

PICK PREP

LEARN • THINK • GROW

**NEET
PHYSICS
ESSENTIALS**

THERMAL PROPERTIES OF MATTER

NEET PHYSICS ESSENTIALS

CONCEPT SUMMARY

KEY CONCEPTS | FORMULAS | RECOGNITION CUES
MISCONCEPTIONS | EXAM TRAPS | QUICK CHECKS



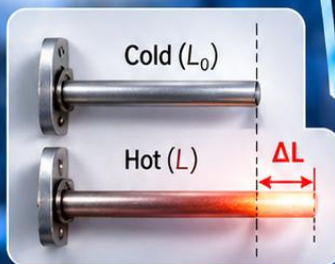
UNDERSTAND
THE PHYSICS



RECOGNIZE
THE PATTERN



SOLVE WITH
CONFIDENCE



**SAME PHYSICS.
A HIGHER SCORE.**

1. Chapter Introduction

Thermal physics connects temperature, internal energy, heat transfer, expansion and changes of state. The central exam skill is to identify whether energy changes temperature, changes the state of a substance, or transfers through a material or across space.

2. Chapter in One View

Central idea: Temperature describes the thermal state of a body. Heat is energy transferred because of a temperature difference. The correct model depends on what changes and how the system exchanges energy.

- Identify the target: temperature, heat energy, expansion, heat-transfer rate, radiation or cooling rate.
- Choose the model: temperature conversion, $Q = mc\Delta T$, $Q = mL$, calorimetry, expansion, conduction, radiation or cooling.
- Check the process: one phase or phase change; insulated or heat-losing system; steady or changing heat flow.
- Use kelvin in absolute-temperature laws, especially radiation laws. Temperature differences in kelvin and Celsius have the same numerical value.
- Check units, direction of energy transfer and whether the result has the expected trend.

3. Must-Know Concepts

Heat and temperature: Temperature helps determine the direction of net heat transfer. Heat is energy in transit due to a temperature difference; a body has internal energy, not stored heat.

Thermal equilibrium and Zeroth Law: Bodies in thermal equilibrium have equal temperatures and no net heat transfer. The Zeroth Law is the basis of temperature measurement.

Temperature scales: Kelvin is the SI scale. $K = ^\circ C + 273.15$. A change of 1 K equals a change of 1 $^\circ C$. Fahrenheit conversion is useful when explicitly given.

Internal energy: Internal energy is the microscopic kinetic and potential energy of the particles. Heat and work are modes of energy transfer.

Specific heat and heat capacity: Heat capacity C belongs to the whole body; specific heat capacity c is per unit mass; molar heat capacity is per mole.

Thermal expansion: A material's dimensions generally change with temperature. The coefficients relate the fractional change in length, area or volume to the temperature change.

Thermal stress: If thermal expansion or contraction is fully prevented, stress can develop. Free expansion alone does not produce the ideal restraint stress.

Phase change and latent heat: During an ideal phase change at fixed pressure, energy changes the phase while temperature remains constant.

Calorimetry and water equivalent: For an insulated system, heat lost plus heat gained equals zero. Water equivalent expresses a body's heat capacity as the equivalent mass of water.

Real and apparent liquid expansion: The observed rise of a liquid in a vessel depends on expansion of both the liquid and the vessel.

Anomalous expansion of water: From 0°C to 4°C , water contracts as it warms; its density reaches a maximum at 4°C .

Conduction: Energy transfer occurs through a material without bulk transport of the material. In steady slab conduction, rate depends on conductivity, area, temperature difference and thickness.

Convection: Energy is carried by bulk motion of a fluid. In common natural-convection situations, warm, less-dense fluid rises and cooler fluid sinks.

Thermal radiation: Radiation is electromagnetic energy transfer and does not require a material medium. All bodies above 0 K emit radiation. Emissivity compares a surface's emission with an ideal black body.

Black body and radiation laws: An ideal black body absorbs incident radiation perfectly. Stefan–Boltzmann law describes total emitted power; Wien's law relates peak wavelength to absolute temperature.

Newton's law of cooling: For a small temperature excess over steady surroundings, the rate of cooling is approximately proportional to the temperature difference.

4. Formula + Meaning

Newton's Law of Cooling – core relation:

Rate of cooling $\propto (T - T_s)$, or $\frac{dT}{dt} = -k(T - T_s)$. The negative sign indicates that T decreases when the body is hotter than its surroundings.

Meaning: The instantaneous rate depends on the body's temperature excess over the surroundings, not on its temperature alone.

Use when: Comparing instantaneous cooling rates under the same conditions, or predicting temperature after a time when k is constant.

Integrated form: $T - T_s = (T_0 - T_s)e^{(-kt)}$, for constant k and fixed surrounding temperature. T_0 is the initial body temperature.

Conditions: The temperature difference is small enough for the approximation to be reasonable, and surroundings and heat-transfer conditions remain approximately constant.

Exam trap: As T approaches T_s , the magnitude of the cooling rate approaches zero. Do not assume k is universal or use body temperature T in place of temperature excess $T - T_s$.

K = °C + 273.15 (often approximated as °C + 273)

Meaning: Converts Celsius to kelvin.

Use when: Absolute-temperature calculations.

Condition: Use kelvin in radiation laws.

Exam trap: Do not apply the 273 offset to ΔT ; temperature intervals have the same numerical value in K and °C.

$$^{\circ}\text{F} = \left(\frac{9}{5}\right)^{\circ}\text{C} + 32 ; \Delta^{\circ}\text{F} = \left(\frac{9}{5}\right)^{\circ}\text{C}$$

Meaning: Converts Celsius readings and temperature intervals to Fahrenheit.

Use when: When Fahrenheit is used in the question.

Condition: Distinguish an absolute reading from a temperature interval.

Exam trap: For a rise of 10°C , the interval is 18°F .

$$Q = mc\Delta T ; C = \frac{Q}{\Delta T} ; C = mc ; C_m = \frac{Q}{n\Delta T}$$

Meaning: Relates heat transfer to temperature change and defines heat capacity and molar heat capacity.

Use when: Heating/cooling within a single phase.

Condition: Assume the relevant heat capacity is constant or use a suitable average.

Exam trap: Do not use $Q = mc\Delta T$ for the energy absorbed during a phase change.

$$Q = mL$$

Meaning: Energy transferred during a phase change.

Use when: Melting/freezing or vaporisation/condensation.

Condition: Use the correct latent heat for the process.

Exam trap: Temperature is constant during the ideal phase-change interval; do not add a temperature-change term for that interval.

$\Sigma Q = 0$ (insulated system)

Meaning: Total signed heat transfer sums to zero for the chosen insulated system.

Use when: Mixing and calorimetry.

Condition: Include all bodies that exchange heat, including vessel/calorimeter if relevant.

Exam trap: Final temperature is not generally the arithmetic mean.

Water equivalent: $W = \frac{C_{body}}{C_{water}}$

Meaning: The mass of water with the same heat capacity as the body.

Use when: Calorimetry problems that specify or ask for water equivalent.

Condition: Use consistent units for heat capacity and specific heat.

Exam trap: Water equivalent is not necessarily the actual mass of the object.

$\Delta L = \alpha L_0 \Delta T$; $\Delta A \approx \beta A_0 \Delta T$; $\Delta V \approx \gamma V_0 \Delta T$

Meaning: Linear, area and volume expansion.

Use when: A solid's dimensions change with temperature.

Condition: For small expansion and approximately constant coefficients; for isotropic solids $\beta \approx 2\alpha$ and $\gamma \approx 3\alpha$.

Exam trap: Use initial dimensions and the coefficient matching

the requested dimension.

Thermal stress magnitude = $Y\alpha\Delta T$

Meaning: Stress caused by fully preventing the thermal expansion of a uniform rod.

Use when: A rod is heated or cooled while fully constrained.

Condition: Ideal uniform rod, full restraint and linear-elastic behaviour.

Exam trap: A freely expanding rod does not develop this ideal thermal stress.

$$\Delta V_{\text{real}} = \Delta V_{\text{apparent}} + \Delta V_{\text{container}}$$

Meaning: Corrects apparent liquid expansion for expansion of the vessel.

Use when: Liquid expansion measured in a container.

Condition: Use volume changes over the same temperature interval.

Exam trap: Do not mistake the observed level rise for the liquid's real expansion.

$$P = \frac{kA(T_1 - T_2)}{L} ; R_{th} = \frac{L}{kA} ; P = \frac{\Delta T}{R_{th}}$$

Meaning: Steady conduction rate and thermal resistance of a flat slab.

Use when: Steady one-dimensional heat flow through a slab.

Condition: Constant k , fixed geometry and negligible side losses.

Exam trap: Doubling L doubles resistance and halves rate if all

else stays fixed.

Series layers: $R_{\text{total}} = \sum R_i$; $P = \frac{\Delta T}{R_{\text{total}}}$

Meaning: Thermal resistances add in series for steady heat flow through layers.

Use when: Composite wall with layers arranged one after another.

Condition: Same steady heat rate passes through each layer; contact resistance may matter if given.

Exam trap: Do not average conductivities directly without the geometry and layer thicknesses.

Parallel paths: $\frac{1}{R_{\text{eq}}} = \sum \left(\frac{1}{R_i} \right)$

Meaning: Equivalent thermal resistance for parallel heat-flow paths.

Use when: Heat can pass through separate parallel paths between the same temperatures.

Condition: Each path has the same temperature difference.

Exam trap: Parallel resistance is less than any individual path resistance.

⁴ $P_{\text{emit}} = \epsilon \sigma A T^4$; $P_{\text{net}} = \epsilon \sigma A (T^4 - T_s^4)$

Meaning: Total emitted radiative power and net exchange with surroundings.

Use when: Radiation power from a surface.

Condition: Temperatures in kelvin; ϵ is emissivity and σ is the Stefan–Boltzmann constant.

Exam trap: Net power must include the surroundings term; emissivity applies to the stated surface model.

$$\lambda_{\max} T = b ; b \approx 2.9 \times 10^{-3} \text{ m}\cdot\text{K}$$

Meaning: Wien's displacement law: peak wavelength decreases as temperature rises.

Use when: Comparing radiation spectra or finding peak wavelength.

Condition: Use absolute temperature in kelvin.

Exam trap: Hotter means shorter peak wavelength, not longer.

$$\text{Cooling rate} \propto (T - T_s)$$

Meaning: Newton's law of cooling in approximate proportional form.

Use when: Cooling when the body's temperature is not very different from surroundings.

Condition: Surroundings and heat-transfer conditions remain approximately constant.

Exam trap: The rate slows as the temperature excess becomes smaller.

5. Formula Selection Guide

SEE THIS SITUATION	THINK THIS MODEL	USE THIS RELATION
Compare instantaneous cooling rates	Newton's law; same body/conditions	$\left \frac{dT}{dt} \right \propto (T - T_s)$
Find temperature after time t ; k given	Exponential cooling; constant k	$T - T_s = (T_0 - T_s)e^{(-kt)}$
Body approaches steady room temperature	Temperature excess decays	$T - T_s$ decreases toward zero
Temperature scale given in $^{\circ}\text{C}$; absolute temperature needed	Convert scale first	$K = ^{\circ}\text{C} + 273.15$
Temperature changes within one phase	Sensible heating/cooling	$Q = mc\Delta T$
Substance melts, freezes, boils or condenses	Latent heat	$Q = mL$
Hot and cold bodies exchange energy in an	Calorimetry balance	$\Sigma Q = 0$

insulated setup		
Calorimeter heat capacity is given	Convert to water-equivalent mass if useful	$W = \frac{C_{body}}{C_{water}}$
Solid changes dimensions	Thermal expansion	$\Delta L = \alpha L_0 \Delta T$; $\Delta V \approx \gamma V_0 \Delta T$
Rod is fully restrained while temperature changes	Thermal stress	stress magnitude = $Y\alpha\Delta T$
Liquid level changes in a vessel	Separate liquid and vessel expansion	real = apparent + container expansion
Steady heat passes through a slab	Conduction rate	$P = \frac{kA\Delta T}{L}$
Several layers lie one after another	Series thermal resistance	$R_{total} = \sum R_i$
Separate parallel paths carry heat	Parallel thermal resistance	$\frac{1}{R_{eq}} = \sum \frac{1}{R_i}$
Asked for emitted power or net radiation	Choose the radiation quantity	$P_{emit} = \epsilon\sigma AT^4$; $P_{net} = \epsilon\sigma A(T^4 - T_s^4)$
Asked for peak wavelength	Radiation spectrum	$\lambda_{max} T = b$
Cooling rate	Newton's law of	Rate $\propto T - T_s$

compared at different temperature excesses	cooling	
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6. When to Use / When Not to Use

$Q = mc\Delta T$ — Use for a temperature change within one phase. Do not use it for the phase-change energy itself; use $Q = mL$ for that interval.

$Q = mL$ — Use during a phase change at its transition temperature. For a full heating curve, split the process into sensible-heating and phase-change stages.

$\Sigma Q = 0$ — Use for the chosen system when external heat exchange is negligible. If heat escapes or a calorimeter absorbs energy, include those terms or state the approximation.

Thermal expansion — Use the coefficient corresponding to length, area or volume. The common $\beta \approx 2\alpha$ and $\gamma \approx 3\alpha$ relations assume an isotropic solid and small expansion.

Thermal stress — Use the ideal $Y\alpha\Delta T$ magnitude only for complete restraint. Partial restraint or nonuniform temperature requires a different model.

Conduction relation — Use for steady conduction under the assumed geometry. For multiple layers, combine thermal resistances rather than treating the whole wall as one material without justification.

Stefan–Boltzmann law — Use kelvin and decide whether the question asks for emitted or net power. Net power includes the surroundings term under the stated model.

Newton's law of cooling — Use as an approximation for a small temperature difference and stable surroundings. Do not assume identical cooling constants for different setups.

7. Common Misconceptions

- Wrong: "A body contains heat." → Correct: A body has internal energy; heat is energy transferred because of a temperature difference.
- Wrong: "Heat supplied must raise temperature." → Correct: During a phase change, energy can change the state at constant temperature.
- Wrong: "The final temperature is always the average." → Correct: Masses, heat capacities and energy exchange determine the result.
- Wrong: "The observed expansion is the liquid's real expansion." → Correct: The vessel expands too.
- Wrong: "Free thermal expansion produces the same stress as a blocked rod." → Correct: The ideal restraint stress requires expansion to be prevented.
- Wrong: "Radiation needs air." → Correct: Thermal radiation can cross a vacuum.
- Wrong: "Only very hot bodies radiate." → Correct: All bodies above 0 K emit radiation.

- Wrong: “Water always becomes denser as it cools.” →
Correct: Between 4 °C and 0 °C, water’s density decreases as it cools.

8. Exam Traps

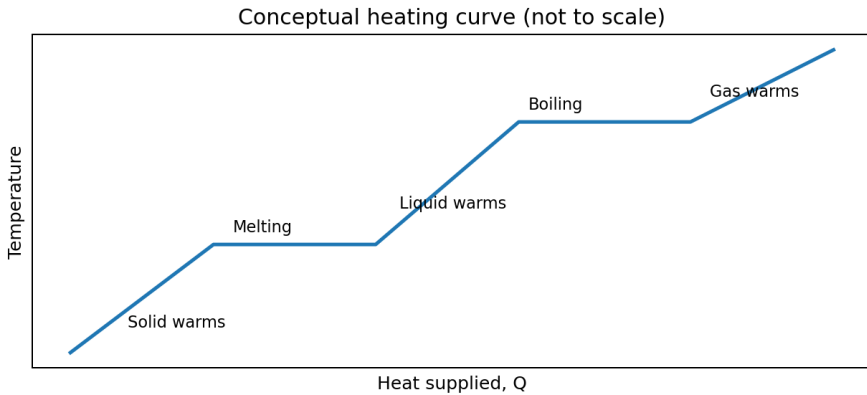
- Using Celsius in T^4 or Wien’s law instead of kelvin.
- Using $Q = mc\Delta T$ across a phase-change interval.
- Leaving out the calorimeter or water equivalent when it is relevant.
- Assuming the arithmetic mean is the final temperature without checking heat capacities.
- Mixing up real and apparent expansion.
- Using area/volume expansion coefficients as though they were linear coefficients.
- Applying $Y\alpha\Delta T$ when the rod is not fully restrained.
- Adding conductivities rather than thermal resistances for layers in series.
- Confusing emitted radiation with net radiative exchange.
- Using Newton’s law of cooling outside its approximate conditions.

9. See This → Think This

- Equal temperatures and no net heat transfer → thermal equilibrium.
- Temperature changes within a phase → $Q = mc\Delta T$.
- Temperature remains constant while heat is supplied → check for a phase change and use $Q = mL$.

- Hot and cold bodies in an insulated vessel → define the system and set $\Sigma Q = 0$.
- Calorimeter heat capacity supplied → include it or convert it to water equivalent.
- Rod heated with free ends → expansion; fully blocked rod → thermal stress.
- Liquid in an expanding vessel → real expansion differs from apparent expansion.
- Steady heat flow through a wall → conduction and thermal resistance.
- Several wall layers in series → add thermal resistances.
- Fluid circulation transports energy → convection.
- Heat crosses a vacuum → radiation.
- Asked for net radiation with surroundings given → include T_s^4 .
- Asked for peak wavelength → Wien's law; hotter body has shorter peak wavelength.
- Water near 0–4 °C → remember anomalous expansion and maximum density at 4 °C.

10. Key Diagrams / Graphs

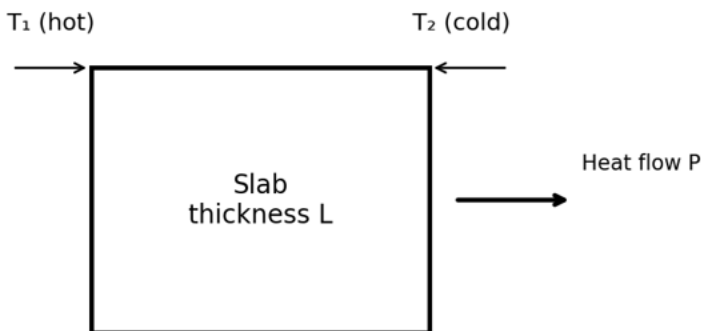


Heating curve

Notice: Sloping parts show temperature change; flat parts show phase change at constant temperature.

Exam Use: Use $Q = mc\Delta T$ for sloping stages and $Q = mL$ for flat stages. A multi-stage process may require adding the energy for each stage.

Steady conduction through a slab



Conduction through a slab

Notice: Heat flows from higher temperature to lower temperature; L is thickness and A is cross-sectional area.

Exam Use: Use $P = kA\Delta T/L$ for steady one-dimensional conduction. Larger L lowers the rate; larger k or A increases it.

Thermal expansion and restraint

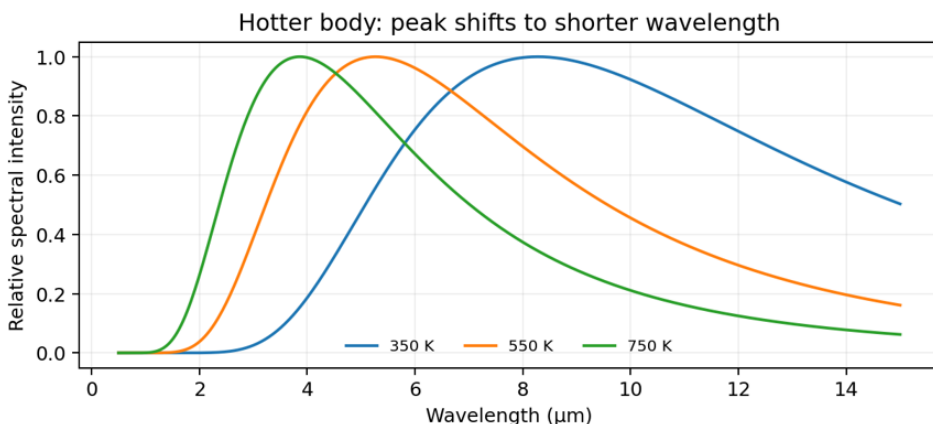
Notice: A freely heated rod becomes longer; a fully restrained rod cannot expand and can develop thermal stress.

Exam Use: First identify whether the rod is free, partially restrained or fully restrained before choosing an expansion or stress relation.

Convection circulation

Notice: Bulk motion of the fluid carries energy; the circulation pattern depends on heating, cooling and fluid properties.

Exam Use: Use convection when fluid motion transports energy; do not confuse it with conduction through a stationary fluid.

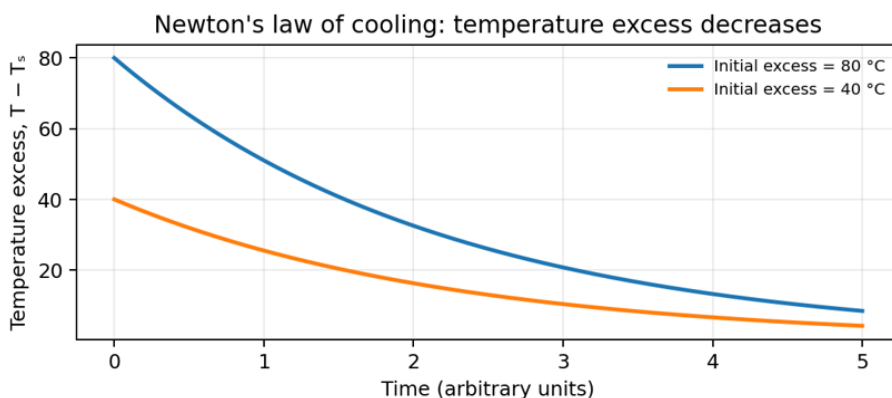


Thermal radiation spectrum

Notice: As temperature rises, the spectral peak shifts toward shorter wavelengths. Curves are illustrative.

Exam Use: Use $\lambda_{\text{max}} T = b$ to compare peak wavelengths. Use kelvin.

Newton's Law of Cooling – Graph and Interpretation



Notice: The temperature excess $T - T_s$ decreases with time and approaches zero in the ideal model.

Exam Use: Use the proportionality for rate comparisons and the exponential form when k and elapsed time are given.

11. Quick Checks

- **Q: What does temperature help determine?** → The direction of net heat transfer.
- **Q: Does a body store heat?** → No; it has internal energy. Heat is energy in transit.
- **Q: Which relation applies to heating within one phase?** → $Q = mc\Delta T$.

- **Q: Which relation applies during melting or boiling?** →

$$Q = mL.$$

- **Q: What does water equivalent represent?** → The mass of water with the same heat capacity as the body.
- **Q: If slab thickness doubles, what happens to steady conduction rate?** → It halves if all other quantities remain fixed.
- **Q: What distinguishes convection from conduction?** → Convection involves bulk fluid motion.
- **Q: Does radiation require a material medium?** → No.
- **Q: Which temperature scale is needed for T^4 and Wien's law?** → Kelvin.
- **Q: What happens to peak wavelength as temperature rises?** → It decreases.
- **Q: At what temperature is water's density maximum?** → 4 °C.
- **Q: When is the ideal thermal-stress relation $Y\alpha\Delta T$ appropriate?** → When thermal expansion is fully prevented under the ideal assumptions.
- **Q: What must be added for layers in series?** → Their thermal resistances.
- **Q: What controls the approximate cooling rate in Newton's law?** → The temperature difference from the surroundings.

Q: A body at 80 °C cools in surroundings at 30 °C. Another is at 60 °C in the same surroundings. Under Newton's law and

identical conditions, what is the ratio of instantaneous cooling-rate magnitudes? $\rightarrow 50:30 = 5:3$.

12. Mini Exam Reasoning

Clue: A body cools in surroundings at constant temperature and k is known. $\rightarrow$ Physics situation: Temperature excess decays. $\rightarrow$ Model: Newton's law of cooling. $\rightarrow$ Relation:

$T - T_s = (T_0 - T_s)e^{(-kt)}$. $\rightarrow$ Check: Substitute excess temperatures; do not treat T itself as the decaying quantity.

Clue: Ice at 0°C melts to water at 0°C . Physics situation: Phase change. $\rightarrow$ Model: Latent heat. $\rightarrow$ Relation: $Q = mL_f$. $\rightarrow$ Check: No temperature rise during melting.

Clue: Hot metal is placed in cooler water in an insulated calorimeter. Physics situation: Energy exchange. $\rightarrow$ Model: Calorimetry. $\rightarrow$ Relation: $\Sigma Q = 0$. $\rightarrow$ Check: Include the calorimeter or its water equivalent if given.

Clue: A wall has two material layers and steady heat flow. Physics situation: Series conduction. $\rightarrow$ Model: Thermal resistance. $\rightarrow$ Relation: $R_{\text{total}} = R_1 + R_2$; $P = \Delta T/R_{\text{total}}$. $\rightarrow$ Check: The same steady heat rate passes through each layer.

Clue: A radiating body and its surroundings have different temperatures. Physics situation: Net radiative exchange. $\rightarrow$ Model: Stefan-Boltzmann. $\rightarrow$ Relation: $P_{\text{net}} = \epsilon\sigma A(T^4 - T_s^4)$. $\rightarrow$ Check: Both temperatures are in kelvin.

Clue: A heated metal rod is clamped so it cannot change length. Physics situation: Restrained thermal expansion. $\rightarrow$ Model:

Thermal stress. → Relation: stress magnitude = $Y\alpha\Delta T$. → Check: The rod is fully restrained and remains in the linear-elastic regime.

Clue: Water is cooled from 6 °C to 2 °C. Physics situation: Anomalous expansion. → Model: Density variation near 4 °C. → Check: Density increases as water cools from 6 °C to 4 °C, then decreases as it cools from 4 °C to 2 °C.

13. One-Minute Recall

- Heat is energy transferred; internal energy belongs to the body.
- Use kelvin for absolute-temperature laws; ΔT in K equals ΔT in °C numerically.
- Single phase: $Q = mc\Delta T$. Phase change: $Q = mL$.
- Insulated calorimetry: $\Sigma Q = 0$; include the calorimeter when relevant.
- Water equivalent $W = C_{\text{body}}/C_{\text{water}}$.
- Expansion: $\Delta L = \alpha L_0 \Delta T$; for isotropic solids $\beta \approx 2\alpha$ and $\gamma \approx 3\alpha$.
- Full restraint can produce thermal stress of magnitude $Y\alpha\Delta T$.
- Real liquid expansion = apparent expansion + vessel expansion.
- Water has maximum density at 4 °C.
- Conduction: $P = kA\Delta T/L$; thermal resistance $R_{\text{th}} = L/(kA)$.
- Series thermal resistances add; parallel conductances add.
- Convection needs bulk fluid motion; radiation does not need a medium.

- Stefan–Boltzmann: emitted power $\propto T^4$; Wien: $\lambda_{\text{max}} T = \text{constant}$.
- Newton cooling rate is approximately proportional to temperature excess.

For constant k and fixed surroundings: $dT/dt = -k(T - T_s)$;

$$T - T_s = (T_0 - T_s)e^{(-kt)}.$$

Formula Map – Fast Revision

Topic	Core Relation(s)
Temperature	$K = {}^\circ C + 273.15$; ${}^\circ F = \frac{9}{5} {}^\circ C + 32$
Heat capacity	$Q = mc\Delta T$; $C = \frac{Q}{\Delta T} = mc$; $C_m = \frac{Q}{n\Delta T}$
Phase change	$Q = mL$
Calorimetry	$\Sigma Q = 0$; $W = \frac{C_{\text{body}}}{C_{\text{water}}}$
Expansion	$\Delta L = \alpha L_0 \Delta T$; $\Delta A \approx \beta A_0 \Delta T$; $\Delta V \approx \gamma V_0 \Delta T$
Thermal stress	Stress magnitude = $Y\alpha\Delta T$ (for full restraint)
Liquid expansion	Real expansion = Apparent expansion + Container expansion
Conduction	$P = \frac{kA\Delta T}{L}$; $R_{\text{th}} = \frac{L}{kA}$
Layered conduction	Series: $R_{\text{total}} = \Sigma R_i$; Parallel: $\frac{1}{R_{\text{eq}}} = \Sigma \frac{1}{R_i}$
Radiation	$P_{\text{emit}} = \varepsilon\sigma AT^4$; $P_{\text{net}} = \varepsilon\sigma A(T^4 - T_s^4)$
Wien law	$\lambda_{\text{max}} T = b \approx 2.9 \times 10^{-3} \text{ m}\cdot\text{K}$

Topic	Core Relation(s)
Cooling	Rate $\propto (T - T_s)$, under Newton's cooling approximation

Want to Go Deeper?

This concept summary is designed for rapid understanding, formula selection and NEET revision. The complete NEET Physics Essentials Concept Book provides full concept development, detailed derivations and diagrams, microquestions, solved examples, integrated problem-solving and a complete exam playbook.

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