STGT
PURE SCIENCE

Unit-wise Study Material with PYQ Analysis

VOLUME 2 — PHYSICS (Group-B Syllabus | Tripura STGT)

UNIT 5
HEAT

Complete theory · Derivations · Diagrams · Solved examples · All 25 PYQs (2016–2026) with solutions
Trend analysis · Predicted questions · Practice sets · Formula sheet · Quick revision

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UNIT 5

HEAT

SYLLABUS

Heat and temperature — definition and differences between them, Units of heat, Celsius and Fahrenheit Scale of temperature and their relationship with numerical problems. Thermometer (clinical and laboratory), Idea of Specific heat with unit, Principle of Calorimetry, definition of water equivalent and thermal capacity. (STGT Syllabus 2016 — Group-B, Topic 5)

INTRODUCTION

Touch a metal spoon left in hot tea and energy flows into your hand: that energy in transit is **heat**, and the property deciding its direction is **temperature**. This unit builds careful definitions of the two, the scales and thermometers that measure temperature, and the book-keeping of heat — specific heat, thermal capacity, water equivalent, latent heat — through the **principle of calorimetry**.

Historical background

- **Galileo** (~1593) built the first thermoscope — the earliest thermometer (asked in STGT 2019!).
- **Fahrenheit** (1724) made reliable mercury thermometers and his scale; **Celsius** (1742) introduced the centigrade scale; **Kelvin** (1848) defined the absolute scale.
- The 18th-century *caloric theory* treated heat as an invisible fluid; **Rumford** (cannon boring) and **James Joule** (paddle-wheel experiment, 1840s) established heat as a *form of energy*, with $1\,\text{cal} = 4.2\,\text{J}$ (mechanical equivalent).

Significance of this unit

- Celsius–Fahrenheit conversions are **guaranteed numericals** — five PYQs.
- Calorimetry (mixtures, ice–water–steam) gives the chapter's quantitative core — six PYQs.
- Definitions (thermal capacity, water equivalent, specific heat, critical temperature) supply quick one-mark wins.

EXAM FACT This chapter produced 25 of 286 Physics MCQs ($\approx 8.7\%$) in 2016–2026 — and it is accelerating: 0 questions in 2018 but 8 in 2026. The 2026 paper loved definitions (thermal capacity, calorimetry conditions, thermometer ranges) plus one full calorimeter numerical.

HEAT AND TEMPERATURE

Heat

Heat is energy in transit, flowing from a body at higher temperature to one at lower temperature when they are in thermal contact. Microscopically it is the **total** kinetic + potential energy of the random motion of *all* molecules.

- Scalar; SI unit **joule (J)**; practical unit **calorie**.
- **1 calorie** = heat needed to raise 1 g of water through $1\,^\circ\text{C}$ (from 14.5 to $15.5\,^\circ\text{C}$); $\boxed{1\,\text{cal} = 4.2\,\text{J}}$; 1 kcal = 1000 cal.
- Mechanical equivalent of heat: $W = JH$ with $J = 4.2\,\text{J cal}^{-1}$ — work and heat interconvert (Joule).

Temperature

Temperature is the degree of hotness or coldness of a body — the property that decides the *direction of heat flow*. Microscopically it measures the **average** translational kinetic energy of the molecules.

KEY POINT STGT 2026: heat and temperature differ because heat is the total energy of molecular motion while temperature is the average energy. A spark at $1000\,^\circ\text{C}$ carries far less heat than a bathtub at $40\,^\circ\text{C}$.

Thermal equilibrium

Heat flows only across a *temperature difference*. Bodies at the same temperature exchange no net heat — they are in **thermal equilibrium**. (STGT 2017: an iron ball at $50\,^\circ\text{C}$ dropped into water at $50\,^\circ\text{C}$ ⇒ **no heat flows**.)

Heat	Temperature
energy in transit due to temperature difference	degree of hotness/coldness; drives the flow
total molecular (kinetic + potential) energy	**average** molecular kinetic energy
measured by calorimeter; units J, cal	measured by thermometer; units °C, °F, K
depends on mass (extensive)	independent of mass (intensive)
dimensions $[ML^2T^{-2}]$	dimension [K] (base quantity)

Table 5.1 Heat vs temperature — the 2026 conceptual question in full.

STATES OF MATTER AND VAPOUR

Three PYQs (2019, 2022) come from this corner of the syllabus:

- **Why a gas fills its container (2019):** gas molecules have **large intermolecular spaces and high kinetic energy** with negligible attractions, so they wander through the whole volume.
- **Vapour vs gas (2019):** a substance in the gaseous state is called a **vapour** if it is normally a solid or liquid at room temperature (below its critical temperature) — *sulphur vapour*, water vapour. He, N_2, CO_2 at room temperature are true gases.
- **Critical temperature (2022):** the temperature **below** which a gas can be liquefied *by pressure alone*; above it, no pressure suffices.

EXAM FACT A thermostat (STGT 2019) is the automatic switch that *controls* temperature (bimetallic strip or sensor switching the circuit); a *pyrometer* only *measures* very high temperatures from radiation.

TEMPERATURE SCALES

A scale needs two **fixed points** — the *lower fixed point* (LFP, melting ice) and the *upper fixed point* (UFP, steam over boiling water at 1 atm) — and a number of divisions between them.

- **Celsius (centigrade):** LFP = 0 °C, UFP = 100 °C, 100 divisions.
- **Fahrenheit:** LFP = 32 °F, UFP = 212 °F, 180 divisions.
- **Kelvin (absolute):** $K = C + 273.15$ ($\approx C + 273$); LFP = 273 K, UFP = 373 K. No negative values; 0 K = −273 °C is the **absolute zero**.

The conversion relation (derive it once)

The fraction of the scale above the LFP must be equal on every scale:

$$\frac{C-0}{100} = \frac{F-32}{180} = \frac{K-273}{100}$$

$$\boxed{\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5}} \qquad F = \frac{9}{5}C + 32$$

Interval (difference) conversion: a *change* of 1 °C = a change of $\frac{9}{5}$ °F = a change of 1 K. So $\Delta C = 10\,°C \Rightarrow \Delta F = 18\,°F$ (STGT 2026: answer "None of the above"!).

The five asked patterns, worked

(a) 86 °F → °C (2017): $C = \frac{5(86-32)}{9} = \frac{5\times 54}{9} = 30\,°C$.

(b) **Equality point** $C = F$ **(2016):** set $x = \frac{9}{5}x + 32 \Rightarrow -\frac{4}{5}x = 32 \Rightarrow x = \boxed{-40}$. Only at −40° do both scales read the same.

(c) $F = 2C$ **(2022):** $2C = \frac{9}{5}C + 32 \Rightarrow \frac{C}{5} = 32 \Rightarrow C = 160$, $F = 320\,°F$. (The printed key chose "160°F" — the Celsius value; know the full working.)

(d) **Check 20 °C = 68 °F (2026):** $\frac{9}{5}(20) + 32 = 36 + 32 = 68$ ✓— **equal** temperatures.

(e) $\Delta C \to \Delta F$ **(2026):** multiply by $\frac{9}{5}$ — *no* +32 for differences.

COMMON MISTAKE The +32 belongs to *readings*, never to *differences*. And −40° is the *only* common reading of C and F — remember "minus forty, where the scales shake hands".

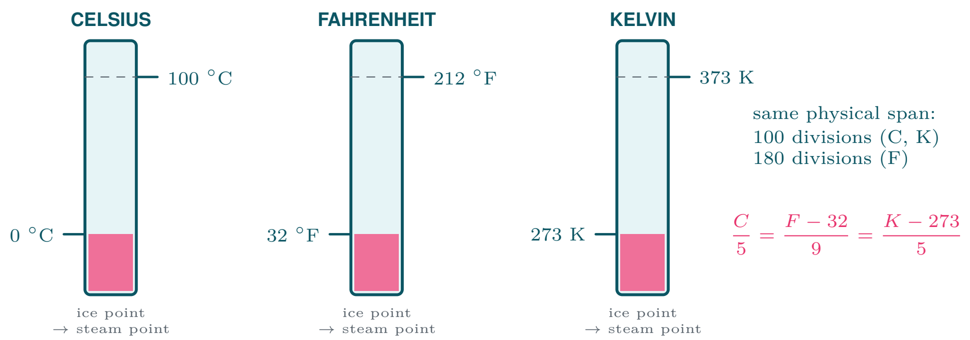

Fig. 5.1 The three temperature scales share the same two fixed points.

THERMOMETERS

A **liquid-in-glass thermometer** uses the uniform thermal expansion of a liquid (usually mercury) in a fine capillary.

Why mercury?

(i) Opaque and shiny — easily visible; (ii) good conductor, quickly reaches the body's temperature; (iii) uniform expansion; (iv) does not wet glass; (v) wide liquid range ($-39\,^\circ$C to $357\,^\circ$C); (vi) low specific heat — absorbs little heat from the object.

Clinical vs laboratory thermometer (STGT 2026)

Clinical	Laboratory
range **35–42 °C** (95–108 °F)	range -10 **to** $110\,^\circ$**C**
has a **kink** (constriction) near the bulb	no kink
kink stops backflow — reading holds outside the mouth	read *while* the bulb stays in contact
jerked to reset before reuse	no jerking needed
measures body temperature ($\approx 37\,^\circ$C / $98.6\,^\circ$F)	general lab use

Table 5.2 The 2026 PYQ on ranges, answered.

COMMON MISTAKE Never measure boiling water with a clinical thermometer — beyond $42\,^\circ$C the mercury's expansion can burst the fine bore. The kink, not gravity, is what preserves the maximum reading.

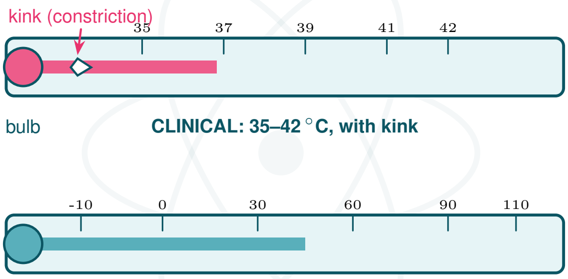

Fig. 5.2 Clinical and laboratory thermometers (schematic).

SPECIFIC HEAT

Definition. The **specific heat (capacity)** c of a substance is the heat required to raise the temperature of **unit mass** through $1\,^\circ$C (or 1 K):

$$\boxed{Q = mc\,\Delta\theta} \qquad c = \frac{Q}{m\,\Delta\theta}$$

- Units: $\mathrm{cal\,g^{-1}\,^\circ C^{-1}}$ or SI $\mathrm{J\,kg^{-1}\,K^{-1}}$; dimensions $[\mathrm{M^0L^2T^{-2}K^{-1}}]$.
- **Water has an exceptionally high** $c = 1\,\mathrm{cal\,g^{-1}\,^\circ C^{-1}} = 4200\,\mathrm{J\,kg^{-1}\,K^{-1}}$ — the reference value.
- Consequences: water as coolant (car radiators), hot-water bags, moderate coastal climates, land/sea breezes (sand heats faster — lower c).

EXAM FACT Heat content $\propto$ mass (asked in 2017 *and* 2019 with identical wording): two blocks of the same metal at the same temperature, one twice as heavy — heat content ratio $= Q_{2m}/Q_m = \boxed{2}$, since $Q = mc\theta$ with equal c and θ.

THERMAL CAPACITY AND WATER EQUIVALENT

Thermal (heat) capacity

Heat to raise the **whole body** through $1\,^\circ$C:

$$\boxed{C_{\text{th}} = \frac{Q}{\Delta\theta} = mc} \qquad \text{unit: } \mathrm{J\,^\circ C^{-1}}\ (\mathrm{cal\,^\circ C^{-1}})$$

STGT 2026: $Q = 2000$ J for $\Delta\theta = 5\,^\circ\mathrm{C} \Rightarrow C_{\text{th}} = 400\,\mathrm{J\,^\circ C^{-1}}$. STGT 2017: the heat needed to raise a substance through $1\,^\circ$C is its **heat capacity** (per unit mass it would be *specific* heat).

Water equivalent

The **water equivalent** W of a body is the mass of water that absorbs the *same heat* for the *same temperature rise*:

$$W\,c_w\,\Delta\theta = mc\,\Delta\theta \;\Rightarrow\; \boxed{W = \frac{mc}{c_w} \overset{\text{cal units}}{=} mc}$$

Numerically equal to the thermal capacity in calorie units but its **unit is the gram (kg)** — it is a mass. In calorimetry the calorimeter's water equivalent is simply *added to the water mass.*

PRINCIPLE OF CALORIMETRY

Statement. When a hot and a cold body are mixed in an isolated system (no loss to surroundings, no chemical change):

$$\boxed{\text{Heat lost by hot body} = \text{Heat gained by cold body}}$$

This is just energy conservation. It **fails when heat leaks to the surroundings** (STGT 2026).

Method of mixtures — the master formula

Mixing m_1 (at θ_1, specific heat c_1) with m_2 (at $\theta_2 < \theta_1$, c_2); final temperature θ:

$$m_1c_1(\theta_1 - \theta) = m_2c_2(\theta - \theta_2) \;\Rightarrow\; \theta = \frac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2c_2}$$

Equal masses of the same liquid $\Rightarrow \theta = \frac{\theta_1+\theta_2}{2}$: STGT 2026, 100 g at 80 °C + 100 g at 20 °C $\rightarrow \boxed{50\,°C}$.

Worked: calorimeter with water equivalent (STGT 2026)

Calorimeter $W = 10$ g + 100 g water at 20 °C; 50 g metal at 100 °C dropped in; final 25 °C; $c_w = 4200\,\mathrm{J\,kg^{-1}\,°C^{-1}}$:

$$\text{gain} = (0.100 + 0.010)(4200)(25 - 20) = 2310\,\mathrm{J}$$
$$\text{loss} = 0.050\,c_m\,(100 - 25) = 3.75\,c_m$$

$$c_m = \frac{2310}{3.75} = \boxed{616\,\mathrm{J\,kg^{-1}\,°C^{-1}}}$$

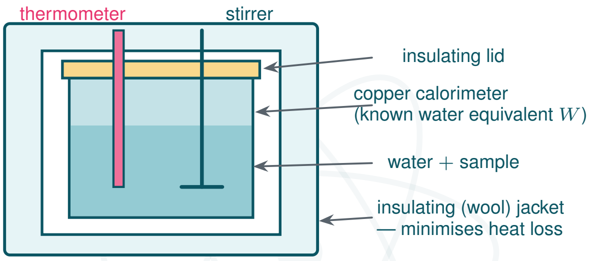

Fig. 5.3 The calorimeter: an isolated vessel so that heat lost = heat gained.

LATENT HEAT

Definition. The heat absorbed or released during a **change of state at constant temperature**, per unit mass:

$$\boxed{Q = mL}$$

- **Latent heat of fusion of ice:** $L_f = 80\,\mathrm{cal\,g^{-1}}$ ($= 3.36 \times 10^5\,\mathrm{J\,kg^{-1}}$) — ice $\leftrightarrow$ water at 0 °C.
- **Latent heat of vaporisation of water:** $L_v = 540\,\mathrm{cal\,g^{-1}}$ ($= 2.26 \times 10^6\,\mathrm{J\,kg^{-1}}$) — water $\leftrightarrow$ steam at 100 °C. (Older books quote 536–537; the 2017 key used 536.)
- "Latent" = hidden: the temperature does *not* rise while the state changes — energy goes into breaking intermolecular bonds.

Ice → steam: the staircase calculation

Heat to take m g of ice at 0 °C to steam at 100 °C:

$$Q = \underbrace{mL_f}_{\text{melt}} + \underbrace{mc_w(100-0)}_{\text{heat water}} + \underbrace{mL_v}_{\text{boil}}$$

(2017) $m = 1$ g: $80 + 100 + 536 = \boxed{716\,\text{cal}}$. **(2019)** $m = 5$ g (with $L_v = 540$): $400 + 500 + 2700 = \boxed{3600\,\text{cal}}$.

Ice–water mixtures: check the budget first (STGT 2022)

10 g ice + 40 g water at 15 °C: cooling all the water to 0 °C releases $40 \times 1 \times 15 = 600$ cal, but melting all the ice needs $10 \times 80 = 800$ cal. Since $600 < 800$, only part of the ice melts and the mixture sits at $\boxed{0\,°C}$.

KEY POINT Mixture recipe: (1) energy available from hot side down to 0 °C; (2) energy needed to melt all ice; (3) compare. If available < needed → final 0 °C; else melt everything and balance the books for the final temperature.

EXAM FACT Why steam scalds worse than boiling water: each gram of steam first *releases 540 cal* on condensing, then cools as water. Conversely, ice at 0 °C cools a drink better than water at 0 °C — it *absorbs* 80 cal/g while melting.

TWO ADVANCED PYQ TOOLS

Newton's law of cooling (STGT 2022)

The rate of cooling is proportional to the excess of the body's (average) temperature over the surroundings T_0:

$$\frac{T_1 - T_2}{t} = k\left[\frac{T_1 + T_2}{2} - T_0\right]$$

Worked (2022): tea cools 80 → 60 °C in 60 s with $T_0 = 30$: $\frac{20}{60} = k(70 - 30) \Rightarrow k = \frac{1}{120}$. Then 60 → 50: $\frac{10}{t} = \frac{1}{120}(55 - 30) \Rightarrow t = \frac{10\times120}{25} = 48 \approx \boxed{50\,\text{s}}$. Cooling *slows down* as the body nears room temperature.

Mechanical equivalent of heat (STGT 2022)

When mechanical energy becomes heat: $W = JH$ with $J = 4.2\,\mathrm{J\,cal^{-1}}$. **Worked:** a lead ball (specific heat S, cal units) hits a wall at speed v; half its KE becomes heat in the ball:

$$H = \frac{\frac{1}{2}\left(\frac{1}{2}mv^2\right)}{J} = \frac{mv^2}{4J} = mS\,\Delta T \Rightarrow \boxed{\Delta T = \frac{v^2}{4JS}}$$

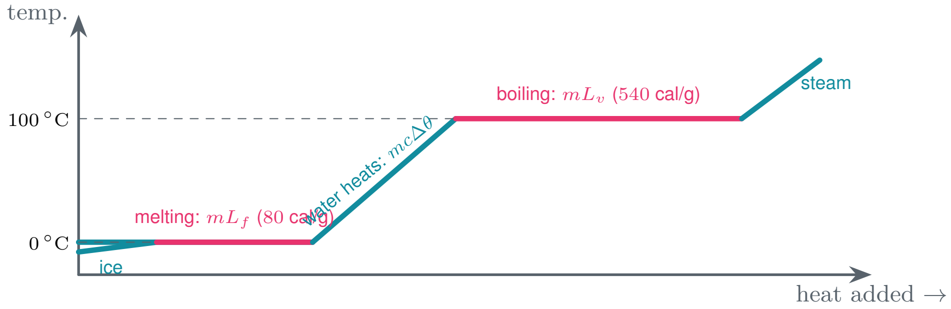

Fig. 5.4 Heating curve of water: flat plateaus are the latent heats (1 g ice → steam $= 80 + 100 + 540 \approx 720$ cal).

SOLVED EXAMPLES

EXAMPLE 1 [Easy] **Celsius to Fahrenheit**

Convert 40 °C to the Fahrenheit scale.

Solution.

$$F = \frac{9}{5}C + 32 = \frac{9}{5}(40) + 32 = 72 + 32 = \boxed{104\,{}^\circ F}$$

EXAMPLE 2 [Easy] **Fahrenheit to Celsius**

Normal body temperature is 98.6 °F. Express it in Celsius.

Solution.

$$C = \frac{5(F-32)}{9} = \frac{5(98.6-32)}{9} = \frac{5\times 66.6}{9} = \boxed{37\,{}^\circ C}$$

EXAMPLE 3 [Easy] **Kelvin scale**

Express 27 °C in kelvin, and 373 K in Celsius.

Solution. $K = C + 273 = 27 + 273 = \boxed{300\,\mathrm{K}}$; $C = K - 273 = 373 - 273 = \boxed{100\,{}^\circ C}$.

EXAMPLE 4 [Moderate] **Where the scales agree**

At what temperature do the Celsius and Fahrenheit scales show the same reading?

Solution. Set $C = F = x$:

$$x = \frac{9}{5}x + 32 \Rightarrow -\frac{4}{5}x = 32 \Rightarrow \boxed{x = -40^\circ}$$

$-40\,{}^\circ$C $= -40\,{}^\circ$F — the unique meeting point (STGT 2016).

EXAMPLE 5 [Moderate] **Heating water, $Q = mc\Delta\theta$**

How much heat raises 2 kg of water from 20 °C to 100 °C? ($c_w = 4200\,\mathrm{J\,kg^{-1}\,{}^\circ C^{-1}}$)

Solution.

$$Q = mc\Delta\theta = 2\times 4200\times 80 = \boxed{6.72\times 10^5\ \mathrm{J}}$$

In calories: $672000/4.2 = 1.6\times 10^5$ cal $= 160$ kcal.

UNIT CHECK $\mathrm{kg}\times\mathrm{J\,kg^{-1}\,{}^\circ C^{-1}}\times{}^\circ\mathrm{C} = \mathrm{J}$ ✓

EXAMPLE 6 [Easy] **Thermal capacity and water equivalent**

(a) A body needs 3000 J to warm by 6 °C — find its thermal capacity. (b) Find the water equivalent of 200 g of copper ($c = 0.09\,\mathrm{cal\,g^{-1}\,{}^\circ C^{-1}}$).

Solution. (a) $C_{\text{th}} = \frac{3000}{6} = \boxed{500\,\mathrm{J\,{}^\circ C^{-1}}}$.
(b) $W = mc = 200\times 0.09 = \boxed{18\,\mathrm{g}}$ — 18 g of water would absorb the same heat per degree.

EXAMPLE 7 [Moderate] **Method of mixtures**

50 g of water at 80 °C is mixed with 100 g of water at 20 °C. Find the final temperature.

Solution. Heat lost = heat gained:

$$50(80-\theta) = 100(\theta-20) \Rightarrow 4000 - 50\theta = 100\theta - 2000$$

$$150\theta = 6000 \Rightarrow \boxed{\theta = 40\,{}^\circ C}$$

(Weighted toward the larger cold mass, as expected.)

EXAMPLE 8 [Moderate] **Specific heat of a metal**

A 100 g metal piece at 95 °C is dropped into 200 g of water at 25 °C; the final temperature is 27.5 °C. Find the metal's specific heat (cal units).

Solution. Gain $= 200 \times 1 \times 2.5 = 500$ cal; loss $= 100 \times c \times (95 - 27.5) = 6750c$:

$$c = \frac{500}{6750} = \boxed{0.074\,\text{cal}\,\text{g}^{-1}\,{}^\circ\text{C}^{-1}}$$

EXAMPLE 9 [Moderate] Latent heat of fusion

How much heat converts 50 g of ice at 0 °C into water at 20 °C?

Solution.

$$Q = 50(80) + 50(1)(20) = 4000 + 1000 = \boxed{5000\,\text{cal}}$$

EXAMPLE 10 [Advanced] Ice–water mixture (budget check)

20 g of ice at 0 °C is added to 100 g of water at 30 °C. Find the final temperature.

Solution. Energy available cooling water to 0 °C: $100 \times 30 = 3000$ cal. Energy to melt all ice: $20 \times 80 = 1600$ cal < 3000 — all ice melts. Balance with final temperature θ:

$$100(30 - \theta) = 1600 + 20(\theta - 0)$$

$$120\theta = 1400 \Rightarrow \boxed{\theta \approx 11.7\,{}^\circ C}$$

(Compare STGT 2022, where the budget fell short and the answer was 0 °C.)

EXAMPLE 11 [Advanced] Why steam scalds worse

Compare the heat given to the skin (at 37 °C) by 5 g of steam at 100 °C and 5 g of boiling water at 100 °C.

Solution. Boiling water: $5 \times 1 \times (100 - 37) = 315$ cal.
Steam: condense $5 \times 540 = 2700$ cal, then cool: $+315$ cal $= \boxed{3015\,\text{cal}}$ — nearly **ten times** the burn. The latent heat is the culprit.

EXAMPLE 12 [Advanced] Mechanical equivalent — waterfall

Water falls through 84 m and all its PE becomes heat. Find the temperature rise ($g = 9.8\,\text{m}\,\text{s}^{-2}$, $c_w = 4200\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$).

Solution. Per kilogram: $mgh = mc\,\Delta T$:

$$\Delta T = \frac{gh}{c} = \frac{9.8 \times 84}{4200} = \boxed{0.196 \approx 0.2\,{}^\circ C}$$

UNIT CHECK $\frac{(m\,s^{-2})(m)}{J\,kg^{-1}K^{-1}} = \frac{J\,kg^{-1}}{J\,kg^{-1}K^{-1}} = K$ ✓

EXAMPLE 13 [Advanced] Newton's law of cooling

A body cools from 70 °C to 60 °C in 5 min in a room at 20 °C. How long will it take to cool from 60 °C to 50 °C?

Solution. First interval: $\frac{10}{5} = k(65 - 20) \Rightarrow k = \frac{2}{45}$ min^{-1}. Second: $\frac{10}{t} = \frac{2}{45}(55 - 20) = \frac{70}{45}$:

$$t = \frac{10 \times 45}{70} \approx \boxed{6.4\,\text{min}}$$

Cooling slows as the body approaches room temperature.

PREVIOUS YEAR QUESTIONS (PYQS)

All **25 MCQs** asked from this unit in STGT 2016, 2017, 2018, 2019, 2022 and 2026, grouped by sub-topic. Question numbers match the detailed solutions that follow. Exam: **Tripura STGT (Pure Science)**, 1 mark each.

A. HEAT, TEMPERATURE AND STATES OF MATTER

Q4. [2017] Easy An iron ball at 50 °C is dropped in a mug containing water at 50 °C. The heat will

(A) flow from the ball to the water
(B) flow from the water to the ball
(C) not flow
(D) increase the temperature of water

Q18. [2026] Moderate Heat and temperature are related but not the same because

(A) heat is energy, temperature is its cause
(B) heat is total energy, temperature is average energy
(C) heat is measured in joule and temperature in kelvin
(D) None of the above

Q7. [2019] Easy A gas fills all the space in a container in which it is kept because

(A) the molecules of gases have large intermolecular spaces and kinetic energy
(B) the molecules are not free to move
(C) the randomly moving molecules hit against the walls of the container
(D) the molecules have large intermolecular forces of attraction

Q8. [2019] Moderate Which of the following substances in gaseous state should be called a vapour?

(A) Helium
(B) Nitrogen
(C) Carbon dioxide
(D) Sulphur

Q15. [2022] Easy The temperature below which a gas can be liquefied by increasing its pressure is known as

(A) critical temperature
(B) Boyle temperature
(C) neutral temperature
(D) inversion temperature

B. TEMPERATURE SCALES — CONVERSIONS

Q1. [2016] Moderate At which temperature do the Centigrade and Fahrenheit scales read the same?

(A) $-60°$
(B) $-55°$
(C) $-40°$
(D) $+40°$

Q3. [2017] Easy $86\,°F$ is equal to

(A) $20\,°C$
(B) $22\,°C$
(C) $30\,°C$
(D) None of the above

Q14. [2022] Moderate The temperature on the Fahrenheit scale which will be double the reading on the Celsius scale is

(A) $160\,°F$
(B) $40\,°F$
(C) $-40\,°F$
(D) None of the above

Q19. [2026] Moderate If the temperature of a body increases by $10\,°C$, then in Fahrenheit it will increase by

(A) $10\,°F$
(B) $12\,°F$
(C) $16\,°F$
(D) None of the above

Q20. [2026] Easy If two temperatures are $20\,°C$ and $68\,°F$, then they will be

(A) equal
(B) double
(C) opposite
(D) None of the above

C. THERMOMETRY

Q9. [2019] Easy The earliest thermometer was developed by

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

Q11. [2019] Easy The automatic switch that controls temperature is

(A) thermostat
(B) pyrometer
(C) photodetector
(D) None of the above

Q21. [2026] Easy In a clinical thermometer and a laboratory thermometer, the ranges of temperature are respectively

(A) $35\,°C$ to $42\,°C$ and $-10\,°C$ to $110\,°C$
(B) $30\,°C$ to $47\,°C$ and $-10\,°C$ to $100\,°C$
(C) $32\,°C$ to $45\,°C$ and $0\,°C$ to $100\,°C$
(D) None of the above

D. SPECIFIC HEAT, HEAT CAPACITY, HEAT CONTENT

Q5. [2017] Easy Two blocks of the same metal, one twice as heavy as the other, are both at $60\,°C$. The ratio of the heat energy of the heavier block to that of the lighter block is

(A) 0.5
(B) 1
(C) 2
(D) 4

Q6. [2017] Easy The amount of heat required to raise the temperature of a substance through $1\,°C$ is called

(A) thermal energy
(B) heat capacity
(C) calorie
(D) specific heat capacity

Q10. [2019] Easy Two blocks of lead, one twice as heavy as the other, are at $50\,°C$. The ratio of the total heat content of the heavier block to that of the lighter block is

(A) 0.5
(B) 1
(C) 2
(D) 4

Q25. [2026] Easy A body requires 2000 J of heat to raise its temperature by $5\,°C$. What is its thermal capacity?

(A) $100\,J\,°C^{-1}$
(B) $200\,J\,°C^{-1}$
(C) $400\,J\,°C^{-1}$
(D) None of the above

E. CALORIMETRY AND LATENT HEAT

Q2. [2017] Moderate Find the heat required to convert 1 g of ice at $0\,°C$ to vapour at $100\,°C$.

(A) 80 cal
(B) 536 cal
(C) 716 cal
(D) None of the above

Q12. [2019] Moderate The amount of heat (in calories) required to convert 5 g of ice at $0\,°C$ to steam at $100\,°C$ is

(A) 3100
(B) 3200
(C) 3600
(D) 4200

Q13. [2022] Moderate 10 g of ice is added to 40 g of water at $15\,°C$. The temperature of the mixture is

(A) $0\,°C$
(B) $3\,°C$
(C) $5\,°C$
(D) $8\,°C$

Q22. [2026] Easy 100 g of water at $80\,°C$ is mixed with 100 g of water at $20\,°C$. The final temperature of the mixture is

(A) $40\,°C$
(B) $45\,°C$
(C) $50\,°C$
(D) None of the above

Q23. [2026] Moderate A calorimeter with water equivalent 10 g contains 100 g of water at $20\,°C$; a 50 g metal at $100\,°C$ is dropped in and the final temperature is $25\,°C$. The specific heat of the metal is ($c_w = 4200\,\mathrm{J\,kg^{-1}\,°C^{-1}}$)

(A) $200\,\mathrm{J\,kg^{-1}\,°C^{-1}}$
(B) $616\,\mathrm{J\,kg^{-1}\,°C^{-1}}$
(C) $210\,\mathrm{J\,kg^{-1}\,°C^{-1}}$
(D) None of the above

Q24. [2026] Easy The principle of calorimetry fails when

(A) there is perfect insulation
(B) heat loss to surroundings is negligible
(C) heat loss to surroundings occurs
(D) None of the above

F. ADVANCED APPLICATIONS

Q16. [2022] Difficult A cup of tea cools from $80\,°C$ to $60\,°C$ in one minute. The ambient temperature is $30\,°C$. In cooling from $60\,°C$ to $50\,°C$, it will take

(A) 90 s
(B) 50 s
(C) 60 s
(D) 30 s

Q17. [2022] Moderate A lead ball moving with velocity v strikes a wall and stops. If 50% of its kinetic energy is converted into heat, the increase in temperature is (specific heat of lead $= S$, mechanical equivalent $= J$)

(A) $\dfrac{2v^2}{JS}$
(B) $\dfrac{v^2}{4JS}$
(C) $\dfrac{v^2}{JS}$
(D) $\dfrac{v^2}{2JS}$

DETAILED PYQ SOLUTIONS

Q1. Answer: (C) — C–F equality point

Set $C = F = x$: $x = \frac{9}{5}x + 32 \Rightarrow -\frac{4}{5}x = 32 \Rightarrow x = -40$. So $-40\,°C = -40\,°F$. Hence (C).

Q2. Answer: (C) — Ice to vapour

$Q = mL_f + mc\Delta\theta + mL_v = 80 + 100 + 536 = 716$ cal (key used $L_v = 536$; with 540 it is 720 — pick the listed value). Hence (C).

Q3. Answer: (C) — F to C

$C = \frac{5(86-32)}{9} = \frac{5\times54}{9} = 30\,°C$. Hence (C).

Q4. Answer: (C) — Thermal equilibrium

Equal temperatures ⇒ no temperature difference ⇒ **no heat flow** (the bodies are already in equilibrium). Hence (C).

Q5. Answer: (C) — Heat content ∝ mass

$Q = mc\theta$; same metal and temperature, double mass ⇒ double heat content: ratio = 2. Hence (C).

Q6. Answer: (B) — Heat capacity

Heat to raise the *substance* (whole body) by $1\,°C$ = **heat (thermal) capacity**. Per unit mass it would be *specific* heat. Hence (B).

Q7. Answer: (A) — Gas fills its container

Large intermolecular spaces + high kinetic energy + negligible attractions let gas molecules roam the entire volume. Hence (A).

Q8. Answer: (D) — Vapour vs gas

A gaseous substance whose room-temperature state is solid/liquid (below critical temperature) is a *vapour*: **sulphur**. He, N_2, CO_2 are true gases. Hence (D).

Q9. Answer: (D) — First thermometer

Galileo built the thermoscope (∼1593), long before the Fahrenheit/Celsius/Kelvin scales. Hence (D).

Q10. **Answer: (C)** Heat content (repeat)

Same as Q5 (2017): $Q \propto m \Rightarrow$ ratio $2:1$. Hence (C).

Q11. **Answer: (A)** Thermostat

The automatic temperature-controlling switch is the **thermostat**; a pyrometer measures (high) temperature only. Hence (A).

Q12. **Answer: (C)** Ice to steam, 5 g

$Q = 5(80)+5(1)(100)+5(540) = 400+500+2700 = 3600$ cal. Hence (C).

Q13. **Answer: (A)** Ice–water budget

Cooling 40 g water $15 \to 0\,°C$ frees 600 cal; melting 10 g ice needs 800 cal. $600 < 800 \Rightarrow$ ice survives, mixture stays at $0\,°C$. Hence (A).

Q14. **Answer: (A)** $F = 2C$

$2C = \frac{9}{5}C + 32 \Rightarrow \frac{C}{5} = 32 \Rightarrow C = 160$, so $F = 320\,°F$. The printed key lists $160\,°F$ (the Celsius number); flagged as ambiguous in our PYQ volume — master the method. Hence (A) as per key.

Q15. **Answer: (A)** Critical temperature

Below the **critical temperature** a gas liquefies under pressure alone; above it, never. Hence (A).

Q16. **Answer: (B)** Newton's law of cooling

$\frac{20}{60} = k(70-30) \Rightarrow k = \frac{1}{120}$; then $\frac{10}{t} = \frac{1}{120}(55-30) \Rightarrow t = \frac{10\times120}{25} = 48 \approx 50$ s. Hence (B).

Q17. **Answer: (B)** KE to heat

Heat $= \frac{1}{2} \times \frac{1}{2}mv^2 = \frac{mv^2}{4}$ J $= \frac{mv^2}{4J}$ cal $= mS\Delta T$ $\Rightarrow \Delta T = \frac{v^2}{4JS}$. Hence (B).

Q18. **Answer: (B)** Heat vs temperature

Heat = **total** molecular energy; temperature = **average** molecular kinetic energy. Hence (B).

Q19. **Answer: (D)** Interval conversion

$\Delta F = \frac{9}{5}\Delta C = \frac{9}{5}(10) = 18\,°F$ — not among the options, so "None of the above". (No +32 for differences!) Hence (D).

Q20. **Answer: (A)** C–F check

$F = \frac{9}{5}(20) + 32 = 68\,°F \Rightarrow 20\,°C$ and $68\,°F$ are **equal**. Hence (A).

Q21. **Answer: (A)** Thermometer ranges

Clinical: **35–42 °C**; laboratory: **−10 to 110 °C**. Hence (A).

Q22. **Answer: (C)** Equal-mass mixing

Same liquid, equal masses: $\theta = \frac{80+20}{2} = 50\,°C$. Hence (C).

Q23. **Answer: (B)** Calorimeter numerical

Gain $= (0.100 + 0.010)(4200)(5) = 2310$ J; loss $= 0.050\,c_m(75) = 3.75c_m$; $c_m = 2310/3.75 = 616\,\mathrm{J\,kg^{-1}\,°C^{-1}}$. Hence (B).

Q24. **Answer: (C)** Calorimetry conditions

Heat lost = heat gained assumes an isolated system; it **fails when heat escapes to the surroundings**. Hence (C).

Q25. **Answer: (C)** Thermal capacity

$C_{\text{th}} = Q/\Delta\theta = 2000/5 = 400\,\mathrm{J\,°C^{-1}}$. Hence (C).

Q	1	2	3	4	5	6	7	8	9	10	11	12	13
Ans	C	C	C	C	C	B	A	D	D	C	A	C	A
Q	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
Ans	A	A	B	B	B	D	A	A	C	B	C	C	

Table 5.3 PYQ answer key at a glance.

PYQ TREND ANALYSIS (2016–2026)

YEAR-WISE DISTRIBUTION

Year	16	17	18	19	22	26	Tot.
Questions	1	5	0	6	5	8	**25**

Table 5.4 8.7% of Physics PYQs — **MEDIUM, rising**.

SUB-TOPIC WEIGHTAGE

Sub-topic	Freq.	Imp.	Repeat
Calorimetry & latent heat	6	**V. high**	⋆⋆⋆
Scale conversions (C–F)	5	**V. high**	⋆⋆⋆
Specific heat / capacity	4	High	⋆⋆⋆
Heat vs temp.; states; critical T	5	High	⋆⋆
Thermometry (history, ranges)	3	Moderate	⋆⋆
Newton's cooling; $W = JH$	2	Moderate	⋆⋆

Table 5.5 Where the 25 questions came from.

EXAM PATTERN ANALYSIS

- 15 Easy, 9 Moderate, 1 Difficult; the unit skipped 2018 entirely, then came back stronger every paper — **8 questions in 2026**.
- **Verbatim repeats:** the "two blocks, one twice as heavy" heat-content question appeared in 2017 *and* 2019; ice-to-steam staircases in 2017 (1 g) and 2019 (5 g).
- 2026 mixed quick definitions (thermal capacity, calorimetry failure, thermometer ranges) with one full calorimeter computation — prepare both speeds.
- Latent-heat values to memorise: $L_f = 80$, $L_v = 540$ (some keys use 536) $\mathrm{cal\,g^{-1}}$; $c_w = 1\,\mathrm{cal\,g^{-1}\,{}^\circ C^{-1}} = 4200\,\mathrm{J\,kg^{-1}\,K^{-1}}$.

MOST IMPORTANT AREAS (RANK ORDER)

1. C–F conversions: readings (+32), differences ($\times\frac{9}{5}$ only), the -40 meeting point, $F = 2C$ pattern.
2. Ice–water–steam staircase $Q = mL_f + mc\Delta\theta + mL_v$ and the mixture *budget check* (does all the ice melt?).
3. Definitions: specific heat vs thermal capacity vs water equivalent; principle of calorimetry and when it fails.
4. Heat content $\propto$ mass; heat vs temperature (total vs average energy).
5. Thermometers: clinical 35–42 °C with kink, laboratory −10–110 °C, Galileo first, thermostat controls.
6. Newton's law of cooling and the mechanical equivalent ($\Delta T = v^2/4JS$ pattern).

COMMON MISTAKES IN THE EXAM HALL

- Adding +32 when converting temperature *differences* (the 2026 trap: $\Delta 10\,^\circ\mathrm{C} = 18\,^\circ\mathrm{F}$, answer "none").
- Assuming all ice melts in a mixture — check the calorie budget first (2022: answer was 0 °C).
- Forgetting the calorimeter's water equivalent in the heat-gain side.
- Confusing specific heat ($\mathrm{J\,kg^{-1}K^{-1}}$, per unit mass) with thermal capacity ($\mathrm{J\,K^{-1}}$, whole body) and water equivalent (a *mass*).
- Treating cooling as linear in time — Newton's law says it slows near room temperature.
- Using $L_v = 80$ or $L_f = 540$ — swap-proof yourself: *fusion 80, vapour 540.*

LAST-MINUTE REVISION POINTS

- $\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5}$; $\Delta F = \frac{9}{5}\Delta C$; $C = F$ at -40; 0 K $= -273\,^\circ$C.
- 1 cal = 4.2 J; $W = JH$; calorie defined on 1 g water 14.5 → 15.5 °C.
- $Q = mc\Delta\theta$; $C_{\mathrm{th}} = mc$ ($\mathrm{J\,{}^\circ C^{-1}}$); $W_{\mathrm{eq}} = mc$ (grams); $c_w = 4200\,\mathrm{J\,kg^{-1}K^{-1}}$ (highest).
- Calorimetry: lost = gained; mixture $\theta = \frac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2c_2}$; equal masses, same liquid → mean.
- Latent: $Q = mL$; ice → steam (1 g): $80 + 100 + 540 \approx 720$ cal; steam burns worse; ice cools better.
- Clinical 35–42 °C (kink); lab −10 to 110 °C; Galileo's thermoscope; thermostat = control.
- Newton's cooling: $\frac{T_1 - T_2}{t} = k\left[\frac{T_1+T_2}{2} - T_0\right]$.

PREDICTED QUESTIONS (HIGH PROBABILITY)

Built from the repeat pattern: conversions, latent heat, definitions. Answers in brackets.

P1. Pure water boils at 100 °C. On the Fahrenheit scale this is

(A) 180 °F
(B) 212 °F
(C) 100 °F
(D) 273 °F

[Ans: B]

P2. Absolute zero equals

(A) 0 °C
(B) −273 °C
(C) −40 °C
(D) −100 °C

[Ans: B]

P3. The specific heat of water in SI units is

(A) $420\,\mathrm{J\,kg^{-1}K^{-1}}$
(B) $4200\,\mathrm{J\,kg^{-1}K^{-1}}$
(C) $42\,\mathrm{J\,kg^{-1}K^{-1}}$
(D) $1\,\mathrm{J\,kg^{-1}K^{-1}}$

[Ans: B]

P4. The latent heat of vaporisation of water is about

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

[Ans: C]

P5. One calorie is the heat needed to raise the temperature of

(A) 1 kg water by 1 °C
(B) 1 g water by 1 °C
(C) 1 g ice by 1 °C
(D) 1 g water by 1 °F

[Ans: B]

P6. Equal masses of the same liquid at θ_1 and θ_2 are mixed. The final temperature is

(A) $\theta_1 + \theta_2$
(B) $\sqrt{\theta_1\theta_2}$
(C) $\dfrac{\theta_1 + \theta_2}{2}$
(D) $\theta_1 - \theta_2$

[Ans: C]

P7. A clinical thermometer cannot measure boiling water because

(A) its range ends at 42 °C
(B) mercury freezes
(C) glass melts
(D) the kink blocks all flow

[Ans: A]

P8. Ice at 0 °C is mixed with an equal mass of water at 0 °C. Then

(A) all ice melts
(B) all water freezes
(C) no change of state occurs
(D) temperature rises

[Ans: C — no temperature difference, no heat flow]

P9. The mechanical equivalent of heat J equals

(A) $4.2\,\mathrm{J\,cal^{-1}}$
(B) $0.42\,\mathrm{J\,cal^{-1}}$
(C) $42\,\mathrm{J\,cal^{-1}}$
(D) $4.2\,\mathrm{cal\,J^{-1}}$

[Ans: A]

P10. The SI unit of thermal capacity is

(A) $\mathrm{J\,kg^{-1}K^{-1}}$
(B) $\mathrm{J\,K^{-1}}$
(C) J
(D) kg

[Ans: B]

P11. Land heats faster than the sea on a sunny day because land has

(A) higher specific heat
(B) lower specific heat
(C) more latent heat
(D) more mass

[Ans: B — basis of sea breezes]

P12. 2 g of ice at 0 °C is converted to steam at 100 °C. The heat required (in cal, $L_v = 540$) is

(A) 1440
(B) 720
(C) 1240
(D) 1600

[Ans: A — $2(80 + 100 + 540)$]

SAMPLE PRACTICE PROBLEMS

LEVEL 1 — EASY

1. The SI unit of heat is the

(A) calorie
(B) joule
(C) watt
(D) kelvin

2. One calorie equals

(A) 0.42 J
(B) 42 J
(C) 4.2 J
(D) 420 J

3. Heat flows between two bodies because of a difference in

(A) mass
(B) temperature
(C) volume
(D) density

4. Pure water boils (at 1 atm) at a Fahrenheit reading of

(A) 100 °F
(B) 180 °F
(C) 212 °F
(D) 373 °F

5. Absolute zero is

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

6. The range of a clinical thermometer is

(A) 0–100 °C
(B) 35–42 °C
(C) −10–110 °C
(D) 30–60 °C

7. The SI unit of specific heat is

(A) $\mathrm{J\,kg^{-1}\,K^{-1}}$
(B) $\mathrm{J\,K^{-1}}$
(C) cal
(D) $\mathrm{J\,kg^{-1}}$

8. The latent heat of fusion of ice is

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

9. The unit of water equivalent is the

(A) joule
(B) calorie
(C) gram
(D) kelvin

10. Mercury is preferred in thermometers because it

(A) is shiny and opaque
(B) expands uniformly
(C) does not wet glass
(D) All of the above

11. The principle of calorimetry states that

(A) heat lost = heat gained
(B) heat lost > heat gained
(C) heat is always lost
(D) temperature is conserved

12. Normal human body temperature is about

(A) $32\,°C$
(B) $37\,°C$
(C) $42\,°C$
(D) $25\,°C$

LEVEL 2 — MODERATE

13. $50\,°C$ expressed on the Fahrenheit scale is

(A) $90\,°F$
(B) $122\,°F$
(C) $82\,°F$
(D) $102\,°F$

14. $59\,°F$ equals

(A) $15\,°C$
(B) $27\,°C$
(C) $12\,°C$
(D) $20\,°C$

15. A temperature *rise* of $20\,°C$ equals a rise of

(A) $20\,°F$
(B) $52\,°F$
(C) $36\,°F$
(D) $68\,°F$

16. Heat needed to warm 500 g of water from $25\,°C$ to $75\,°C$ ($c_w = 4200\,\mathrm{J\,kg^{-1}K^{-1}}$) is

(A) 1.05×10^4 J
(B) 1.05×10^5 J
(C) 2.1×10^5 J
(D) 5.25×10^4 J

17. A body absorbs 1200 J and warms by $4\,°C$. Its thermal capacity is

(A) $4800\,\mathrm{J\,°C^{-1}}$
(B) $300\,\mathrm{J\,°C^{-1}}$
(C) $30\,\mathrm{J\,°C^{-1}}$
(D) $120\,\mathrm{J\,°C^{-1}}$

18. Equal masses of the same liquid at $70\,°C$ and $30\,°C$ are mixed. The final temperature is

(A) $40\,°C$
(B) $60\,°C$
(C) $50\,°C$
(D) $35\,°C$

19. Heat required to melt 25 g of ice at $0\,°C$ is

(A) 2000 cal
(B) 25 cal
(C) 1350 cal
(D) 80 cal

20. Heat released when 10 g of steam at $100\,°C$ condenses to water at $100\,°C$ is

(A) 800 cal
(B) 1000 cal
(C) 5400 cal
(D) 540 cal

21. 310 K equals

(A) $47\,°C$
(B) $37\,°C$
(C) $310\,°C$
(D) $83\,°C$

22. The kink in a clinical thermometer

(A) prevents the mercury from flowing back
(B) speeds up the reading
(C) stores extra mercury
(D) measures pressure

23. The water equivalent of 500 g of copper ($c = 0.09\,\mathrm{cal\,g^{-1}\,°C^{-1}}$) is

(A) 5.55 g
(B) 45 g
(C) 450 g
(D) 0.045 g

24. Three blocks of the same metal at the same temperature have masses $3m$, $2m$ and m. The heat content of the largest compared to the smallest is

(A) equal
(B) double
(C) three times
(D) one-third

LEVEL 3 — ADVANCED / COMPETITIVE

25. The temperature at which the Fahrenheit reading is three times the Celsius reading is (approximately)

(A) $26.7\,°F$
(B) $80\,°F$
(C) $160\,°F$
(D) $320\,°F$

26. 30 g of ice at $0\,°C$ is dropped into 90 g of water at $40\,°C$. The final temperature is

(A) $0\,°C$
(B) $10\,°C$
(C) $20\,°C$

(D) $30\,°C$

27. Heat required to convert 2 g of ice at $0\,°C$ into steam at $100\,°C$ ($L_v = 540$ cal/g) is

(A) 1440 cal
(B) 720 cal
(C) 1240 cal
(D) 1600 cal

28. A calorimeter of water equivalent 20 g holds 80 g of water at $25\,°C$. A 100 g metal at $90\,°C$ brings the mixture to $30\,°C$. The metal's specific heat (cal units) is about

(A) 0.042
(B) 0.083
(C) 0.12
(D) 0.5

29. A body cools from $80\,°C$ to $70\,°C$ in 4 min in a room at $20\,°C$. The time to cool from $70\,°C$ to $60\,°C$ is about

(A) 4 min
(B) 4.4 min
(C) 4.9 min
(D) 6.5 min

30. A lead bullet ($c = 130\,\mathrm{J\,kg^{-1}K^{-1}}$) moving at $200\,\mathrm{m\,s^{-1}}$ stops in a wall and all its KE becomes heat in the bullet. Its temperature rise is about

(A) $77\,°C$
(B) $154\,°C$
(C) $308\,°C$
(D) $15\,°C$

31. According to Newton's law of cooling, a body cools fastest when

(A) its excess temperature over the surroundings is largest
(B) it is near room temperature
(C) its mass is large
(D) its specific heat is large

32. When 1 g of water at $100\,°C$ turns into steam at $100\,°C$, it

(A) releases 540 cal
(B) absorbs 540 cal
(C) absorbs 80 cal
(D) releases 100 cal

HOTS — HIGHER ORDER THINKING

33. Water is used in car radiators and hot-water bags chiefly because of its

(A) high specific heat
(B) low boiling point
(C) high density
(D) transparency

34. Can two bodies of different masses have the same thermal capacity?

(A) Yes — if their specific heats differ suitably
(B) Never
(C) Only if both are water
(D) Only at $0\,°C$

35. Ice at $0\,°C$ cools a drink more effectively than the same mass of water at $0\,°C$ because

(A) ice is colder
(B) melting ice absorbs 80 cal/g of latent heat
(C) ice has higher specific heat
(D) water warms faster

36. At the beach, sand becomes hot while the sea stays cool because sand has

(A) higher specific heat
(B) more latent heat
(C) lower specific heat
(D) more thermal capacity

37. The Celsius and Fahrenheit scales give the same reading at exactly

(A) one temperature
(B) two temperatures
(C) all temperatures
(D) no temperature

ASSERTION–REASON

Mark (A) if both Assertion and Reason are true and the Reason correctly explains the Assertion; (B) if both are true but the Reason does not explain the Assertion; (C) if the Assertion is true but the Reason is false; (D) if the Assertion is false but the Reason is true.

38. Assertion: Steam at $100\,°C$ burns more severely than water at $100\,°C$.
Reason: Steam releases an extra 540 cal per gram while condensing.

39. Assertion: A clinical thermometer retains its reading outside the patient's mouth.
Reason: The kink prevents the mercury from flowing back into the bulb.

40. Assertion: While ice melts at $0\,°C$, its temperature does not rise although heat is supplied.
Reason: The supplied heat is used as latent heat to break intermolecular bonds.

41. Assertion: Heat and temperature are the same physical quantity.
Reason: Heat is the total molecular energy while temperature measures the average molecular kinetic energy.

42. Assertion: Water equivalent is expressed in grams.
Reason: It is the mass of water having the same thermal capacity as the body.

43. Assertion: The principle of calorimetry holds even when the vessel leaks heat to the surroundings.
Reason: The principle assumes a thermally isolated system.

ANSWER KEYS — PRACTICE

Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	12	B	23	B	34	A
2	C	13	B	24	C	35	B
3	B	14	A	25	B	36	C
4	C	15	C	26	B	37	A
5	A	16	B	27	A	38	A
6	B	17	B	28	B	39	A
7	A	18	C	29	C	40	A
8	B	19	A	30	B	41	D
9	C	20	C	31	A	42	A
10	D	21	B	32	B	43	D
11	A	22	A	33	A	—	—

Table 5.6 Practice answer key. Selected hints: Q15 $\Delta F = \frac{9}{5}(20) = 36$; Q16 $0.5 \times 4200 \times 50$; Q25 $3C = \frac{9}{5}C + 32 \Rightarrow C \approx 26.7$, $F = 80$; Q26 melt needs 2400, available 3600; final $= \frac{3600-2400}{120} = 10$; Q28 gain $= 100 \times 5 = 500$ cal, loss $= 100c(60)$; Q29 $k = \frac{10}{4\times55}$, $t = \frac{10\times22}{45}$; Q30 $\Delta T = \frac{v^2}{2c} = \frac{40000}{260}$.

QUICK REVISION — ONE-PAGE SUMMARY

QUICK NOTES

The unit in 12 lines

1. Heat = energy in transit (total molecular energy); temperature = degree of hotness (average molecular KE); flow needs a *difference*.
2. 1 cal = 4.2 J; calorie defined on 1 g water 14.5 → 15.5 °C; $W = JH$.
3. Scales: $\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5}$; $F = \frac{9}{5}C + 32$.
4. Differences: $\Delta F = \frac{9}{5}\Delta C$ (no +32); $C = F$ only at -40; 0 K $= -273$ °C.
5. Thermometers: clinical 35–42 °C with *kink*; laboratory -10 to 110 °C; Galileo built the first; thermostat *controls*.
6. Specific heat $c = \frac{Q}{m\Delta\theta}$; water's $c = 4200\,\mathrm{J\,kg^{-1}K^{-1}}$ is the highest (coolant, climate, breezes).
7. Thermal capacity $= mc$ ($\mathrm{J\,°C^{-1}}$); water equivalent $= mc$ expressed as a *mass* (g).
8. Calorimetry: heat lost = heat gained (isolated system only); mixture $\theta = \frac{m_1c_1\theta_1+m_2c_2\theta_2}{m_1c_1+m_2c_2}$.
9. Equal masses, same liquid: final = mean temperature.
10. Latent heat $Q = mL$: fusion 80 cal/g, vaporisation 540 cal/g; plateaus on the heating curve.
11. Ice–water mixtures: *budget check* first — if heat available < heat to melt all ice, answer is 0 °C.
12. Newton's cooling: rate ∝ excess over surroundings (cooling slows); KE-to-heat: $\Delta T = \frac{v^2}{4JS}$ for 50% conversion.

MEMORY TRICKS

MEMORY TRICK "Fusion is 80s music, Vapour is a 540 flip." $L_f = 80$, $L_v = 540$ cal/g — and 1 g ice → steam $= 80 + 100 + 540 \approx 720$ cal ("a 720° spin").

MEMORY TRICK C-to-F in two moves: "*multiply by 1.8, add 32*". Landmarks: $0 \to 32$, $37 \to 98.6$, $100 \to 212$, $-40 \to -40$. **Differences skip the** $+32$.

MEMORY TRICK Three cousins, three units: ***specific heat*** $\mathrm{J\,kg^{-1}K^{-1}}$ **(per kilogram),** ***thermal capacity*** $\mathrm{J\,K^{-1}}$ **(whole body),** ***water equivalent*** **kg (a mass). Same** mc**, three costumes.**

FREQUENTLY CONFUSED CONCEPTS

This. . .	is NOT that
heat (total energy, J)	temperature (average KE, K)
specific heat (per unit mass)	thermal capacity (whole body)
water equivalent (a mass, g)	heat capacity ($\mathrm{J\,K^{-1}}$)
reading conversion (needs +32)	difference conversion ($\times\frac{9}{5}$ only)
vapour (below critical T)	gas (above critical T)
clinical (35–42, kink)	laboratory (-10–110, no kink)
latent heat (state change, T fixed)	specific heat (T rises)
thermostat (controls T)	pyrometer (measures high T)

FORMULA SHEET — UNIT 5

Result	Formula
Scale relation	$\dfrac{C}{5}=\dfrac{F-32}{9}=\dfrac{K-273}{5}$; $F=\frac{9}{5}C+32$; $K=C+273$
Special values	$C=F$ at -40; $\Delta F=\frac{9}{5}\Delta C$; $0\text{ K}=-273\,°\text{C}$; $37\,°\text{C}=98.6\,°\text{F}$; $100\,°\text{C}=212\,°\text{F}$
Heat units	$1\,\text{cal}=4.2\,\text{J}$; $1\,\text{kcal}=4200\,\text{J}$; $W=JH$, $J=4.2\,\text{J}\,\text{cal}^{-1}$
Specific heat	$Q=mc\Delta\theta$; $c_w=1\,\text{cal}\,\text{g}^{-1}\,°\text{C}^{-1}=4200\,\text{J}\,\text{kg}^{-1}\text{K}^{-1}$ (highest)
Capacity & equivalent	thermal capacity $C_{\text{th}}=mc$ ($\text{J}\,°\text{C}^{-1}$); water equivalent $W=mc/c_w$ (a mass)
Calorimetry	lost = gained; $\theta=\dfrac{m_1c_1\theta_1+m_2c_2\theta_2}{m_1c_1+m_2c_2}$; equal masses, same liquid: $\theta=\frac{\theta_1+\theta_2}{2}$
With calorimeter	$(m_w+W)\,c_w\,\Delta\theta_{\text{cold}}=m_{\text{hot}}c_{\text{hot}}\Delta\theta_{\text{hot}}$
Latent heat	$Q=mL$; $L_f=80$ cal/g $=3.36\times10^5$ J/kg; $L_v=540$ cal/g $=2.26\times10^6$ J/kg
Ice $\rightarrow$ steam	$Q=mL_f+mc_w(100)+mL_v$; 1 g: ≈ 720 cal; 5 g: 3600 cal
Ice–water mixing	compare $m_wc_w\theta_w$ (available) with $m_{\text{ice}}L_f$ (needed); short $\Rightarrow$ final $0\,°\text{C}$
Newton's cooling	$\dfrac{T_1-T_2}{t}=k\left[\dfrac{T_1+T_2}{2}-T_0\right]$ — cooling slows near T_0
KE $\rightarrow$ heat	full: $\Delta T=\dfrac{v^2}{2Jc}$; half: $\Delta T=\dfrac{v^2}{4Jc}$ (c in cal units; drop J if c in $\text{J}\,\text{kg}^{-1}\text{K}^{-1}$)

Table 5.7 Everything quotable from Unit 5.

— END OF UNIT 5 —

Next unit: Light (reflection, mirrors, refraction, TIR, lenses — the highest-weight chapter).