

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

1. 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).

2. 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.

3. 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.

4. 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

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leaving any change on the working substance.

5. 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:

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.

6. 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.

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7. 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.

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

Ans. Heat Death:

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.

9. 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.

10. 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.

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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.

11. 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

$$W = F\Delta Y$$

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

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

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

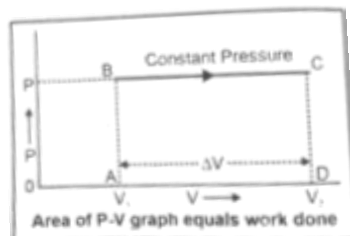
The plot between P and V is a horizontal straight line parallel to volume axis.

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.



12. 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 $W > 0$)