PHYSICAL SCIENCE

Heat & Temperature

Complete Study Notes with Diagrams, Tables and 50 MCQs
For West Bengal Government Job Examinations: WBP, WBPSC, SSC, Railway, Group D, Banking and other competitive exams

Topics Covered in this Chapter

No.	Topic	Key Areas
1	Heat and Temperature	Definitions, units, temperature scales, conversion formulas, thermometers
2	Modes of Heat Transfer	Conduction, Convection and Radiation, laws, daily-life examples
3	Thermal Expansion	Linear, area and volume expansion, anomalous expansion of water, applications
4	Specific Heat	Heat capacity, water equivalent, principle of calorimetry, Cp and Cv
5	Change of State	Latent heat, melting, boiling, evaporation, sublimation, heating curve
6	Practice Section	Important formulas, quick revision facts, 50 MCQs with answer key

How to use these notes

- Read each topic once, then study the tables and the boxes marked "Exam Focus" carefully; most exam questions are taken from them.
- Remember the units and standard values (for example, 4200 J/kg·K for water, 80 cal/g for ice); numerical questions are based on these.
- Attempt the 50 MCQs at the end and check your answers with the answer key.

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1. Heat and Temperature

Heat is a form of energy that flows from a body at higher temperature to a body at lower temperature. It is the total thermal energy (kinetic plus potential energy of the molecules) contained in a body. Heat is energy in transit: it exists only while it is flowing because of a temperature difference.

Temperature is the degree of hotness or coldness of a body. It is a measure of the average kinetic energy of the molecules of the body and it decides the direction of flow of heat. Heat always flows from the body of higher temperature to the body of lower temperature, until both reach the same temperature (thermal equilibrium).

1.1 Difference between Heat and Temperature

Basis	Heat	Temperature
Meaning	Total thermal energy of all the molecules of a body	Degree of hotness or coldness; average kinetic energy per molecule
Nature	A form of energy	A physical quantity that shows the thermal state of a body
Depends on mass	Yes, depends on the mass and the nature of the substance	No, does not depend on the mass
SI unit	Joule (J)	Kelvin (K)
Other units	Calorie, kilocalorie, BTU	Degree Celsius (°C), degree Fahrenheit (°F)
Measured by	Calorimeter	Thermometer
Role	Heat flows because of temperature difference	Temperature decides the direction of heat flow

1.2 Units of Heat

- **SI unit:** joule (J).
- **Calorie (cal):** the heat needed to raise the temperature of 1 gram of water by 1 °C (from 14.5 °C to 15.5 °C).
- **1 calorie = 4.186 J** (approximately 4.2 J). This value is called the mechanical equivalent of heat (Joule's constant).
- **1 kilocalorie (kcal) = 1000 cal = 4186 J.** The "Calorie" used for food energy is actually a kilocalorie.
- **1 BTU** (British Thermal Unit) is approximately 252 cal or 1055 J.

1.3 Temperature Scales

A temperature scale is made from two fixed points: the **lower fixed point** (ice point, the melting point of pure ice at normal pressure) and the **upper fixed point** (steam point, the boiling point of pure water at normal pressure). The gap between them is divided into equal parts.

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Scale	Lower fixed point	Upper fixed point	Number of divisions	Remark
Celsius (°C)	0 °C	100 °C	100	Used in daily life and science
Fahrenheit (°F)	32 °F	212 °F	180	Used in USA and for body temperature in many places
Kelvin (K)	273.15 K (about 273 K)	373.15 K (about 373 K)	100	SI scale; no negative values; starts at absolute zero
Reaumur (°R)	0 °R	80 °R	80	Old scale, asked occasionally

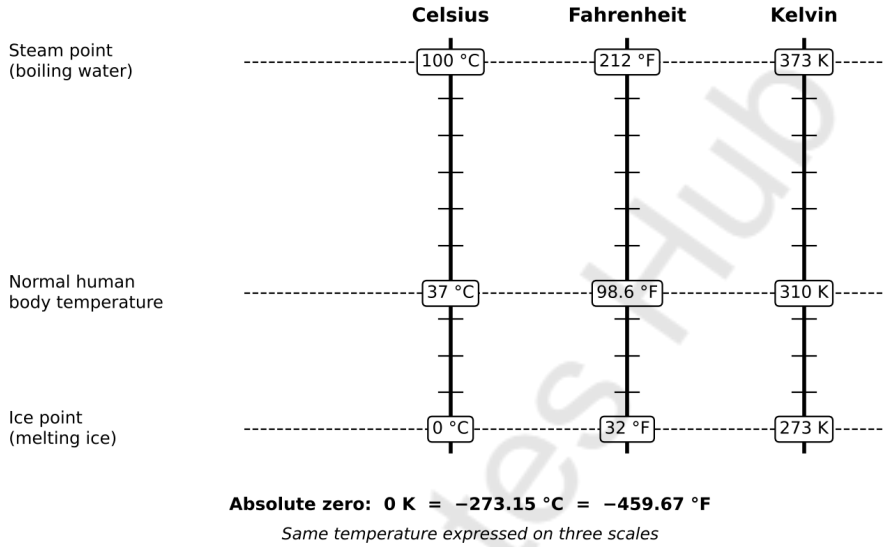


Fig. 1: Fixed points on the Celsius, Fahrenheit and Kelvin scales

Conversion Formula

C / 5 = (F − 32) / 9 = (K − 273) / 5 = R / 4

- Celsius to Fahrenheit: **F = (9/5) × C + 32**
- Fahrenheit to Celsius: **C = (5/9) × (F − 32)**
- Celsius to Kelvin: **K = C + 273** (more precisely C + 273.15)
- A change of 1 °C is equal to a change of 1 K, and a change of 1 °C is equal to a change of 1.8 °F.

Example 1. Convert 50 °C into Fahrenheit. F = (9/5) × 50 + 32 = 90 + 32 = **122 °F**.

Example 2. Convert 98.6 °F into Celsius. C = (5/9) × (98.6 − 32) = (5/9) × 66.6 = **37 °C**.

Exam Focus: Important Temperature Facts

- **−40 ° is the same on both** the Celsius and Fahrenheit scales (−40 °C = −40 °F).
- Normal human body temperature: **37 °C = 98.6 °F = 310 K**.
- **Absolute zero** = 0 K = −273.15 °C = −459.67 °F. It is the lowest possible temperature; molecular motion is minimum.
- Kelvin is the SI unit of temperature. It is written as K, without the degree symbol.
- Temperature of the Sun's surface is about 5800 K (6000 K approx.), while its core is about 15 million K.

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1.4 Thermometers

A thermometer is an instrument that measures temperature. Different thermometers work on different physical principles.

Thermometer	Principle	Range / Use
Mercury thermometer	Uniform expansion of mercury with temperature	About −39 °C to 357 °C; laboratory and general use
Alcohol thermometer	Expansion of alcohol (coloured)	Down to about −114 °C; used in very cold regions
Clinical thermometer	Mercury with a constriction (kink) that stops mercury from falling back	35 °C to 42 °C (94 °F to 108 °F); body temperature
Six's max-min thermometer	Expansion of alcohol and mercury	Records maximum and minimum temperature of a day (meteorology)
Platinum resistance thermometer	Change of electrical resistance with temperature	About −200 °C to 1200 °C; accurate
Thermocouple	Seebeck effect (emf produced at the junction of two metals)	Very wide range; used up to about 1600 °C
Pyrometer	Thermal radiation emitted by the hot body; no contact needed	Very high temperatures such as furnaces, molten metal, stars
Constant-volume gas thermometer	Pressure of a gas changes with temperature	Standard thermometer, most accurate; used to calibrate others

- **Why mercury is used:** it expands uniformly, does not wet glass, is opaque and shiny (easy to read), has a high boiling point (357 °C) and is a good conductor of heat.
- **Why alcohol is used for low temperatures:** its freezing point (about −114 °C) is much lower than that of mercury (−39 °C).
- The clinical thermometer is **not** placed in boiling water because its maximum range is 42 °C; it would break.

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2. Modes of Heat Transfer

Heat travels from one place to another in three ways: **conduction, convection and radiation**. In most real situations, more than one mode acts at the same time.

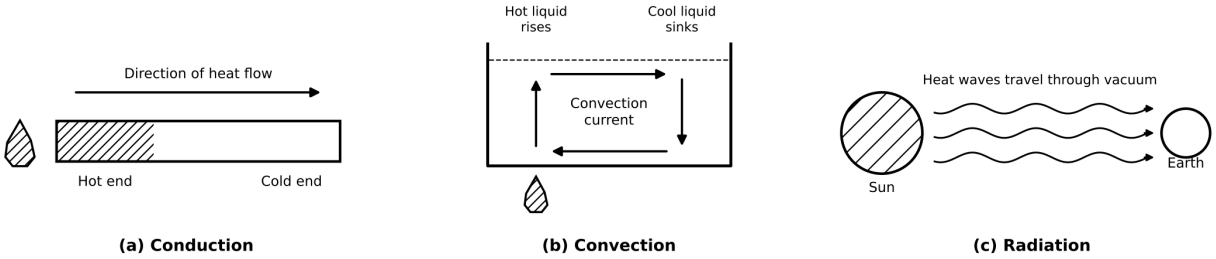


Fig. 2: The three modes of heat transfer

Basis	Conduction	Convection	Radiation
Medium needed	Yes (material medium)	Yes (fluid medium)	**No** (can pass through vacuum)
How heat moves	Molecules vibrate and pass energy to neighbours; molecules do not leave their positions	Heated molecules themselves move from one place to another	Electromagnetic waves (mainly infrared)
Speed	Slow	Moderate	Fastest: speed of light (3×10^8 m/s)
Occurs in	Mostly solids (best in metals)	Liquids and gases only	All states and vacuum
Example	Heating of a metal rod	Boiling water, sea breeze	Heat from the Sun, a room heater

2.1 Conduction

Conduction is the transfer of heat through a substance from the hotter part to the colder part without any actual movement of the particles of the substance. It takes place mainly in solids.

- **Good conductors** (conductors of heat): silver, copper, gold, aluminium, iron and other metals. **Silver is the best conductor of heat**, followed by copper.
- **Poor conductors** (insulators): wood, glass, plastic, rubber, wool, asbestos, air, water, ebonite, cork and sawdust.
- Liquids are poor conductors (mercury is an exception: it is a good conductor among liquids). **Gases are the poorest conductors.**
- **Rate of conduction (Fourier's law):** $Q / t = K \times A \times (T_1 - T_2) / d$, where K = coefficient of thermal conductivity, A = area of cross-section, d = length (thickness) and $(T_1 - T_2)$ = temperature difference.
- The SI unit of thermal conductivity is **W/m·K**.

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Material	Thermal conductivity (W/m·K), approximate	Type
Silver	429	Best conductor
Copper	401	Very good conductor
Gold	318	Very good conductor
Aluminium	237	Good conductor
Iron	80	Good conductor
Lead	35	Poor conductor among metals
Glass	1.0	Poor conductor
Water	0.6	Poor conductor
Wood	0.1 to 0.2	Insulator
Air	0.026	Very poor conductor (best insulator here)

Everyday Examples of Conduction

- Cooking utensils have **metal bottoms** (good conductors) and **wooden or plastic handles** (poor conductors).
- A metal spoon or iron rod feels **colder than wood** at the same room temperature, because metal is a good conductor and quickly draws heat away from the hand.
- **Woolen clothes** keep us warm in winter because the air trapped between the fibres is a poor conductor and stops body heat from escaping. Birds fluff their feathers in cold weather for the same reason.
- Ice is packed in **sawdust** to prevent it from melting quickly, because sawdust is a poor conductor.
- **Igloos** (houses of ice) are warm inside because ice and trapped air are poor conductors.
- **Davy's safety lamp** uses a wire gauze that conducts heat away rapidly, so the flame cannot ignite the explosive gases in mines.

2.2 Convection

Convection is the transfer of heat in liquids and gases by the actual movement of the heated particles. When a fluid is heated from below, the hot part becomes lighter (less dense) and rises, while the cooler, denser fluid sinks to take its place. This circulation is called a **convection current**.

- **Natural convection:** motion of the fluid is caused by differences in density (example: boiling water, sea breeze).
- **Forced convection:** the fluid is made to move by a fan, blower or pump (example: hair dryer, air cooler, radiator fan, human blood circulation).
- Convection **cannot take place in solids** and in a vacuum.

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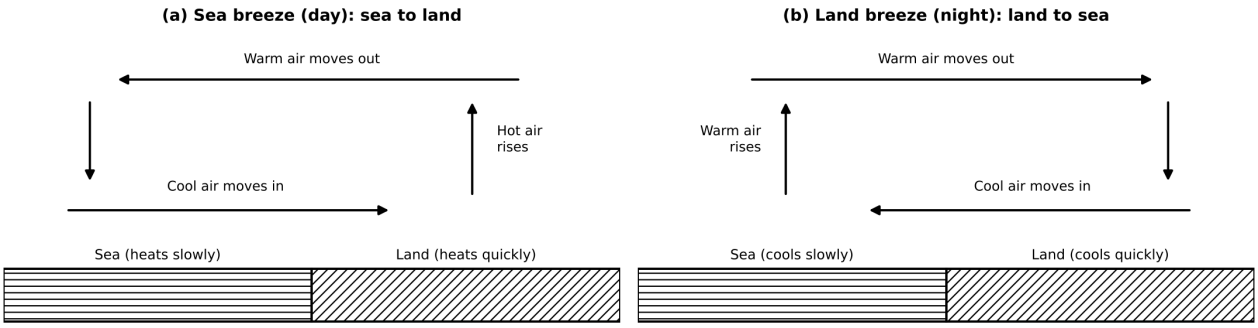


Fig. 3: Sea breeze and land breeze are examples of natural convection

Everyday Examples of Convection

- **Sea breeze (day):** land heats up faster than the sea, so hot air over the land rises and cool air from the sea blows towards the land.
- **Land breeze (night):** land cools faster than the sea, so the warmer air over the sea rises and the air from the land blows towards the sea.
- **Heaters** are fixed near the floor and **air conditioners** near the ceiling for proper circulation of air in a room.
- In a refrigerator the **freezer is at the top** so that cold, dense air sinks and cools the entire cabinet.
- **Ventilators** are made near the roof to let hot air escape. Chimneys work on convection.
- Heating elements of a **geyser, kettle and water boiler** are placed at the bottom.
- Winds, monsoons, trade winds, ocean currents and the movement of magma in the Earth's mantle are caused by convection.
- **Hot air balloons** rise because the heated air inside is lighter than the surrounding air.

2.3 Radiation

Radiation is the transfer of heat in the form of electromagnetic waves (mainly infrared rays) without the need of any material medium. It is the only mode of heat transfer that can take place through a vacuum. The heat of the Sun reaches the Earth by radiation; the light and heat take about **8 minutes 20 seconds** to travel from the Sun to the Earth.

- Radiated heat travels in a straight line with the **speed of light** (3×10^8 m/s).
- A **good absorber is also a good emitter** (Kirchhoff's law). Dark, rough and black surfaces absorb and emit heat well; white, smooth and shiny surfaces reflect heat and are poor absorbers.
- A **black body** is an ideal body that absorbs all the radiation falling on it and emits the maximum possible radiation at a given temperature.
- **Stefan's law (Stefan-Boltzmann law):** the total energy radiated per second per unit area of a black body is directly proportional to the **fourth power** of its absolute temperature: $E = \sigma T^4$, where $\sigma = 5.67 \times 10^{-8}$ W/m^{2}K^4.
- **Wien's displacement law:** $\lambda_{max} \times T$ = constant (2.898×10^{-3} m·K). As the temperature of a body increases, the wavelength of maximum emission becomes shorter. It is used to find the temperature of the Sun and stars.
- **Newton's law of cooling:** the rate of loss of heat of a body is proportional to the difference between its temperature and that of the surroundings.

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Everyday Examples of Radiation

- We wear **white or light-coloured clothes in summer** (they reflect heat) and **dark clothes in winter** (they absorb heat).
- **Solar cookers** and solar heaters have blackened surfaces to absorb maximum solar radiation.
- **Greenhouse effect:** glass lets the Sun's short-wavelength radiation in, but traps the long-wavelength infrared radiation emitted by the ground. Greenhouse gases such as carbon dioxide and methane cause global warming in the same way.
- Kerosene stoves, cooking vessels and radiators are often painted black; water tanks and aeroplanes are painted white or silver to reduce heat absorption.

Thermos Flask (Dewar Flask)

A thermos flask keeps hot liquids hot and cold liquids cold by reducing all three modes of heat transfer.

Part of the flask	Mode of heat transfer reduced
Vacuum between the double glass walls	Conduction and convection (no medium)
Silvered (shiny) inner surfaces of the walls	Radiation (heat is reflected back)
Cork or plastic stopper and supports	Conduction (poor conductors)

Exam Focus: Modes of Heat Transfer

- Conduction: solids | Convection: liquids and gases | Radiation: no medium needed.
- Sun to Earth: radiation. Sea breeze: convection. Heating of a metal rod: conduction.
- Best conductor of heat: silver. Best insulator among common materials: air (gases are poorest conductors).
- Stefan's law: E is proportional to T^4. Wien's law: $\lambda_{max} \times T$ = constant.
- Thermos flask prevents conduction, convection and radiation.

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3. Thermal Expansion

Thermal expansion is the increase in the size (length, area or volume) of a substance when it is heated. When a substance is heated, its molecules vibrate with larger amplitude and move slightly farther apart, so the body expands. On cooling, the body contracts. Gases expand the most, liquids expand less than gases, and solids expand the least for the same rise in temperature.

3.1 Types of Expansion in Solids

Type	Formula	Coefficient	Meaning of coefficient
Linear expansion (length)	$\Delta L = \alpha L_0 \Delta T$ $L = L_0 (1 + \alpha\Delta T)$	α (alpha)	Fractional increase in length per degree rise in temperature
Superficial expansion (area)	$\Delta A = \beta A_0 \Delta T$	β (beta)	Fractional increase in area per degree rise
Cubical expansion (volume)	$\Delta V = \gamma V_0 \Delta T$	γ (gamma)	Fractional increase in volume per degree rise

Important Relations

- **α : β : γ = 1 : 2 : 3**, that is β = 2α and γ = 3α.
- Unit of the coefficients: per °C or per K (**$°C^{-1}$ or K^{-1}**).
- A hole in a plate expands exactly as if it were made of the same material as the plate (the hole becomes larger on heating).
- For the same rise in temperature: **gases > liquids > solids** in expansion.

Example 3. An iron rail is 20 m long at 20 °C. What is the increase in length at 50 °C if $\alpha = 12 \times 10^{-6}$ $°C^{-1}$? $\Delta L = \alpha L_0 \Delta T = 12 \times 10^{-6} \times 20 \times 30 = 7.2 \times 10^{-3}$ m = **7.2 mm**.

Substance	α (× 10^{-6} per °C), approximate
Zinc	30
Lead	29
Aluminium	23
Brass	19
Copper	17
Iron / Steel	12
Concrete	12
Ordinary glass	9
Pyrex glass	3.3
Invar (nickel-iron alloy)	about 1 (very small)

3.2 Expansion of Liquids

- Liquids have only volume expansion because they have no definite shape.
- Liquids expand much more than solids. A liquid is always kept in a container, which also expands, so we get two types of expansion:
- **Apparent expansion:** the expansion seen by an observer, ignoring the expansion of the container.
- **Real (absolute) expansion:** the actual expansion of the liquid. $\gamma_{real} = \gamma_{apparent} + \gamma_{vessel}$.

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- A mercury thermometer works because mercury expands more than the glass tube.

3.3 Expansion of Gases

- Gases have large expansion. **Charles's law:** at constant pressure, the volume of a fixed mass of gas is directly proportional to its absolute temperature (V / T = constant).
- The volume coefficient of expansion of all ideal gases at constant pressure is **1/273 per °C**.
- $V_t = V_0 (1 + t / 273)$, where V_0 is the volume at 0 °C.

3.4 Anomalous Expansion of Water

Most liquids contract on cooling and their density keeps increasing. Water behaves differently between 0 °C and 4 °C. When water is heated from 0 °C to 4 °C it **contracts** instead of expanding; above 4 °C it expands normally. Hence water has its **minimum volume and maximum density (1000 kg/m^3 or 1 g/cm^3) at 4 °C**. This unusual behaviour is called the anomalous expansion of water.

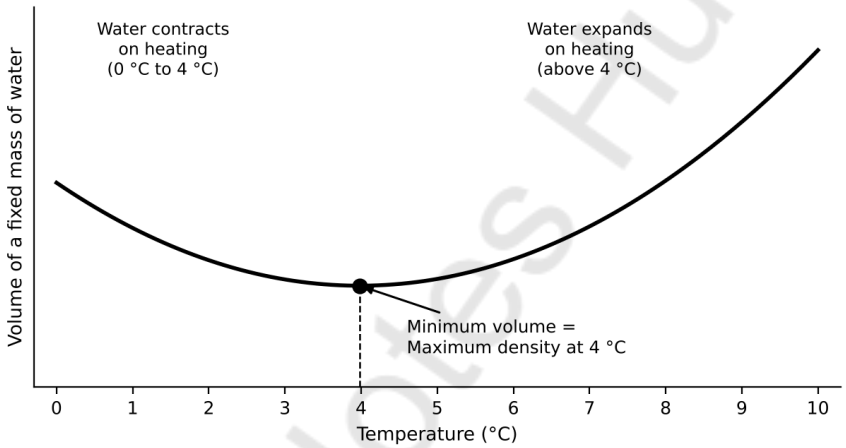


Fig. 4: Anomalous expansion of water (volume is minimum at 4 °C)

Consequences of Anomalous Expansion of Water

- In cold countries the water of lakes and ponds freezes only at the **top**. The water at the bottom stays at 4 °C, so fish and other aquatic life survive.
- **Ice floats on water** because its density (about 917 kg/m^3) is less than that of water. Water expands by about 9% when it freezes.
- Water pipes and bottles filled with water **burst** in freezing weather, and water in rock cracks can split rocks when it freezes.
- Other substances that expand on freezing: bismuth, antimony and cast iron.

3.5 Applications and Precautions of Thermal Expansion

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Situation	Reason / Principle
Small gaps are left between railway tracks	To allow the rails to expand in summer; otherwise they would bend (buckle)
Expansion joints in bridges and concrete roads	To avoid cracks due to expansion and contraction
Telephone and electric wires are left slightly loose (sagging) in summer	To allow for contraction in winter, which would otherwise snap the wires
An iron rim is heated before fitting on a wooden cartwheel	On cooling the iron rim contracts and grips the wheel tightly
Rivets are fixed in a red-hot condition	On cooling they contract and join the plates tightly
A thick glass breaks when hot water is poured suddenly	Uneven expansion of the inner and outer surfaces; Pyrex glass (low α) is used to avoid this
Pendulum clocks use invar	Invar has a very small coefficient of expansion, so the length of the pendulum and time keeping stay constant
A metal lid stuck on a glass jar can be loosened by pouring hot water on the lid	The metal lid expands more than the glass
Bimetallic strip in thermostats, fire alarms and electric irons	Two metals with different α bend on heating and switch the circuit on or off

Bimetallic Strip

A bimetallic strip is made by joining two different metals (for example, brass and iron) of the same length. Because they have different coefficients of linear expansion, the strip bends when the temperature changes. The metal with the **greater** coefficient of expansion (brass) lies on the **outer (convex)** side when the strip is heated.

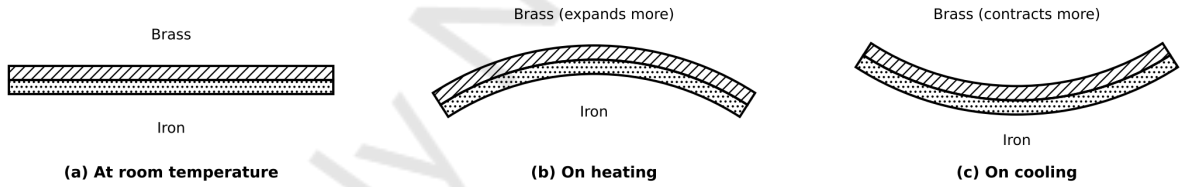


Fig. 5: Bending of a bimetallic strip (brass and iron)

Exam Focus: Thermal Expansion

- α : β : γ = 1 : 2 : 3. Coefficient of cubical expansion of ideal gas = 1/273 per °C.
- Water: maximum density and minimum volume at 4 °C. Ice floats because it is less dense than water.
- Invar (nickel-iron alloy) has the lowest expansion; used in pendulums and measuring tapes.
- Gases expand most, then liquids, then solids.
- Gaps in rail tracks, expansion joints in bridges and bimetallic strips are favourite exam topics.

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4. Specific Heat

When equal amounts of heat are supplied to equal masses of different substances, their temperatures rise by different amounts. This happens because each substance has its own **specific heat**.

Specific heat (specific heat capacity) of a substance is the amount of heat required to raise the temperature of **1 kg** of the substance by **1 °C (or 1 K)**.

Key Formula

- **Q = m × c × ΔT**, where Q = heat absorbed or released, m = mass, c = specific heat and ΔT = change in temperature.
- SI unit of specific heat: **J/kg·K** (or J kg^{-1} K^{-1}). CGS unit: cal/g·°C.
- Specific heat of water = **4200 J/kg·K** (exactly 4186) = **1 cal/g·°C** = 1 kcal/kg·°C.

4.1 Specific Heat of Some Substances

Substance	Specific heat (J/kg·K), approximate	Remark
Water	4200	Highest among common liquids
Ice	2100	Half that of water
Steam	2000	Specific heat changes with the state
Alcohol	2400	
Aluminium	900	
Sand / Glass	840	Low; heats up and cools down quickly
Iron	450	
Copper	390	
Silver	235	
Mercury	140	Low; hence it responds quickly to temperature change
Lead	130	
Gold	129	

4.2 Heat Capacity and Water Equivalent

Term	Definition	Formula	Unit
Heat capacity (thermal capacity)	Heat required to raise the temperature of the whole body by 1 °C	C = m × c	J/K (or cal/°C)
Water equivalent	Mass of water that requires the same amount of heat as the body for the same rise in temperature	W = m × c (in grams if c is in cal/g°C)	kg or g

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4.3 Principle of Calorimetry

When two bodies at different temperatures are mixed (and no heat is lost to the surroundings), **heat lost by the hot body = heat gained by the cold body**. This is based on the law of conservation of energy. The final temperature of the mixture is:

$$\mathbf{T = (m_1c_1T_1 + m_2c_2T_2) / (m_1c_1 + m_2c_2)}$$

Example 4. Heat needed to raise 2 kg of water from 20 °C to 70 °C: Q = m c ΔT = 2 × 4200 × 50 = 420000 J = **420 kJ**.

Example 5. 1 kg of water at 80 °C is mixed with 1 kg of water at 20 °C. Final temperature = (80 + 20) / 2 = **50 °C**.

Example 6. Heat capacity of 500 g of copper (c = 390 J/kg·K): C = m c = 0.5 × 390 = **195 J/K**.

4.4 Importance of the High Specific Heat of Water

- **Moderate climate of coastal areas:** water heats up and cools down slowly, so places near the sea do not have large differences between day and night or summer and winter temperatures.
- **Deserts** are very hot in the day and very cold at night because sand has a low specific heat and changes temperature quickly.
- Water is used as a **coolant** in car radiators and power plants, because it can absorb a large amount of heat with a small rise in its own temperature.
- Water is used in **hot-water bottles** and for central heating because it releases a large amount of heat while cooling.
- The **sea breeze** is caused by the difference in specific heat of land and water.
- Our body, which is about 60 to 70% water, can maintain a nearly steady temperature.

4.5 Specific Heats of a Gas: C_p and C_v

- $\mathbf{C_v}$ is the specific heat of a gas at constant volume; $\mathbf{C_p}$ is the specific heat at constant pressure.
- C_p is always greater than C_v, because at constant pressure the gas also does work in expanding.
- **Mayer's relation:** $C_p - C_v = R$ (for one mole of an ideal gas; R = 8.31 J/mol·K).
- Ratio of specific heats: $\boldsymbol{\gamma = C_p / C_v}$.

Type of gas	Example	$\gamma = C_p/C_v$
Monoatomic	Helium, Neon, Argon	1.67 (5/3)
Diatomic	Hydrogen, Oxygen, Nitrogen	1.40 (7/5)
Triatomic (non-linear)	Water vapour, Methane	1.33 (4/3)

Exam Focus: Specific Heat

- Q = m c ΔT. Specific heat of water = 4200 J/kg·K = 1 cal/g·°C (highest among common liquids).
- Heat capacity = m × c. Unit: J/K.
- Low specific heat: heats quickly and cools quickly (sand, metals). High specific heat: heats slowly and cools slowly (water).
- $C_p - C_v = R$. γ is 1.67 (monoatomic) and 1.40 (diatomic).

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5. Change of State

Matter exists in three common states: **solid, liquid and gas** (the fourth state is plasma). A substance changes from one state to another when heat is given to it or taken from it, at a fixed temperature and pressure. This is called a **change of state** (phase change).

Process	Change	Heat	Example
Melting (fusion)	Solid to liquid	Absorbed	Ice melts into water
Freezing (solidification)	Liquid to solid	Released	Water freezes into ice
Vaporization	Liquid to gas (vapour)	Absorbed	Water changes to steam
Condensation	Gas to liquid	Released	Dew, cloud formation
Sublimation	Solid directly to gas	Absorbed	Camphor, naphthalene, dry ice
Deposition	Gas directly to solid	Released	Frost formation

5.1 Latent Heat

Latent heat is the amount of heat absorbed or released by a substance during a change of state **without any change in its temperature**. The heat given is used to break the bonds between molecules (it changes the potential energy), not to increase the kinetic energy.

Key Formula

- **$Q = m \times L$**, where L = latent heat (heat per unit mass). SI unit: **J/kg**.
- **Latent heat of fusion of ice = 3.34×10^5 J/kg** (336 kJ/kg) = **80 cal/g**.
- **Latent heat of vaporization of water = 2.26×10^6 J/kg** (2260 kJ/kg) = **540 cal/g**.

- **Steam at 100 °C causes a more severe burn than boiling water at 100 °C** because steam carries the extra latent heat of vaporization (540 cal/g), which it releases on condensing on the skin.
- **Ice at 0 °C cools a drink better than water at 0 °C** because ice absorbs the latent heat of fusion (80 cal/g) while melting.
- The temperature of a substance **remains constant** during melting and boiling, even though heat is being supplied.

5.2 Melting and Boiling Points

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Substance	Melting point (°C)	Boiling point (°C)
Water	0	100
Ethyl alcohol	−114	78
Mercury	−39	357
Lead	327	1749
Aluminium	660	2470
Copper	1085	2562
Iron	1538	2862
Tungsten	3422 (highest among metals)	5555
Oxygen	−219	−183
Nitrogen	−210	−196
Hydrogen	−259	−253

Values are approximate, at normal atmospheric pressure (1 atm).

5.3 Heating Curve of Ice

When 1 kg of ice at −20 °C is heated continuously, its temperature changes as shown below. The flat portions (BC and DE) show change of state, where heat is absorbed but the temperature stays constant.

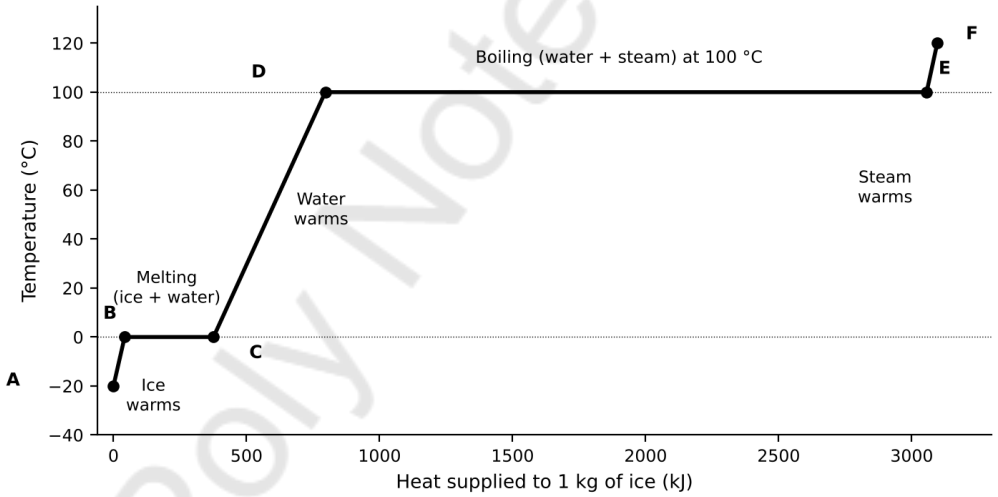


Fig. 6: Heating curve of ice (1 kg) showing change of state

Stage	What happens	Heat required (for 1 kg)
A to B	Ice warms from −20 °C to 0 °C	1 × 2100 × 20 = 42 kJ
B to C	Ice melts at 0 °C (latent heat of fusion)	1 × 334 = about 334 kJ
C to D	Water warms from 0 °C to 100 °C	1 × 4200 × 100 = 420 kJ
D to E	Water boils at 100 °C (latent heat of vaporization)	1 × 2260 = 2260 kJ
E to F	Steam warms above 100 °C	1 × 2000 × 20 = 40 kJ

Example 7. Heat needed to convert 100 g of ice at 0 °C into water at 20 °C: $Q = m\,L + m\,c\,\Delta T = 0.1 \times 3.34 \times 10^5 + 0.1 \times 4200 \times 20 = 33400 + 8400 =$ **41800 J**.

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5.4 Evaporation and Boiling

Basis	Evaporation	Boiling
Temperature	Takes place at any temperature, below the boiling point	Takes place only at the boiling point
Place	Only at the surface of the liquid	Throughout the liquid (bubbles form)
Speed	Slow process	Fast process
Cooling	Causes cooling	No cooling; heat must be supplied continuously
Source of heat	Taken from the liquid itself or its surroundings	Supplied from an external source

Factors Affecting Evaporation

- **Surface area:** larger the area, faster the evaporation.
- **Temperature:** higher the temperature, faster the evaporation.
- **Humidity:** lower the humidity (dry air), faster the evaporation.
- **Wind speed:** faster the wind, faster the evaporation.
- **Nature of the liquid:** volatile liquids (alcohol, petrol, acetone) evaporate faster than water.

Cooling Caused by Evaporation

- We feel cool when **sweat evaporates** from our body.
- Water kept in an **earthen pot (matka)** stays cool because water evaporates through the tiny pores.
- Acetone or spirit feels cold on the skin because it evaporates quickly and takes heat from the skin.
- A wet cloth placed on the forehead of a person with fever lowers the body temperature.
- Desert coolers work better in **dry** weather than in humid weather. In humid weather sweat does not evaporate easily, so we feel sticky and uncomfortable.

5.5 Effect of Pressure and Impurities

Factor	Effect	Application / Example
Increase in pressure on a liquid	Boiling point **rises**	Pressure cooker: water boils at about 120 °C, so food cooks faster
Decrease in pressure (high altitude)	Boiling point **falls**	On high mountains water boils below 100 °C, so cooking takes longer
Reduced pressure in vacuum pans	Boiling at low temperature	Used in sugar and milk industries to avoid burning
Increase in pressure on ice	Melting point of ice **falls**	Regelation: a wire passes through an ice block; ice skating is possible
Dissolved salt or impurity	Freezing point **falls** (depression) and boiling point **rises** (elevation)	Salt is sprinkled on icy roads; ice and salt mixture (freezing mixture) gives about −22 °C

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5.6 Sublimation, Humidity and Special Points

- **Sublimation:** camphor, naphthalene, iodine, ammonium chloride and dry ice change directly from solid to gas.
- **Dry ice** is solid carbon dioxide. It sublimes at −78.5 °C and is used to keep ice cream and food frozen during transport.
- **Humidity** is the amount of water vapour in the air. **Relative humidity** = (actual amount of vapour in the air / amount needed for saturation at that temperature) × 100%. It is measured by a **hygrometer**.
- **Dew point** is the temperature at which air becomes saturated and water vapour starts condensing into dew.
- **Triple point of water:** the unique temperature and pressure where ice, water and vapour exist together: **273.16 K (0.01 °C) and 611.7 Pa**.
- **Critical temperature** is the temperature above which a gas cannot be liquefied by pressure alone (carbon dioxide: 31 °C; water: 374 °C).

Exam Focus: Change of State

- Latent heat of fusion of ice: 80 cal/g (336 kJ/kg). Latent heat of vaporization of water: 540 cal/g (2260 kJ/kg).
- Temperature remains constant during change of state.
- Boiling point rises with pressure (pressure cooker); it falls at high altitudes.
- Evaporation causes cooling. Steam burns are more severe than boiling water burns.
- Sublimation: camphor, naphthalene, dry ice. Triple point of water: 273.16 K.

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Important Formulas and Values at a Glance

Topic	Formula / Value
Temperature conversion	$C/5 = (F - 32)/9 = (K - 273)/5$
Mechanical equivalent of heat	1 cal = 4.186 J (about 4.2 J)
Heat conduction (Fourier)	$Q/t = K\,A\,(T_1 - T_2) / d$
Stefan's law	$E = \sigma T^4$; $\sigma = 5.67 \times 10^{-8}$ W/m^{2}K^4
Wien's law	$\lambda_{max}\,T = 2.898 \times 10^{-3}$ m·K
Linear expansion	$\Delta L = \alpha\,L_0\,\Delta T$
Relation of coefficients	$\alpha : \beta : \gamma = 1 : 2 : 3$
Charles's law	V/T = constant (at constant pressure)
Heat absorbed or released	$Q = m\,c\,\Delta T$
Heat capacity	$C = m\,c$
Principle of calorimetry	Heat lost = Heat gained
Latent heat	$Q = m\,L$
Mayer's relation	$C_p - C_v = R$
Specific heat of water	4200 J/kg·K = 1 cal/g·°C
Latent heat of fusion of ice	3.34×10^5 J/kg = 80 cal/g
Latent heat of vaporization of water	2.26×10^6 J/kg = 540 cal/g

Quick Revision: One-Line Facts

- The SI unit of heat is the joule and of temperature is the kelvin.
- Heat flows from a body at higher temperature to one at lower temperature.
- The Celsius and Fahrenheit scales read the same at −40 degrees.
- Absolute zero is −273.15 °C (0 K); the Kelvin scale has no negative temperature.
- Normal body temperature is 37 °C or 98.6 °F; the clinical thermometer range is 35 °C to 42 °C.
- Pyrometer measures very high temperatures without touching the body.
- Conduction occurs in solids, convection in fluids and radiation does not need a medium.
- Silver is the best conductor of heat; air and other gases are very poor conductors.
- Sea breeze and land breeze are due to convection; the Sun's heat reaches us by radiation.
- Dark surfaces absorb and emit heat better; white and shiny surfaces reflect heat.
- A thermos flask reduces conduction, convection and radiation.
- For the same temperature rise, gases expand more than liquids, and liquids more than solids.
- Water has maximum density at 4 °C; ice floats on water.
- Invar has a very low expansion; bimetallic strips are used in thermostats and fire alarms.
- Water has a very high specific heat (4200 J/kg·K), so coastal areas have a moderate climate.
- Latent heat of ice is 80 cal/g and of steam is 540 cal/g.
- Temperature stays constant during a change of state.
- Boiling point increases with pressure and decreases at high altitude.
- Evaporation causes cooling and takes place at all temperatures.
- Sublimation: solid directly into gas (camphor, naphthalene, dry ice).

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50 Multiple Choice Questions (MCQs)

Choose the correct option. The answer key is given at the end.

1. The SI unit of heat is:

(A) Calorie (B) Joule
(C) Kelvin (D) Watt

2. The SI unit of temperature is:

(A) Fahrenheit (B) Celsius
(C) Kelvin (D) Calorie

3. Heat flows from one body to another because of the difference in their:

(A) Masses (B) Temperatures
(C) Volumes (D) Specific heats

4. At which temperature do the Celsius and Fahrenheit scales show the same reading?

(A) 0 degrees (B) −40 degrees
(C) 40 degrees (D) −273 degrees

5. Normal human body temperature on the Fahrenheit scale is:

(A) 96.8 °F (B) 97.6 °F
(C) 98.6 °F (D) 99.6 °F

6. Absolute zero is equal to:

(A) 0 °C (B) −100 °C
(C) −273.15 °C (D) −373 °C

7. 1 calorie is approximately equal to:

(A) 1 J (B) 4.2 J
(C) 42 J (D) 0.24 J

8. The range of a clinical thermometer is:

(A) 0 °C to 100 °C (B) 35 °C to 42 °C
(C) 20 °C to 60 °C (D) 0 °C to 50 °C

9. Which instrument is used to measure the very high temperature of a furnace without touching it?

(A) Pyrometer (B) Mercury thermometer
(C) Clinical thermometer (D) Alcohol thermometer

10. Which liquid is preferred in thermometers used to measure very low temperatures, as in polar regions?

(A) Alcohol (B) Glycerine
(C) Mercury (D) Water

11. The mode of heat transfer that does not require any material medium is:

(A) Both conduction and convection (B) Convection
(C) Radiation (D) Conduction

12. Heat transfer in solids takes place mainly by:

(A) Convection (B) Conduction
(C) Radiation (D) Evaporation

13. The sea breeze is caused by:

(A) Convection (B) Evaporation
(C) Radiation (D) Conduction

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14. The heat of the Sun reaches the Earth by:

(A) Conduction
(B) Convection
(C) Radiation
(D) Conduction and convection

15. Which metal is the best conductor of heat?

(A) Silver
(B) Gold
(C) Aluminium
(D) Copper

16. Which of the following is a poor conductor of heat?

(A) Copper
(B) Iron
(C) Wood
(D) Aluminium

17. Cooking utensils have wooden or plastic handles because these materials are:

(A) Good conductors
(B) Light in weight
(C) Poor conductors
(D) Cheap

18. Woolen clothes keep us warm in winter because:

(A) Wool reflects the cold
(B) Wool produces heat
(C) Air trapped in the fibres is a poor conductor
(D) Wool is a good conductor

19. A metal spoon feels colder than a wooden spoon at the same temperature because metal is a:

(A) Denser material
(B) Good conductor
(C) Poor conductor
(D) Heavier material

20. In a refrigerator the freezer is kept at the top because:

(A) It prevents conduction
(B) It saves electricity
(C) Cold air rises
(D) Cold air, being denser, sinks and sets up convection currents

21. A thermos flask reduces the loss of heat by:

(A) Conduction only
(B) Convection only
(C) Radiation only
(D) Conduction, convection and radiation

22. Which colour is the best absorber of heat radiation?

(A) Black
(B) White
(C) Yellow
(D) Silver

23. According to Stefan's law, the energy radiated by a black body per unit area is proportional to:

(A) T
(B) T squared
(C) T cubed
(D) T to the power 4

24. Wien's displacement law is used to find the:

(A) Density of a liquid
(B) Temperature of the Sun and stars
(C) Speed of light
(D) Pressure of a gas

25. The relation between the coefficient of linear expansion (α) and the coefficient of cubical expansion (γ) is:

(A) $\gamma = \alpha$
(B) $\gamma = 2\alpha$
(C) $\gamma = 3\alpha$
(D) $\gamma = \alpha/3$

26. Small gaps are left between railway tracks to allow for:

(A) Thermal contraction only
(B) Sound insulation
(C) Thermal expansion
(D) Ventilation

27. A bimetallic strip is made of two metals which differ in their:

(A) Colour
(B) Melting point only
(C) Coefficient of linear expansion
(D) Density

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28. Water has its maximum density at:

(A) 0 °C
(B) 4 °C
(C) 10 °C
(D) 100 °C

29. Ice floats on water because the density of ice is:

(A) Zero
(B) More than water
(C) Equal to water
(D) Less than water

30. Fish survive in frozen lakes because of:

(A) High specific heat of water
(B) Conduction in ice
(C) High latent heat of water
(D) Anomalous expansion of water

31. For the same rise in temperature, which expands the most?

(A) All expand equally
(B) Gases
(C) Solids
(D) Liquids

32. The coefficient of volume expansion of an ideal gas at constant pressure is:

(A) 1/100 per °C
(B) 1/273 per °C
(C) 1/373 per °C
(D) 1/32 per °C

33. Invar is used in pendulum clocks because it has:

(A) High density
(B) High conductivity
(C) Very low coefficient of expansion
(D) Magnetic property

34. An iron rim is fitted on a wooden cartwheel when the rim is:

(A) Hot
(B) Wet
(C) Cold
(D) At 4 °C

35. The SI unit of specific heat is:

(A) J/kg
(B) J/K
(C) J/kg·K
(D) Calorie

36. The specific heat of water is:

(A) 4200 J/kg·K
(B) 2100 J/kg·K
(C) 900 J/kg·K
(D) 420 J/kg·K

37. Coastal areas have a moderate climate because water has a high:

(A) Surface tension
(B) Density
(C) Specific heat
(D) Viscosity

38. The heat required to raise the temperature of 2 kg of water by 10 °C is (c = 4200 J/kg·K):

(A) 8400 J
(B) 42000 J
(C) 84000 J
(D) 840000 J

39. Desert sand becomes very hot in the day and cold at night because it has a:

(A) High density
(B) High specific heat
(C) Low specific heat
(D) High latent heat

40. The heat capacity of a body of mass m and specific heat c is:

(A) $m \times c$
(B) c / m
(C) m / c
(D) $m \times c \times \Delta T$

41. For an ideal gas, $C_p - C_v$ is equal to:

(A) Zero
(B) R
(C) R/2
(D) 2R

42. The latent heat of fusion of ice is:

(A) 80 cal/g
(B) 540 cal/g
(C) 100 cal/g
(D) 4.2 cal/g

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43. The latent heat of vaporization of water is:

(A) 80 cal/g
(B) 540 cal/g
(C) 336 cal/g
(D) 100 cal/g

44. Steam at 100 °C causes more severe burns than boiling water at 100 °C because of its:

(A) High density
(B) Latent heat of vaporization
(C) High conductivity
(D) High specific heat

45. Evaporation of a liquid causes:

(A) Cooling
(B) No change in temperature
(C) Heating
(D) Increase in pressure

46. The boiling point of water at high altitudes is:

(A) Higher than 100 °C
(B) Lower than 100 °C
(C) Exactly 100 °C
(D) 0 °C

47. A pressure cooker cooks food faster because the increased pressure raises the:

(A) Melting point of food
(B) Boiling point of water
(C) Specific heat of water
(D) Latent heat of steam

48. The process in which a solid changes directly into a gas is called:

(A) Melting
(B) Sublimation
(C) Evaporation
(D) Condensation

49. Dry ice is the solid form of:

(A) Nitrogen
(B) Ammonia
(C) Carbon dioxide
(D) Water

50. During melting of ice at 0 °C, the heat supplied is used as:

(A) Heat capacity
(B) Increase in temperature
(C) Specific heat
(D) Latent heat

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Answer Key

1. B	**11.** C	**21.** D	**31.** B	**41.** B
2. C	**12.** B	**22.** A	**32.** B	**42.** A
3. B	**13.** A	**23.** D	**33.** C	**43.** B
4. B	**14.** C	**24.** B	**34.** A	**44.** B
5. C	**15.** A	**25.** C	**35.** C	**45.** A
6. C	**16.** C	**26.** C	**36.** A	**46.** B
7. B	**17.** C	**27.** C	**37.** C	**47.** B
8. B	**18.** C	**28.** B	**38.** C	**48.** B
9. A	**19.** B	**29.** D	**39.** C	**49.** C
10. A	**20.** D	**30.** D	**40.** A	**50.** D

Note: Practise these questions repeatedly and revise the tables and "Exam Focus" boxes before the examination. Visit **www.polynoteshub.co.in** for more free study materials for government job examinations.

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