PHYSICS – CLASS 10

CHAPTER 10

THERMAL PHYSICS

Key Concepts

Thermal expansion

Specific heat capacity

Evaporation

Latent heat

Superconductivity

Detailed Questions & Answers

Q.1 Define and explain thermal expansion. Illustrate linear thermal expansion quantitatively.

Answer:

Thermal Expansion

Definition: "Thermal expansion is the change in length, area, or volume of a substance when it is heated."

1. Cause of Expansion and Contraction

- As temperature rises, particles gain more kinetic energy, move faster, and spread out — causing expansion.
- When a substance is cooled, its particles lose energy and move closer together, causing contraction.

2. Thermal Expansion in Solids

When solids are heated, they expand, and this expansion remains almost consistent over a broad temperature range. A change in temperature may cause a respective change in length or volume of the solid.

3. Linear Thermal Expansion

Definition: "If the length of a solid changes upon heating, it is called linear thermal expansion."

Derivation of Expression

Consider a metal rod with initial length L_0 at temperature T_0. When heated to temperature T, its new length becomes L. Thus:

$$\Delta L = L - L_0 \qquad \text{and} \qquad \Delta T = T - T_0$$

It is observed that the change in length ΔL of a solid is directly proportional to its original length L_0 and the temperature change ΔT. Thus:

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

$$\Delta L = \alpha\, L_0\, \Delta T \quad \Rightarrow \quad \alpha = \Delta L / (L_0\, \Delta T)$$

$$L - L_0 = \alpha\, L_0\, \Delta T$$

$$L = L_0\, (1 + \alpha\Delta T) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10.1)$$

- Here α is called the coefficient of linear thermal expansion of the material.
- The value of α of different solid materials is different.

Q.2 Define and explain volume thermal expansion of a solid.

Answer:

Volume Thermal Expansion

Definition: "The volume of a solid increases when its temperature rises. This is known as volume thermal expansion."

Derivation of Expression

Suppose a solid has an initial volume V_0 at temperature T_0. When heated to temperature T, its new volume becomes V:

$$\Delta V = V - V_0 \qquad \text{and} \qquad \Delta T = T - T_0$$

The increase in volume ΔV is directly proportional to its original volume V_0 and the temperature change ΔT, thus:

$$\Delta V \propto V_0\, \Delta T \quad \Rightarrow \quad \Delta V = \beta\, V_0\, \Delta T$$

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

$$V = V_0 (1 + \beta \Delta T) \quad \text{.....................} \quad (10.2)$$

- Here β is called the coefficient of volume expansion, which determines how much a material expands with temperature.
- Different solids have different values of β — some expand more than others when heated.

$$\beta = \Delta V / (V_0 \Delta T)$$

In solids, atoms are arranged in a tight, regular pattern. As temperature rises, each atom pushes slightly harder against its neighbours due to increased vibration. Since there is no room to move inwards, the structure expands outward instead.

Table 10.1 — Coefficient of Linear Expansion (α) of Common Solids

Substance	α (K^{-1})
Aluminium	2.4×10^{-5}
Brass	1.9×10^{-5}
Copper	1.7×10^{-5}
Steel	1.2×10^{-5}
Silver	1.93×10^{-5}
Gold	1.3×10^{-5}
Platinum	8.6×10^{-6}
Tungsten	0.4×10^{-5}
Glass (pyrex)	0.4×10^{-5}
Glass (ordinary)	0.9×10^{-5}
Concrete	1.2×10^{-5}

Q.3 Explain thermal expansion in liquids.

Answer:

Definition: "When a liquid is heated, its volume increases; this is called thermal expansion in liquid. Heat energy makes liquid molecules move faster, causing them to spread apart and take up more space."

Explanation

- Unlike solids, which have a fixed shape and expand in a limited way, liquids do not have a definite shape, so they expand freely in all directions when heated.
- The degree of expansion depends on the specific coefficient of volumetric expansion, unique to each substance:

$$\Delta V = \beta V_0 \Delta T \quad \text{.....................} \quad (10.3)$$

Explanation with Example

- In a heated flask, the glass expands, causing a decrease in liquid level from A to B — known as apparent expansion of the flask (AB).
- As the liquid heats further, the level rises from B to C — known as the real expansion (BC). AC is the apparent expansion.
- Real expansion is always greater than apparent expansion: BC = AC + AB

Tidbit: Liquids do not have a fixed shape, so they expand more freely than solids. That is why we should not fill a bottle of water to the top before freezing it — it might crack.

Q.4 Explain thermal expansion in gases in detail.

Answer:

Definition: "When the temperature of a gas increases, its volume increases as long as the pressure remains the same. This is called thermal expansion of the gas."

1. Explanation

- As gas temperature increases, the kinetic energy of its particles increases, causing molecules to move faster and collide more frequently and forcefully with the container walls.
- These collisions exert pressure on the container walls.

2. Behaviour in Flexible and Non-flexible Containers

- In a non-flexible container, increased collisions raise the pressure.
- In a flexible container, the volume expands instead, keeping pressure constant — consistent with Charles' Law (volume ∝ temperature at constant pressure).

3. Importance

- Hot air balloons: heated air expands and becomes lighter than the cooler air outside, making the balloon rise.
- Car engines: burning fuel produces hot gases that expand quickly, pushing pistons and moving the vehicle.
- Weather patterns: warm air expands and rises, affecting air pressure, winds and weather changes.

4. Dangers of Uncontrolled Expansion

Aerosol cans and gas cylinders can explode if exposed to high temperatures because the gas inside expands beyond what the container can withstand.

Q.5 Discuss practical applications and consequences of thermal expansion in everyday life.

Answer:

When materials expand or contract due to temperature changes, it can lead to structural, mechanical, and functional consequences.

1. Applications

- Thermometers: Thermal expansion in a narrow tube helps measure temperature.
- Hot Air Balloon: Heating the air inside causes it to expand, reducing its density so it lifts the balloon.

2. Consequences

- Gaps in Railway Tracks: Steel tracks expand on hot days. Without room to expand, tracks may bend/twist ("sun kinks"), causing derailments. Small gaps prevent this.
- Bridges: Have expansion joints that allow them to expand in hot weather and contract in cold weather without breaking.
- Metal Lids on Jars: Running warm water over a stuck metal lid makes it expand slightly, making it easier to open.
- Gas Containers: Gases expand significantly when heated; heat exposure can build pressure and cause explosions, hence warning labels and pressure relief valves.
- Pipes and Plumbing: Water pipes expand/contract, especially with hot water, which may cause bursts or leaks; flexible joints and loops absorb this movement.

Brain Teaser — *Why do train tracks not buckle in winter but do in summer, even though the metal is the same?* In summer, rising temperature causes tracks to expand significantly; without room to expand, they buckle/twist. In winter, low temperatures cause contraction, so there is no risk of buckling.

Q.6 Define and explain specific heat of solids.

Answer:

Specific Heat of a Substance

Definition: "Specific heat capacity (c) is the amount of heat energy needed to increase the temperature of 1 kg of a substance by 1 °C (or 1 K)."

SI Unit: $J\ kg^{-1}\ K^{-1}$

$$Q = m\,c\,\Delta T \quad \text{.....................} \ (10.4)$$

Where Q = heat energy, m = mass of substance, ΔT = change in temperature, c = specific heat capacity.

Explanation

The energy required to heat a material depends on three factors: (a) mass of the substance, (b) change of temperature, (c) nature of the material. Some substances absorb heat more easily than others — e.g., heating 1 kg of water by 1 °C requires more energy than heating 1 kg of alcohol by the same amount.

Specific Heat Capacity of Solids

- The specific heat capacity of solids is the heat energy needed to raise the temperature of 1 kg of a solid by 1 °C.
- Materials with high specific heat capacity (e.g., wood, rubber) require more heat to increase temperature, making them useful for cooking utensils and thermal insulation.
- Metals like steel and copper have low specific heat capacities — they heat up and cool down quickly, so are used in kettles, radiators, and heat engines.

Q.7 Define and explain specific heat of liquids. Discuss everyday effect due to large specific heat of water.

Answer:

Specific Heat of Liquids

Definition: "The specific heat capacity of a liquid is the amount of heat energy needed to raise the temperature of 1 kg of the liquid by 1°C or 1 K."

1. Explanation

- Water has a high specific heat capacity of 4200 J kg^{-1} K^{-1}, allowing it to absorb and store large amounts of heat with only a small temperature increase — used in cooling/heating systems and as a natural temperature stabilizer.
- Other liquids such as alcohol and mercury have lower specific heat capacities and heat up/cool down more quickly than water.

2. Effects of Large Specific Heat Capacity of Water

- Large water bodies absorb heat during the day and release it slowly at night, preventing drastic temperature changes and giving coastal areas milder climates.
- Water's specific heat capacity (4200 J kg^{-1} K^{-1}) is about five times that of dry soil (810 J kg^{-1} K^{-1}), so soil heats/cools five times faster than the same mass of water.
- This makes water useful for storing and transferring heat, e.g., in automobile engine cooling systems: water absorbs engine heat via jackets around cylinders, flows through a thermostat to the radiator where a fan cools it, and the cooled water returns to the engine — repeating the cycle. A pressure release cap keeps the system safe.

Q.8 Define the following terms involved in change of state of a substance: Melting, Boiling, Condensation, Solidification.

Answer:

1. Melting —

"Converting from a solid to liquid is called melting." When a substance absorbs energy, atoms/molecules move more rapidly and need more space, turning solid to liquid.

2. Boiling —

Converting the liquid to gas is known as boiling.

3. Condensation —

"Converting from a gas to liquid is called condensation." Atoms and molecules slow down by losing energy, leading to less separation between them.

4. Solidification —

Converting a liquid to solid is known as solidification.

Role of Intermolecular Force and Order of Thermal Expansion

- Intermolecular forces are strongest in solids (least separation) and weakest in gases (molecules far apart compared to liquids and solids).
- This is why gases exhibit the greatest relative thermal expansion, while solids have the least.

Q.9 Define and explain evaporation. Discuss different factors affecting evaporation.

Answer:

Evaporation

Definition: "Evaporation is a natural process by which a liquid changes into a gas at its surface without boiling."

1. Explanation

- It occurs at all temperatures but is faster at higher temperatures. It occurs at the liquid surface, where some particles have enough energy to escape into the air as vapour.
- Evaporation does not require the entire liquid to be heated — it can occur at room temperature.
- It plays a key role in daily life: drying wet clothes and cooling our bodies through sweating.

2. Factors Affecting Evaporation

- Temperature: The higher the temperature, the faster evaporation occurs (e.g., water evaporates faster on a hot summer day than a cold winter day).
- Surface Area: A larger surface area speeds up evaporation (e.g., a wide shallow dish evaporates quicker than a tall narrow container).
- Air Movement (Wind Speed): Wind carries away vapour molecules, preventing saturation and speeding evaporation (e.g., clothes dry faster on a windy day).
- Humidity: In humid air, evaporation slows down; in dry air it occurs more rapidly (e.g., clothes take longer to dry in humid weather).
- Nature of the Liquid: Different liquids evaporate at different rates — alcohol evaporates faster than water because its molecules need less energy to escape.
- Pressure: Lower atmospheric pressure enhances evaporation, e.g., water evaporates faster at the top of a mountain than at sea level.

Q.10 Discuss how cooling is produced by evaporation? Describe the use of cooling caused by evaporation in refrigeration to avoid harmful CFCs. Differentiate between evaporation and boiling.

Answer:

Cooling Caused by Evaporation

- During evaporation, molecules that evaporate take away heat from the remaining liquid — the higher-energy molecules leave, leaving behind cooler molecules.
- Example: when we sweat, the evaporating sweat takes heat away from our body, making us feel cooler.
- Similarly, wet clothes dry faster on a hot day because water evaporates quickly, cooling the clothes.

Brain Teaser — *If evaporation produces cooling, why does boiling water not feel cold?* Boiling requires a continuous supply of external heat; the liquid must reach its boiling point (100 °C) and absorbs a large amount of thermal energy, so it feels hot despite the phase change.

1. Refrigeration without Chlorofluorocarbons (CFCs)

- Modern refrigeration systems use the cooling effect of evaporation instead of relying on harmful CFCs.
- Environmentally friendly refrigerants evaporate at low temperatures inside the cooling coils.
- As the refrigerant evaporates, it absorbs a large amount of heat from the surrounding area (e.g., inside a refrigerator), causing the temperature to drop.
- This absorbed heat is carried away as the vapour is compressed and condensed back into a liquid outside the cooling compartment.
- This cycle of evaporation and condensation enables continuous cooling while avoiding the environmental damage once caused by ozone-depleting CFCs.

2. Difference Between Evaporation and Boiling

Property	Evaporation	Boiling
Occurs	At the surface of liquid	Throughout the liquid
Temperature	At any temperature	Only at boiling point of liquid
Energy source	Uses surrounding energy	Uses continuous external heat source
Rate / speed	Generally slower; depends on many factors	Fast process (after reaching boiling point)
Completion time	Takes longer to complete	Quicker process than evaporation
Effect of pressure	Less affected by external pressure	Highly affected by external pressure
Bubble formation	No bubble formation	Bubbles form throughout liquid, rise from surface
Dependence on surface area	Depends on surface area	Does not depend on surface area
Effect on surrounding temp.	Causes cooling in surrounding	Increases temperature of surrounding

Q.11 What is latent heat? Define latent heat of fusion and latent heat of vaporization. How can these be determined experimentally by sketching a temperature–time graph on heating?

Answer:

Latent Heat

Definition: "Latent heat is the heat energy required to change the state of a substance without changing its temperature." This heat is used to break or form bonds between particles instead of increasing their movement.

1. Latent Heat of Fusion

Definition: "The heat energy required to convert 1 kg of a solid into a liquid at its melting point while keeping the temperature constant."

- When a solid melts into a liquid, it absorbs heat without a rise in temperature. This heat breaks the strong bonds between solid particles, allowing them to move more freely as a liquid.
- Temperature remains constant until the entire solid has melted.

$$Q = m L_f \quad .... (10.5)$$

Example: The latent heat of fusion of ice is 3.36×10^5 J kg^{-1}, meaning 3.36×10^5 J of heat is needed to melt 1 kg of ice into water at 0 °C.

Experiment 1 — Determining Latent Heat of Fusion

- Place small ice pieces in a beaker over a stand and suspend a thermometer to measure temperature.
- Heat the beaker; the ice melts, keeping the mixture at 0 °C until all ice melts. Note the time for complete melting.
- Further heating raises the water temperature from 0 °C to 100 °C. Record the time for this increase.
- Plot a temperature–time graph and calculate the latent heat of fusion using: $L_f = Q / m$, where $Q = c\, m\, \Delta T = m_u c_u (T_1 - T_2)$.

2. Latent Heat of Vaporization

Definition: "The heat energy needed to change 1 kg of a liquid into gas at its boiling point without changing the temperature."

- When a liquid changes into gas, it absorbs heat, but temperature remains constant until the entire liquid has evaporated.
- This heat breaks bonds between liquid molecules, allowing them to escape as gas.

$$Q = m L_v \quad .... (10.6)$$

The latent heat of vaporization of water is 2.26×10^6 J kg^{-1} — meaning 2.26×10^6 J of heat is needed to convert 1 kg of water into steam at 100 °C.

Experiment 2 — Determining Latent Heat of Vaporization

- Take boiling water in a beaker and continue heating until all the water changes into steam, noting the temperature.
- Note the time the water takes to completely change into steam at its boiling point (100 °C).
- Extend the temperature–time graph and calculate $L_v = Q / m$, where $Q = mcc_u \Delta T$ and $\Delta T = T_2 - T_1$.

Table 10.2 — Melting/Boiling Points and Latent Heats of Common Substances

Substance	Melting Pt (°C)	Boiling Pt (°C)	Heat of Fusion (J g^{-1})	Heat of Vaporization (J g^{-1})
Aluminium	660	2250	39.7	10500

Substance	Melting Pt (°C)	Boiling Pt (°C)	Heat of Fusion (J g^{-1})	Heat of Vaporization (J g^{-1})
Copper	1083	2595	205.0	4810
Gold	1063	2660	64.0	1580
Helium	−270	−269	5.5	21
Lead	327	1750	23.0	858
Mercury	−39	357	11.7	270
Nitrogen	−210	−196	25.5	200
Oxygen	−219	−183	13.8	210
Water	0	100	336.0	2260

Q.12 Define and explain superconductivity. Explain its working and applications.

Answer:

Superconductivity

- Superconductivity is a special property of some materials where they have zero electrical resistance when cooled below a certain temperature, called the critical temperature.
- In this state, electricity flows without any energy loss, making superconductors very efficient.

1. Explanation

Since there are no collisions, electric current flows without facing any resistance as superconductors have zero electrical resistance. The resistivity of a superconductor drops to zero below the critical temperature (Tc), whereas a normal metal shows a gradual decrease in resistivity.

2. Materials That Show Superconductivity

- Mercury — becomes superconducting below 4.2 K.
- Lead — becomes superconducting below 7.2 K.
- High-temperature superconductors (ceramics) work at higher temperatures, such as 135 K.

3. Uses of Superconductors

- MRI Machines: to generate strong magnetic fields for medical imaging.
- Maglev Trains: use superconductors to float the train above tracks, reducing friction.
- Particle Accelerators: help scientists study fundamental particles.

Brain Teaser — *Why do superconductors need extreme cold temperature to work?* They exhibit zero electrical resistance only below their critical temperature. Above this point, the material loses its superconducting ability and behaves like a normal metal with resistance.

Formula Sheet

Sr.#	Formula	Description
1	$L = L_0(1 + \alpha\Delta T)$	Final length after heating
2	$\Delta L = \alpha L_0\Delta T$	Change in length
3	$\alpha = \Delta L / (L_0\Delta T)$	Coefficient of linear thermal expansion
4	$V = V_0(1 + \beta\Delta T)$	Final volume after heating
5	$\Delta V = \beta V_0\Delta T$	Change in volume
6	$\beta = \Delta V / (V_0\Delta T)$	Coefficient of volume thermal expansion
7	Real = Apparent + Vessel expansion	Real expansion of liquid
8	$Q = mc\Delta T$	Quantity of heat (specific heat)
9	$Q = mH_f$	Quantity of heat (latent heat of fusion)
10	$Q = mH_v$	Quantity of heat (latent heat of vaporization)

Solved Examples

Example 10.1:

A metal rod of length 1.5 m expands by 0.025 m when heated from 30 °C to 180 °C. Calculate its coefficient of linear expansion.

Given: $L_0 = 1.5$ m, $\Delta L = 0.025$ m, $\Delta T = 180 - 30 = 150$ °C (150 K)

$$\alpha = \Delta L / (L_0\Delta T) = 0.025 / (1.5 \times 150) = 0.025 / 225 = 1.11 \times 10^{-4}\ K^{-1}$$

Result: The coefficient of linear expansion of the metal rod is 1.11×10^{-4} K^{-1}.

Example 10.2:

How much heat is required to melt 600 g of ice at 0 °C into water at 0 °C? (Latent heat of fusion of ice = 336 J g^{-1} = 3.36×10^5 J kg^{-1})

Given: m = 600 g = 0.600 kg, $Lf = 3.36 \times 10^5$ J kg^{-1}

$$Q = m \times Lf = 0.600 \times 3.36 \times 10^5 = 201{,}600\ J = 201.6\ kJ$$

Result: The heat required to melt the ice is 201.6 kJ.

Multiple Choice Questions Exercise

1. When the temperature of a rod of copper is increased, its length:

(a) remains the same (b) increases (c) decreases (d) becomes double

2. The amount by which unit length of a material increases when the temperature is raised to 1°C, is called the coefficient of:

(a) cubic expansion (b) volume expansion (c) linear expansion (d) none of these

3. What does liquid turn into once it is evaporated?

(a) Gas (b) Water vapour (c) Air (d) Both (a) and (b)

4. Which property determines how much heat a solid can absorb before its temperature changes significantly?

(a) Density (b) Specific heat capacity (c) Colour (d) Hardness

5. High-temperature superconductors typically involve which type of material?

(a) Pure metals (b) Organic compounds (c) Ceramics (d) Liquid crystals

Answer Key:

Q#	1	2	3	4	5
Ans	b	c	d	b	c

SLO Based Additional MCQs + Past Papers MCQs of Punjab Boards

1. The formula for linear thermal expansion of a solid is:

(a) $L = L_0(1+\beta\Delta T)$ (b) $L = L_0(1+\alpha\Delta T)$ (c) $L = L_0(1-\alpha\Delta T)$ (d) $L = \alpha L_0\Delta T$

2. Which relationship correctly represents the thermal expansion of liquids?

(a) $\beta r = \beta a - \beta f$ (b) $\beta a = \beta r + \beta f$ (c) $\beta r = \beta a + \beta f$ (d) $\beta f = \beta r - \beta a$

3. Small gaps are left between railway tracks to prevent:

(a) Rusting (b) Contraction in winter (c) Buckling due to expansion (d) Vibration

4. In the linear expansion formula, the symbol α represents:

(a) Coefficient of volume expansion (b) Change in length (c) Coefficient of linear thermal expansion (d) Specific heat capacity

5. The SI unit of specific heat capacity is:

(a) $J\,kg^{-1}$ (b) $J\,k^{-1}$ (c) $J\,kg^{-1}K^{-1}$ (d) JkgK

6. The specific heat capacity of water is:

(a) $810\ J\,kg^{-1}K^{-2}$ (b) $2100\ J\,kg^{-1}K$ (c) $4200\ J\,kg^{-1}K^{-1}$ (d) $33600\ J\,kg^{-1}K^{-1}$

7. Soil heats up faster than water because the specific heat capacity of dry soil is:

(a) Higher than water (b) Equal to water (c) Lower than water (d) Zero

8. Evaporation is a process where a liquid changes into gas:

(a) At its boiling point only (b) Without boiling (c) At 100°C only (d) By absorbing latent heat of fusion

9. Which of the following factors does not increase the rate of evaporation?

(a) Higher temperature (b) Larger surface area (c) High humidity (d) Air movement (Wind)

10. The heat energy required to change a solid into a liquid at its melting point without changing temperature is called:

(a) Specific heat capacity (b) Latent heat of fusion (c) Latent heat of vaporization (d) Coefficient of expansion

11. The value of latent heat of fusion of ice is:

(a) 2.26×10^{6} J kg^{-1} (b) 3.36×10^{5} J kg^{-1} (c) 4200 J kg^{-1} (d) 334 J kg^{-1}

12. The latent heat of vaporization of water is:

(a) 3.36×10^{5} J kg^{-1} (b) 4.2×10^{3} J kg^{-1} (c) 2.26×10^{6} J kg^{-1} (d) 2.26×10^{5} J kg^{-1}

13. Superconductivity is a state where materials exhibit:

(a) High electrical resistance (b) Zero electrical resistance (c) Zero thermal expansion (d) Infinite density

14. Mercury becomes a superconductor at a critical temperature of:

(a) 7.2 K (b) 0 K (c) 4.2 K (d) 100 K

15. Which of the following is an application of superconductors?

(a) Electric heaters (b) Filament bulbs (c) MRI Machines (d) Diesel engines

Answer Key:

Q#	1	2	3	4	5	6	7	8
Ans	b	c	c	c	c	c	c	b

Q#	9	10	11	12	13	14	15
Ans	c	b	b	c	b	c	c

Exercise Short Questions

10.1 What factors influence the thermal expansion of solids?

The expansion of a solid depends on its original length (L_0), the temperature change (ΔT), and the thermal expansion coefficient (α). Formula: $\Delta L = \alpha L_0 \Delta T$

Factors: Original length (longer rod expands more); Temperature change (larger ΔT gives larger expansion); Thermal expansion coefficient (different materials have different α values — e.g., aluminium expands more than steel).

Materials with weaker bonding expand more, while those with strong bonding expand less. Gases expand more than liquids and solids due to their weak bonding.

10.2 What is latent heat of fusion?

The heat energy required to convert 1 kg of a solid into a liquid at its melting point while keeping the temperature constant is called latent heat of fusion. This energy is used to break bonds between solid particles, so the temperature stays constant during melting. Formula: $Q = mL_f$. Unit: J/kg.

10.3 How do different materials exhibit varying thermal expansion behaviours?

Different materials expand by different amounts on heating because their atoms are bonded with different strengths. Materials with weaker bonding expand more, while those with strong bonding expand less. Gases expand more than liquids and solids due to their weak bonding.

10.4 How does evaporation contribute to cooling processes in everyday life?

Evaporation causes cooling because the faster (higher energy) molecules of a liquid escape into the air during evaporation. These molecules take heat energy with them, so the remaining liquid loses heat and becomes cooler.

Example: When sweat evaporates from our skin, it absorbs heat from the body to change into vapour. As a result, the body loses heat and we feel cool — helping regulate body temperature, especially in hot weather.

10.5 What is latent heat of vaporization, and how is it calculated?

The heat energy needed to change 1 kg of a liquid into gas at its boiling point without changing the temperature is called latent heat of vaporization. When a liquid boils, it absorbs heat without a temperature rise until all the liquid has evaporated. Formula: $Q = mL_v$. Unit: J/kg.

SLO Based Additional Short Questions + Past Papers Short Questions of Punjab Boards

Q.1 Define thermal expansion and explain why it occurs.

The change in length, area, or volume of a substance when it is heated is called thermal expansion.

Reason: As temperature rises, particles gain more kinetic energy, move faster, and spread out, leading to expansion. Conversely, cooling causes particles to lose energy and move closer together, resulting in contraction.

Q.2 Define the coefficient of linear thermal expansion. Write its formula and SI units.

The fractional change in length per degree change in temperature for a specific material is called the coefficient of linear thermal expansion. Formula: $\Delta L = \alpha L_0 \Delta T$, where α is the coefficient. SI Unit: K^{-1} (per Kelvin).

Q.3 Define linear thermal expansion and volume thermal expansion. Write their formulas.

Linear thermal expansion is the expansion in length due to heating, given by $\Delta L = \alpha L_0 \Delta T$, where α is the coefficient of linear thermal expansion.

Volume thermal expansion is the increase in volume of a solid or liquid when heated, given by $\Delta V = \beta V_0 \Delta T$, where β is the coefficient of volume expansion.

Q.4 Differentiate between real and apparent expansion of liquids.

Real Expansion	Apparent Expansion
This is the actual increase in the volume of the liquid itself, independent of the container's expansion.	When a liquid is heated in a container, the container also expands. The observed rise in liquid level, which is less than the actual expansion, is called apparent expansion.
Real expansion is always greater than apparent expansion.	Apparent expansion is always smaller than real expansion.
It accounts for both the thermal expansion of the liquid and the container.	It only accounts for the visible change in liquid level due to unequal expansion rates.
Formula: Real expansion = Apparent expansion + Expansion of vessel	The difference between real and apparent expansion equals the expansion of the flask itself.

Q.5 Why are gaps left in railway tracks?

Steel tracks expand on hot days. If no room is left for this expansion, the tracks may bend or twist — a phenomenon known as “sun kinks” — which can cause train derailments. Small gaps are left between tracks to allow for this expansion safely.

Q.6 Explain the principle behind the rising of a hot air balloon.

When the air inside a balloon is heated, it expands and becomes less dense (lighter) than the cooler air outside. This difference in density creates an upward lift, causing the balloon to rise.

Q.7 Define specific heat capacity and write its SI unit.

Specific heat capacity is the amount of heat energy needed to increase the temperature of 1 kg of a substance by 1°C (or 1 K). Formula: $Q = mc\Delta T$. SI Unit: $J\ kg^{-1}\ K^{-1}$ (Joules per kilogram per Kelvin).

Q.8 Why does the temperature of land rise faster than that of the sea during the day?

Water has a high specific heat capacity ($4200\ J\ kg^{-1}K^{-1}$) compared to dry soil ($810\ J\ kg^{-1}K^{-1}$). This means soil heats up five times faster than the same mass of water under the same heat, causing land temperatures to rise more quickly than sea temperatures.

Q.9 How does water help in the cooling system of an automobile?

Water is used because of its high specific heat capacity ($4200\ J\ kg^{-1}K^{-1}$), allowing it to absorb a large amount of heat with only a small rise in temperature.

Water circulates around the engine cylinders, absorbing heat. The heated water moves to the radiator, where it is cooled by air drawn in by a fan. The cooled water returns to the engine to repeat the cycle.

Q. (a) Why does water have a high specific heat capacity?

Water can absorb and store a large amount of heat with only a small temperature increase due to its molecular structure, making it effective for temperature regulation.

Q.10 Define evaporation and explain how it causes cooling.

The process by which a liquid changes into a gas at its surface without boiling is called evaporation.

Cooling Effect: It occurs when more energetic particles escape from the surface of the liquid as vapour. As these high-energy particles leave, the remaining liquid has lower average kinetic energy, resulting in a drop in temperature (cooling).

Q.11 List the factors that affect the rate of evaporation with brief detail.

Temperature: Higher temperature increases the rate of evaporation.

Surface Area: Larger surface area speeds up evaporation.

Air Movement (Wind): Wind carries away vapour molecules, preventing saturation and speeding up the process.

Humidity: High humidity slows down evaporation; dry air speeds it up.

Nature of Liquid: Liquids with weaker molecular forces (like alcohol) evaporate faster than water.

Q.12 How does a refrigerator cool food without using CFCs?

Environmentally friendly refrigerants are used, which evaporate at low temperatures inside cooling coils. As the refrigerant evaporates, it absorbs a large amount of heat from inside the refrigerator. The vapour is then compressed and condensed back into a liquid outside the compartment, releasing the heat.

Q.13 Define Latent Heat of Fusion and state its value for ice.

The heat energy required to convert 1 kg of a solid into a liquid at its melting point while keeping the temperature constant is called latent heat of fusion. Formula: $Q = mH_f$. Value for ice: 3.36×10^5 J kg^{-1} (or 336 J g^{-1}).

Q.14 Why does the temperature of ice remain the same while it is melting, even though heat is applied?

The heat absorbed during melting is used to break the strong bonds between solid particles rather than increasing their kinetic energy. Therefore, the temperature remains constant until the entire solid has melted.

Q.15 Define Latent Heat of Vaporization and state its value required to vaporize water.

Latent heat of vaporization is the heat energy needed to change 1 kg of a liquid into gas at its boiling point without changing the temperature. Formula: $Q = mH_v$. Value for water: 2.26×10^6 J kg^{-1} (or 2260 J g^{-1}).

Q.16 What is superconductivity? Give examples of superconducting materials.

Superconductivity is a state in which materials exhibit zero electrical resistance. This occurs when the material is cooled below a specific temperature.

Examples: Mercury (becomes superconductor below 4.2 K) and Lead (below 7.2 K).

Q.17 What is the critical temperature? Give example.

The temperature below which a material exhibits zero electrical resistance is called the critical temperature, e.g., the critical temperature of Hg is 4.2 K.

Q.18 Write applications for superconducting materials.

MRI Machines: generating strong magnetic fields for medical imaging.

Maglev Trains: floating trains above tracks to reduce friction.

Particle Accelerators: help scientists study fundamental particles — superconducting magnets accelerate particles to nearly the speed of light.

Constructed Response Questions

10.1 Why do bridges need expansion joints but glass jars with metal lids do not, even though both experience temperature changes? Discuss in terms of the nature of thermal expansion.

Bridges are long metal structures, so they expand significantly when heated. Small gaps (expansion joints) are placed in bridges to allow this expansion and contraction without damage. A glass jar with a metal lid is much shorter, so heating only causes a very small increase in length. In fact, warming the metal lid (e.g., by running it under warm water) makes it expand just enough to loosen the lid.

10.2 If two liquids are heated under the same conditions, but one of them heats up faster, what does this indicate about specific heat capacity?

Since heat capacity is given by $Q = mc\Delta T$, for the same heat and mass 'm', $\Delta T \propto 1/c$. This means the liquid which heats up faster has a smaller specific heat capacity.

10.3 Why does a liquid evaporate faster when the air is dry?

Evaporation depends on humidity. Low humidity increases evaporation, while high humidity reduces it.

Explanation: A liquid evaporates faster when the air is dry because dry air can hold more water vapour. When humidity is low, water molecules easily leave the liquid and mix with the air. Since the air is not saturated, evaporation continues quickly. If the air is humid, it already contains a lot of water vapour and cannot absorb much more, so evaporation slows down.

10.4 When a piece of ice melts, the temperature does not increase even though heat is supplied. Where does the energy go, and why is this important in phase change?

When ice melts, the heat supplied is used to break the bonds between water molecules. This energy is called latent heat of fusion. It helps change ice into water instead of raising the temperature. Therefore, the temperature remains at 0 °C until all the ice has melted. This is important in phase change because it allows a substance to change its state at a constant temperature.

10.5 Why do electric transmission wires sag in summer and tighten in winter?

Electric transmission wires are made of metal and follow the formula $\Delta L = \alpha L_0 \Delta T$.

Explanation: Metals expand when temperature increases and contract when temperature decreases. In summer, high temperature makes the wires expand, so they become longer and sag. In winter, low temperature causes the wires to contract, so they become shorter and tight.

Comprehensive Questions

10.1 How does thermal expansion differ between solids, liquids, and gases? Provide examples to illustrate these differences.

Thermal expansion differs because the distance between particles and the strength of forces between them are different.

Solids: Particles are very close and strongly bonded, so expansion is very small. Example: Railway tracks expand slightly in summer.

Liquids: Particles are less tightly packed, so expansion is more than solids. Example: Mercury rises in a thermometer when heated.

Gases: Particles are far apart with very weak forces, so expansion is very large. Example: A balloon expands when filled with hot air.

Conclusion: Gases expand most, liquids expand more than solids, and solids expand the least due to differences in particle spacing and bonding.

10.2 What are some practical consequences of thermal expansion in everyday life, such as in construction materials or household appliances?

See Q.5 of theory section (railway track gaps, bridge expansion joints, metal jar lids, gas containers, pipes and plumbing).

10.3 What is latent heat, and why is it important in phase transitions like melting and vaporization?

See Q.11 of theory section (definition, latent heat of fusion, latent heat of vaporization).

10.4 Why do solids, liquids, and gases expand when heated? Explain with examples.

See Q.1 of theory section.

10.5 If we have an equal amount of water in a wide, shallow dish and a tall, narrow container kept at the same temperature, in which container will evaporation occur faster? Explain the reason scientifically.

The shallow dish has a larger surface area compared to the tall, narrow container, so more water molecules will evaporate from the dish.

Numerical Problems

10.1 A metal rod of length 1 m expands by 0.02 m when heated from 20 °C to 120 °C. Calculate its coefficient of linear expansion.

Solution:

$L_0 = 1.00$ m

$\Delta L = 0.02$ m

$T_0 = 20$ °C, $T = 120$ °C ⇒ $\Delta T = 100$ °C (100 K)

To Find: α = ?

$$\alpha = \Delta L / (L_0 \times \Delta T) = 0.02 / (1.00 \times 100) = 2.0 \times 10^{-4}\ K^{-1}$$

Result: $\alpha = 2.0 \times 10^{-4}\ K^{-1}$

10.2 A container holds 1 litre of water at 20 °C. What will be its volume at 80 °C, assuming water's coefficient of volume expansion is 2.1×10^{-4} per °C?

Solution:

$V_0 = 1.00$ L = 1000 cm^3

$\beta = 2.1 \times 10^{-4}$ /°C

$T_0 = 20$ °C, $T = 80$ °C ⇒ $\Delta T = 60$ °C

To Find: V = ?

$$\Delta V = \beta \times V_0 \times \Delta T = 2.1 \times 10^{-4} \times 1000 \times 60 = 12.6\ cm^3$$

$$V = \Delta V + V_0 = 12.6 + 1000 = 1012.6\ cm^3$$

Result: V = 1012.6 cm^3

10.3 A steel rod initially measures 2 m at 20 °C. If its coefficient of linear expansion is 1.2×10^{-5} °C^{-1}, what will be its length at 100 °C?

Solution:

$L_0 = 2.00$ m

$\alpha = 1.2 \times 10^{-5}\ K^{-1}$

$T_0 = 20$ °C, $T = 100$ °C ⇒ $\Delta T = 80$ °C

To Find: L = ?

$$L = L_0 \times (1 + \alpha \times \Delta T) = 2.00 \times (1 + 1.2 \times 10^{-5} \times 80) = 2.00 \times 1.00096$$

Result: L = 2.00192 m

10.4 A steel bridge expands by 5 cm on a hot summer day. If the bridge originally spanned 100 m, what is the temperature change?

Solution:

$L_0 = 100.0$ m

$\Delta L = 5$ cm = 0.050 m

$\alpha = 1.2 \times 10^{-5}\ K^{-1}$

To Find: ΔT = ?

$$\Delta T = \Delta L / (\alpha \times L_0) = 0.050 / (1.2 \times 10^{-5} \times 100.0) = 41.67\ °C$$

Result: ΔT = 41.67 °C

10.5 How much heat is required to raise the temperature of a 2 kg iron bar from 20 °C to 100 °C, given that the specific heat capacity of iron is 450 J $kg^{-1}K^{-1}$?

Solution:

m = 2.00 kg

c = 450 J $kg^{-1}K^{-1}$

T_0 = 20 °C, T = 100 °C ⇒ ΔT = 80 °C (80 K)

To Find: Q = ?

$$Q = m \times c \times \Delta T = 2 \times 450 \times 80 = 72000\ J$$

Result: Q = 72000 J = 72 kJ

10.6 How much heat is required to melt 500 g of ice at 0 °C into water at 0 °C? (Latent heat of fusion of ice = 3.36 × 10^5 J kg^{-1})

Solution:

m = 500 g = 0.5 kg

L_f = 3.36 × 10^5 J kg^{-1}

To Find: Q = ?

$$Q = m \times L_f = 0.5 \times 3.36 \times 10^5 = 168\ kJ$$

Result: Q = 168 kJ

10.7 Calculate the heat required to completely vaporize 1 kg of water at 100 °C. (Latent heat of vaporization of water = 2.26 × 10^6 J kg^{-1})

Solution:

m = 1.00 kg

L_v = 2.26 × 10^6 J kg^{-1}

To Find: Q = ?

$$Q = m \times L_v = 1 \times 2.26 \times 10^6 = 2.26 \times 10^6\ J$$

Result: Q = 2.26 × 10^6 J = 2.26 MJ

Important Questions of Board Examination

- (i) Define co-efficient of linear thermal expansion and derive an expression for the same.
- (ii) Define specific heat. Explain effects of large specific heat of water.
- (iii) Define evaporation. Explain different factors affecting evaporation.
- (iv) Differentiate between latent heat of fusion and vaporization.

Important Short Questions of Board Examination

- (i) Define thermal expansion.
- (ii) Define specific heat capacity of a substance. Write down its formula and SI units.
- (iii) Define evaporation. Name different factors affecting evaporation.
- (iv) Differentiate between latent heat of fusion and latent heat of vaporization. Write their SI units.
- (v) Define: (i) Superconductor (ii) Critical temperature
- (vi) Write down uses of superconductors in advanced technology.
- (vii) Define: (i) Melting (ii) Boiling
- (viii) Define: (i) Condensation (ii) Solidification
- (ix) Define linear thermal and volume thermal expansion of a solid. Write their formulas.
- (x) Define co-efficient of linear thermal expansion. Write down its SI units.
- (xi) Why does the temperature-time graph for heating ice remain flat during melting and boiling but rise when the substance is not changing?
- (xii) Explain why gases expand more than solids and liquids when heated, based on kinetic theory.
- (xiii) Why are bridges and railway tracks designed with expansion gaps?
- (xiv) Differentiate between real and apparent expansion of liquids.
- (xv) Differentiate between boiling and evaporation.
- (xvi) Why does sand and beach heat up faster during day compared to water in sea?
- (xvii) How does a hot air balloon rise in air?
- (xviii) Explain and compare the thermal expansion for solids, liquids and gases.

