9TH CLASS • PHYSICS

COMPLETE SOLVED EXERCISE

Thermal Properties of Matter

CHAPTER 07

Inside this guide:

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A. Multiple Choice Questions

Tick (✓) the correct answer

7.1 How do the molecules in a solid behave?

(a) Move randomly

✓ **(b) Vibrate about their mean positions**

(c) Rotate and vibrate randomly at their own positions

(d) Move in a straight line from hot to cold ends

Explanation: In a solid, the intermolecular forces are very strong, and the molecules are tightly packed. They cannot move freely from one place to another. Instead, they possess enough kinetic energy to vibrate constantly back and forth around their fixed mean positions.

7.2 What type of motion is of the molecules in a gas?

(a) Linear motion

✓ **(b) Random motion**

(c) Vibratory motion

(d) Rotatory motion

Explanation: Gas molecules have negligible intermolecular forces and large intermolecular spaces. They move at high speeds in straight lines until they collide with each other or the walls of the container, resulting in continuous, random, zig-zag motion.

7.3 Temperature of a substance is:

(a) the total amount of heat contained in it

(b) the total number of molecules in it

✓ **(c) degree of hotness or coldness**

(d) dependent upon the intermolecular distance

Explanation: Temperature is a physical quantity that expresses quantitatively the perceptions of hotness and coldness. It is related to the average kinetic energy of the particles in a substance.

7.4 Heat is the:

(a) total kinetic energy of the molecules

(b) the internal energy

(c) work done by the molecules

✓ **(d) the energy in transit**

Explanation: Heat is not something a body "contains"; rather, it is energy that is transferred from one body to another due to a difference in temperature. It exists only during the process of transfer.

7.5 In Kelvin scale, the temperature corresponding to melting point of ice is:

(a) zero

(b) 32

(c) −273

✓ **(d) +273**

Explanation: The melting point of ice is 0°C. The relationship between Celsius and Kelvin is K = °C + 273.15. Therefore, 0 + 273 = 273 K.

7.6 The temperature which has the same value on Celsius and Fahrenheit scale is:

✓ **(a) −40**

(b) +40

(c) +45

(d) −45

Explanation: Using the formula C/5 = (F−32)/9. If C = F, then x/5 = (x−32)/9. Solving this gives 9x = 5x − 160, which simplifies to 4x = −160, so x = −40. Thus, −40°C = −40°F.

7.7 Which one is a better choice for a liquid-in-glass thermometer?

(a) Is colourless

(b) Is a bad conductor

✓ **(c) Expand linearly**

(d) Wets glass

Explanation: For a thermometer to give accurate readings across its entire range, the thermometric liquid must expand uniformly (linearly) with an increase in temperature.

7.8 One disadvantage of using alcohol in a liquid-in-glass thermometer:

(a) it has large expansivity

(b) it has low freezing point (−112°C)

✓ **(c) it wets the glass tube**

(d) its expansion is linear

Explanation: Alcohol has a strong adhesive force with glass, causing it to stick to the walls of the capillary tube. This makes it difficult to read the exact position of the meniscus.

7.9 Water is not used as a thermometric liquid mainly due to:

(a) colourless

(b) a bad conductor of heat

✓ **(c) non-linear expansion**

(d) a low boiling point (100°C)

Explanation: Water has an anomalous expansion between 0°C and 4°C (it contracts when heated in this range). This non-linear behavior makes it impossible to have a uniform scale.

7.10 A thermometer has a narrow capillary tube so that it:

(a) quickly responds to temperature changes

(b) can read the maximum temperature

✓ **(c) gives a large change for a given temperature rise**

(d) can measure a large range of temperature

Explanation: A narrow bore increases the sensitivity of the thermometer. A small change in the volume of the liquid causes a large, easily measurable change in the length of the liquid column.

7.11 Which thermometer is most suitable for recording rapidly varying temperature?

✓ **(a) Thermocouple thermometer**

(b) Mercury-in-glass laboratory thermometer

(c) Alcohol-in-glass thermometer

(d) Mercury-in-glass clinical thermometer

Explanation: A thermocouple has a very small mass and low thermal capacity, allowing it to heat up and cool down almost instantly, making it ideal for measuring rapidly changing temperatures.

B. Short Answer Questions

7.1. Why solids have a fixed volume and shape according to particle theory of matter?

According to the particle theory, the molecules in a solid are packed very closely together. The intermolecular forces of attraction between them are extremely strong. Because of this, the molecules cannot move freely; they can only vibrate about their fixed mean positions. This rigid structure gives solids a definite shape and a fixed volume.

7.2. What are the reasons that gases have neither a fixed volume nor a fixed shape?

In gases, the intermolecular spaces are very large, and the intermolecular forces of attraction are negligible. The molecules possess high kinetic energy and move randomly at very high speeds. Because they are free to move anywhere, they completely fill any container they are put in, taking its shape and volume.

7.3. Compare the spacing of molecules in the solid, liquid and gaseous state.

- **Solid:** Molecules are very tightly packed (minimum spacing).
- **Liquid:** Molecules are loosely packed compared to solids (intermediate spacing).
- **Gas:** Molecules are very far apart (maximum spacing).

7.4. What is the effect of raising the temperature of a liquid?

Raising the temperature increases the average kinetic energy of the liquid molecules. This causes them to vibrate and move faster, overcoming some intermolecular forces. As a result, the liquid expands (increases in volume) and eventually may change state into a gas (evaporation or boiling).

7.5. What is meant by temperature of a body?

The temperature of a body is a measure of the average kinetic energy of its molecules. It determines the degree of hotness or coldness of the body and dictates the direction in which heat will flow.

7.6. Define heat as 'energy in transit'.

Heat is defined as energy in transit because it only exists when energy is actively moving from a region of higher temperature to a region of lower temperature. A body does not "contain" heat; it contains internal energy. Once the transfer stops, it is no longer called heat.

7.7. What is meant by thermometric property of a substance? Enlist some thermometric properties.

A thermometric property is a physical property of a substance that changes predictably and measurably with a change in temperature.

- Volume of a liquid (used in liquid-in-glass thermometers).
- Electrical resistance of a metal (used in resistance thermometers).
- Pressure of a gas at constant volume.
- Electromotive force (EMF) of a thermocouple.

7.8. State the main scales used for the measurement of temperature.

- Celsius scale (°C)
- Fahrenheit scale (°F)
- Kelvin scale (K)

7.9. What is meant by sensitivity of a thermometer?

Sensitivity of a thermometer is its ability to detect and measure very small changes in temperature. A highly sensitive thermometer shows a large, measurable change in its thermometric property (e.g., a long movement of the liquid column) for a very small change in temperature.

7.10. What do you mean by the linearity of a thermometer?

Linearity of a thermometer means that the thermometric property it uses changes uniformly (in direct proportion) with temperature changes across its entire scale range. If a thermometer is not linear, its scale markings will not be evenly spaced.

7.11. What makes the scale reading of a thermometer accurate?

The accuracy of a thermometer's scale depends on proper calibration using standard fixed points (like melting ice and boiling water), the linearity of the thermometric material, and the sensitivity of the design (e.g., a uniform, narrow capillary tube).

7.12. What does determine the direction of heat flow?

The direction of heat flow is determined by the temperature difference between two bodies. Heat always flows naturally from a body at a higher temperature to a body at a lower temperature.

7.13. Distinguish between the heat and internal energy.

- **Heat:** It is energy in transit due to a temperature difference. It is a process quantity.
- **Internal Energy:** It is the total sum of the kinetic and potential energies of all the molecules of a body. It is a state quantity (depends on the state of the body).

7.14. When you touch a cold surface, does cold travel from the surface to your hand or does energy travel from your hand to cold surface?

Energy (heat) travels from your hand to the cold surface. "Cold" is not a form of energy; it is simply the absence of heat. Because your hand is at a higher temperature, heat flows out of your hand into the cold surface.

7.15. Can you feel your fever by touching your own forehead? Explain.

No, you cannot accurately feel your own fever by touching your forehead with your hand. This is because both your hand and your forehead are part of the same body and are likely at the same temperature. Since there is no temperature difference, no heat flows between them, and you cannot sense a temperature difference.

C. Constructed Response Questions

7.1. Is kinetic molecular theory of matter applicable to the plasma state of matter? Describe briefly.

Yes, the kinetic molecular theory (KMT) is applicable to the plasma state of matter. Plasma is an ionized gas consisting of free electrons and positive ions. Just like gases, the particles in plasma are far apart, have high kinetic energy, and move randomly. However, because plasma contains charged particles, the KMT must be modified to account for electromagnetic forces between the particles, in addition to simple mechanical collisions.

7.2. Why is mercury usually preferred to alcohol as a thermometric liquid?

Mercury is preferred because:

- It is opaque and silvery, making it easy to read.
- It does not wet the glass tube, so its meniscus is convex and clearly visible.
- It has a linear expansion over a wide range of temperatures.
- It has a high boiling point (357°C) and a low freezing point (−39°C), allowing a wide temperature range.
- It is a good conductor of heat, so it responds quickly to temperature changes.

7.3. Why is water not suitable for use in thermometers? Without calculations, guess what is equivalent temperature of 373 K on Celsius and Fahrenheit scales?

Water is not suitable because:

- It has anomalous expansion between 0°C and 4°C.
- It has a high specific heat capacity, so it responds slowly.
- It wets glass, making the meniscus difficult to read.
- It has a low boiling point (100°C) and freezes at 0°C, limiting its range.

Equivalent temperature: 373 K is equivalent to **100°C** (boiling point of water) and **212°F**.

7.4. Mention two ways in which the design of a liquid-in-glass thermometer may be altered to increase its sensitivity.

- **Making the bore of the capillary tube narrower:** A narrower tube means a small change in liquid volume will result in a larger length change.
- **Increasing the volume of the bulb:** A larger bulb holds more liquid, so a given temperature change will cause a larger volume change, pushing the liquid further up the tube.

7.5. One litre of water is heated by a stove and its temperature rises by 2°C. If two litres of water is heated on the same stove for the same time, what will be then rise in temperature?

The temperature rise will be **1°C**.

Reasoning: The heat supplied by the stove is the same in both cases. Since Q = mcΔT, if the mass (m) is doubled (2 litres instead of 1 litre) and Q and c remain constant, the temperature change (ΔT) must be halved. 2°C / 2 = 1°C.

7.6. Why are there no negative numbers on the Kelvin scale?

The Kelvin scale is an absolute thermodynamic scale. Its zero point (0 K) represents absolute zero, the theoretical temperature at which the molecules of a substance have the minimum possible kinetic energy (essentially zero). Since it is impossible for a substance to have less than zero kinetic energy, there can be no negative numbers on this scale.

7.7. Comment on the statement. "A thermometer measures its own temperature."

The statement is true. When a thermometer is placed in contact with an object, heat flows between them until they reach thermal equilibrium (i.e., they are at the same temperature). At this point, the thermometer's reading reflects its own temperature, which is now equal to the temperature of the object being measured.

7.8. There are various objects made of cotton, wood, plastic, metals, etc. In a winter night, compare their temperatures with the air temperature by touching them with your hand.

In a winter night, all these objects will be at the same temperature as the surrounding air. However, when you touch them, metals will feel much colder than cotton or wood. This is because metals are good conductors of heat; they rapidly draw heat away from your hand. Cotton and wood are poor conductors (insulators), so they draw heat away from your hand much more slowly, making them feel warmer.

7.9. Which is greater: an increase in temperature 1°C or one 1°F?

An increase of **1°C is greater**.

Explanation: A change of 1°C is equivalent to a change of 1.8°F. Therefore, a 1°C increase represents a larger temperature change than a 1°F increase.

7.10. Why would you not expect all the molecules in a gas to have the same speed?

Gas molecules are in constant random motion and frequently collide with each other and the walls of the container. These collisions transfer energy between molecules. As a result, some molecules speed up while others slow down, leading to a distribution of speeds (known as the Maxwell-Boltzmann distribution) rather than a single uniform speed.

7.11. Does it make sense to talk about the temperature of a vacuum?

No, it does not make sense. Temperature is a measure of the average kinetic energy of particles. A perfect vacuum is completely devoid of particles. Since there are no particles to possess kinetic energy, temperature is undefined for a vacuum.

7.12. Comment on the statement: "A hot body does not contain heat".

The statement is correct. Heat is defined as energy in transit due to a temperature difference. A body contains internal energy (the sum of kinetic and potential energies of its molecules), not heat. Heat only exists during the transfer of energy from the hot body to a colder one.

7.13. Discuss whether the Sun is matter.

Yes, the Sun is matter. It is primarily composed of hydrogen and helium plasma. Since it has mass, occupies space, and is made of particles (ions and electrons), it meets the definition of matter. It exists in the plasma state, which is the fourth state of matter.

D. Comprehensive Questions

7.1. Describe the main points of particle theory of matter which differentiate solids, liquids and gases.

The particle theory of matter explains the differences based on three main factors: intermolecular spacing, intermolecular forces, and molecular motion.

- **Solids:** Particles are tightly packed with very little space between them. The intermolecular forces are very strong. Particles can only vibrate about fixed mean positions. This gives solids a definite shape and volume.
- **Liquids:** Particles are loosely packed with moderate spacing. Intermolecular forces are weaker than in solids. Particles can slide past one another, allowing liquids to flow and take the shape of their container, but they still have a definite volume.
- **Gases:** Particles are very far apart with large intermolecular spaces. Intermolecular forces are negligible. Particles move randomly at very high speeds. Gases have neither a definite shape nor a definite volume, expanding to fill any container.

7.2. What is temperature? How is it measured? Describe briefly the construction of a mercury-in-glass thermometer.

Temperature: It is the measure of the average kinetic energy of the particles in a substance, indicating its degree of hotness or coldness.

Measurement: It is measured using a thermometer, which relies on a thermometric property that changes linearly with temperature (e.g., volume expansion of a liquid).

Construction of Mercury-in-Glass Thermometer:

- **Bulb:** A thin-walled glass bulb at the bottom containing pure mercury.
- **Capillary Tube:** A very narrow, uniform bore glass tube connected to the bulb. The mercury expands into this tube when heated.
- **Stem:** The thick glass casing that protects the capillary tube.
- **Scale:** Markings on the stem calibrated between the ice point (0°C) and steam point (100°C).
- **Inert Gas:** The space above the mercury is filled with an inert gas (like nitrogen) under pressure to prevent the mercury from boiling at high temperatures.

7.3. Compare the three scales used for measuring temperature.

Feature	Celsius Scale (°C)	Fahrenheit Scale (°F)	Kelvin Scale (K)
Ice Point	0°C	32°F	273.15 K
Steam Point	100°C	212°F	373.15 K
Absolute Zero	−273.15°C	−459.67°F	0 K
Division	100 divisions	180 divisions	100 divisions
Conversion	—	F = (C × 1.8) + 32	K = C + 273.15

7.4. What is meant by sensitive, range and linearity of thermometers? Explain with examples.

- **Sensitivity:** The ability of a thermometer to detect small temperature changes. A sensitive thermometer shows a large change in reading for a small temperature change. *Example:* A thermometer with a very narrow bore and large bulb is highly sensitive.
- **Range:** The minimum and maximum temperatures a thermometer can measure. *Example:* A clinical thermometer has a narrow range (35°C to 42°C), while a laboratory thermometer might have a range of −10°C to 110°C.
- **Linearity:** The property where the thermometric substance expands uniformly with temperature, resulting in evenly spaced scale markings. *Example:* Mercury expands linearly over a wide range, making it highly linear.

7.5. Explain how the parameters mentioned in question 7.4 are improved in the structure of liquid-in-glass thermometer.

- **Improving Sensitivity:** Achieved by making the capillary bore extremely narrow and the bulb relatively large. This ensures that a small volume expansion of the liquid produces a large, visible movement of the liquid column.
- **Improving Range:** Achieved by using a thick glass bulb to withstand high pressure, filling the space above the liquid with an inert gas (like nitrogen) to prevent boiling, and choosing a liquid with a wide liquid state (like mercury: −39°C to 357°C).
- **Improving Linearity:** Achieved by using a uniform (cylindrical) capillary bore and choosing a thermometric liquid like mercury, which has a highly uniform coefficient of expansion over its liquid range.

E. Numerical Problems

7.1. The temperature of a normal human body on Fahrenheit scale is 98.6°F. Convert it into Celsius scale and Kelvin scale.

Given: Temperature = 98.6°F

Step 1: Convert to Celsius (°C)

Formula: $C = 5/9 \times (F - 32)$

$C = 5/9 \times (98.6 - 32)$

$C = 5/9 \times 66.6$

$C = 5 \times 7.4 = 37°C$

Step 2: Convert to Kelvin (K)

Formula: $K = C + 273.15$

$K = 37 + 273 = 310$ K

Answer: 37°C, 310 K

7.2. At what temperature Celsius and Fahrenheit thermometer reading would be the same?

Given: C = F = x

Step 1: Use conversion formula

Formula: $C/5 = (F - 32)/9$

Substitute C = F = x: $x/5 = (x - 32)/9$

Step 2: Solve for x

Cross-multiply: $9x = 5(x - 32)$

$9x = 5x - 160$

$9x - 5x = -160$

$4x = -160$

$x = -40$

Answer: −40°

7.3. Convert 5°F to Celsius and Kelvin scale.

Given: Temperature = 5°F

Step 1: Convert to Celsius (°C)

Formula: $C = 5/9 \times (F - 32)$

$C = 5/9 \times (5 - 32)$

$C = 5/9 \times (-27)$

$C = 5 \times (-3) = -15°C$

Step 2: Convert to Kelvin (K)

Formula: $K = C + 273$

$K = -15 + 273 = 258$ K

Answer: −15°C, 258 K

7.4. What is equivalent temperature of 25°C on Fahrenheit and Kelvin scales?

Given: Temperature = 25°C

Step 1: Convert to Fahrenheit (°F)

Formula: $F = (9/5 \times C) + 32$

$F = (9/5 \times 25) + 32$

$F = (9 \times 5) + 32$

$F = 45 + 32 = 77°F$

Step 2: Convert to Kelvin (K)

Formula: $K = C + 273$

$K = 25 + 273 = 298$ K

Answer: 77°F, 298 K

7.5. The ice and steam points on an ungraduated thermometer are found to be 192 mm apart. What temperature will be on Celsius scale if the length of mercury thread is at 67.2 mm above the ice point mark?

Given: Distance between ice point (0°C) and steam point (100°C) = 192 mm; Length of mercury thread above ice point = 67.2 mm

Step 1: Calculate temperature using proportionality

Formula: T = (Length measured / Total length) × 100°C
T = (67.2 / 192) × 100
T = 0.35 × 100
T = 35°C

Answer: 35°C

7.6. The length between the fixed point of liquid-in-glass thermometer is 20 cm. If the mercury level is 4.5 cm above the lower mark, what is the temperature on the Fahrenheit scale?

Given: Length between fixed points (Ice point to Steam point) = 20 cm; Mercury level above lower mark (Ice point) = 4.5 cm

Step 1: Calculate temperature rise in Celsius (°C)

Formula: C = (Length measured / Total length) × 100°C
C = (4.5 / 20) × 100
C = 0.225 × 100 = 22.5°C

Step 2: Convert 22.5°C to Fahrenheit (°F)

Formula: F = (9/5 × C) + 32
F = (9/5 × 22.5) + 32
F = (9 × 4.5) + 32
F = 40.5 + 32 = 72.5°F

Answer: 72.5°F

Chapter Complete!

You've worked through every MCQ, short answer, constructed response, comprehensive question, and numerical problem in Chapter 07 — Thermal Properties of Matter. Keep practicing and keep shining!

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