in temperature of the object indicates an increase in the internal energy.

7. What is the similarity between internal energy and gravitational P.E.?

Ans. The change in internal energy and change in gravitational potential energy, both are independent of path followed.

8. What are Isothermal and Adiabatic Processes?

Ans. Isothermal Process:

- The process in which temperature of the system remains constant is called isothermal process. So it must obey the Boyle's law (i.e. $PV = \text{Constant}$).

Adiabatic Process:

- The process in which no heat enter or leave the system is called adiabatic process. In such cases.

$$PV^\gamma = \text{constant} \quad \text{where } \gamma = \frac{C_p}{C_v}$$

- This is the ratio of molar specific heat of gas at constant pressure to the molar specific heat of the gas at constant volume.

9. Give two examples of adiabatic processes.

Ans. The examples of adiabatic process are:

- Rapid escape of air from burst tyre.
- Cloud formation in atmosphere.
- Propagation of sound through air.

10. If $PV^r = \text{constant}$; prove that $TV^{r-1} = \text{constant}$.

Ans. We know that for an adiabatic process

$$PV^\gamma = \text{constant} \quad \dots(1)$$

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For an ideal gas, $\frac{PV}{T} = \text{constant} = C$

Or $p = \frac{CT}{V} \quad \dots(2)$

Using equation (2) in (1),

$$\frac{CT}{V} V^\gamma = \text{constant}$$

i.e. $TV^{\gamma-1} = \text{constant}$

11. A heat engine works between 327°C and 27°C. Find its efficiency.

Ans. $T_1 = 327^\circ\text{C} = 600 \text{ K}$ $T_2 = 27^\circ\text{C} = 300 \text{ K}$

So
$$\eta = 1 - \frac{T_2}{T_1}$$

$$= 1 - \frac{300}{600} = 1 - \frac{1}{2} = \frac{1}{2} = 0.5 \text{ (50\%)}$$

12. A system absorbs 200 J heat at an absolute temperature 200K. Calculate the change in entropy.

Ans. $\Delta Q = 200\text{J}, \quad T = 200\text{K}$

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

$$\Delta S = \frac{200}{200}$$

$$\Delta S = 1 \text{ JK}^{-1}$$

13. An engine absorbs heat of 10 J and rejects 5 J heat, what is the heat being used by the engine?

Ans. $Q = 10\text{J}, Q_2 = 5\text{J}$

$$W = ?$$

As $W = Q_1 - Q_2$

$$W = 10 - 5$$

$$W = 5\text{J}$$

14. What is meant by thermal equilibrium? Explain briefly.

Ans. Thermal Equilibrium:

When two bodies are at the same temperature means the kinetic energy of particles of each body is equal, so there is no driving force for heat transfer between them. Then system is said to be in thermal equilibrium.

Example:

- When we put a metal spoon into a hot cup of coffee.
- Initially, the coffee is hotter than the spoon.
- Over time, heat flows from the coffee to the spoon.
- Finally, the coffee and spoon reach the same temperature (thermal equilibrium).

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15. What is meant by internal energy? How is it related to temperature of an ideal gas?

Ans. The sum of all the forms of molecular energies (such as kinetic and potential energy) of a substance called internal energy.

The internal energy of an ideal gas system is generally the translational K.E. of its molecules. Since the temperature of a system is defined as the average K.E. of its molecules, thus for an ideal gas system, the internal energy is directly proportional to its temperature.

According to the kinetic theory of gases, the average kinetic energy of gas molecules is given by

$$\left\langle \frac{1}{2} m v^2 \right\rangle = \frac{3}{2} k_B T$$

where k_B is Boltzmann constant.

Therefore, the rise in temperature of an object represents an increase in the internal kinetic energy of its particles.

16. State 2nd law of thermodynamics in two different forms.

Ans. Kelvin-Planck Statement:

It is impossible to make a heat engine which converts all the heat absorbed from a hot reservoir into work without rejecting any heat to sink.

Clausius Statement:

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

17. Is it possible to construct a heat engine of 100% efficiency? Explain.

Ans. No, it is not possible.

Reason:

In order to devise a perfect heat engine (i.e. 100% efficient), the whole energy transfer from source must convert into work.

If it is possible, then it will be violation of second law of thermodynamics, which states that it is not possible to construct a heat engine that will not expel heat into atmosphere without leaving any change on the working substance.

18. Differentiate between reversible and irreversible processes.

Ans. Reversible Process:

A reversible process is one which can be retraced in exactly reverse order, without producing any change in the surroundings.

Examples:

- The transformation between water in liquid state and ice.
- Liquefactions and evaporation of a substance performed slowly.
- Melting, freezing, boiling, condensing and dissolving are the reversible process.

Irreversible Process:

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An irreversible process is one which cannot be retraced in exactly reverse order, without producing any change in the surroundings.

Examples:

- Explosion is an example of highly irreversible process.
- Process involves friction or dissipation of energy is irreversible.

19. Why adiabat is steeper than isotherm? Explain.

Ans. During an adiabatic process, there is no heat transfer between the system and its surroundings. As a result, the temperature of the system changes more rapidly with changes in pressure or volume.

Mathematically:

For adiabatic process: $PV^\gamma = \text{constant}$ ($\gamma > 1$)

Whereas, an isothermal process occurs at a constant temperature, which means that any heat added to or removed from the system is balanced by an equal amount of heat transfer between the system and its surroundings.

For isothermal process: $PV = \text{constant}$

Since $\gamma > 1$ for an adiabatic process, the curve is steeper than the isothermal curve, which has a slope of 1.

Physical reason:

During an adiabatic compression, the temperature of the gas increases because the gas is doing work on itself (no heat transfer). As a result, the pressure increases more rapidly with a decrease in volume.

In contrast, during an isothermal compression, the temperature remains constant, and the heat produced during compression is transferred to the surroundings. This means that the pressure increases less rapidly with a decrease in volume.

20. A refrigerator transforms heat from cold to hot body. Does this violate the second law of thermodynamics? Justify your answer.

Ans. No, this does not violate the Second Law of Thermodynamics.

Reason:

- The Second Law states that heat cannot spontaneously flow from a colder body to a hotter body.
- However, the refrigerator does not spontaneously transfer heat from the cold body to the hot body.
- This process is consistent with the Second Law, as the total entropy (disorder) of the system and its surroundings still increases. The refrigerator decreases the entropy of the cold body, but increases the entropy of the surroundings by releasing heat to the hot body.

21. Explain briefly heat death of universe in terms of entropy.

Ans. Heat Death:

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The "heat-death" of the universe is when the universe has reached a state of maximum entropy. This happens when all available energy (such as from a hot source) has transferred to places of less energy (such as a colder source). Once this has happened, no more work can be obtained from the universe. Since no more work can be extracted from the universe at that point, it is effectively dead, especially for the purposes of humankind.

22. Is it possible for a cyclic reversible heat engine to absorb heat at constant temperature and transforms it completely into work without rejecting some heat at low temperature? Explain.

Ans. No, it is not possible for a cyclic reversible heat engine.

Reasoning:

According to the Second Law of Thermodynamics, it is impossible for a heat engine to convert all the heat energy put into it into useful work.

A reversible heat engine operating in a cycle can convert all the heat energy absorbed at a high temperature into work only if it rejects an equal amount of heat at a lower temperature. If the engine were to transform all the heat energy into work without rejecting any heat, it would violate the Second Law of Thermodynamics.

23. How does behaviour of real gases differ from ideal gas at high pressure and low temperature? Identify the reasons behind these differences based on kinetic theory of gases.

Ans. Intermolecular Forces:

Real gases have intermolecular forces (e.g., van der Waals forces) that become important at high pressure and low temperature, leading to deviations from ideal gas behavior.

Molecular Size:

Real gas molecules occupy space, whereas ideal gas molecules are assumed to be point particles. At high pressure, the molecules are forced closer together, and their size becomes significant, leading to deviations from ideal gas behavior.

Inelastic Collisions:

At low temperature, the gas molecules have lower kinetic energy, and their collisions become less elastic. This leads to a loss of kinetic energy and a deviation from ideal gas behavior.

24. Show that area under P-V graph is equal to work done.

Ans. Pressure-Volume Work:

If a gas that is contained in a cylinder with a movable, frictionless piston with a cross-sectional area of "A." When the system is in equilibrium, it occupies volume "V" and applies pressure "p" on the cylinder's walls and the piston. As pressure is defined, force per unit area.

The gas steadily expands through ΔV in order to maintain equilibrium. A little distance = $d = \Delta y$ is covered by the piston as it rises. The work done by the gas is

$$W = F\Delta y$$

$$W = P\Delta y \text{ (Since } F = PA \text{)}$$

$$W = P\Delta V \text{ (since } \Delta V = A \Delta y \text{)}$$

This is the work done by gas on piston. We can express work in terms of directly measurable quantities.

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The plot between P and V is a horizontal straight line parallel to volume axis.

Area under graph = area of rectangle

Area under graph = (length)(breadth)

Area under graph = $P\Delta V = W$

So, Work done can be calculated from the area under P-V graph.

25. How is work done (i) by a gas (ii) on a gas? Calculate.

Ans. Work done by / on a gas is calculated by using the formula $W = P(\Delta V)$ or by calculating the area under PV- diagram

Where W = work done, P = pressure of the gas, ΔV = change in volume of the gas

Work done by / on a gas is calculated by finding the area under PV-diagram

However, the sign convention is opposite:

If the volume decreases ($\Delta V < 0$), work is done on the gas is negative (i.e $W < 0$)

If the volume increases ($\Delta V > 0$), work is done by the gas is positive (i.e $W > 0$)