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Introduction

Concept Overview

- Temperature measures the hotness or coldness of a body.
- During phase changes like boiling or freezing, temperature remains constant despite heat flow.
- Thermal properties explain why ice feels cold and why temperature stays steady during state changes.

Solved Examples

- **Ex 1:** Why does temperature remain constant during boiling?
  - Heat energy is used for phase change, not temperature rise.

Practice Set

- Q1: What does temperature measure?
  - A) Energy content B) Hotness or coldness C) Heat flow D) Pressure
- Q2: During freezing, temperature of water
  - A) Increases B) Decreases C) Remains constant D) Fluctuates
- Q3: Why does ice feel cold to touch?
  - A) It has low temperature B) It absorbs heat from hand C) It emits heat D) It has high temperature

Answer Key

- Q1: B - Temperature indicates hotness or coldness, not energy or heat flow.
- Q2: C - Temperature remains constant during freezing as heat is used for phase change.
- Q3: B - Ice absorbs heat from the hand, making it feel cold.

Memory Aids

- Temperature = Hotness/Coldness indicator

- Phase change = Constant temperature despite heat flow
- Ice feels cold because it absorbs heat

Temperature and Heat

Key Concepts

- Temperature: Relative measure of hotness or coldness (SI unit: Kelvin, °C).
- Heat: Energy transferred due to temperature difference (SI unit: Joule).
- Heat transfer causes changes: temperature rise, expansion, or state change.
- Heat flow direction: from higher to lower temperature.

Solved Examples

- **Ex 1:** Define heat.
  - Heat is energy transferred due to temperature difference.
- **Ex 2:** What happens when an object is heated?
  - Temperature may rise, object may expand or change state.

Practice Set

- Q1: Heat is transferred because of
  - A) Pressure difference B) Temperature difference C) Volume difference D) Mass difference
- Q2: Which is a relative measure?
  - A) Heat B) Temperature C) Energy D) Work
- Q3: When an object is heated, which change is NOT possible?
  - A) Temperature rise B) Expansion C) Change of state D) Decrease in temperature

Answer Key

- Q1: B - Heat flows due to temperature difference.
- Q2: B - Temperature is a relative measure of hotness or coldness.
- Q3: D - Heating cannot decrease temperature.

Memory Aids

- Heat = Energy transfer due to temperature difference
- Temperature = Relative hotness/coldness
- Heating effects: Rise in temperature, expansion, or phase change

Measurement of Temperature

Thermometer and Temperature Measurement

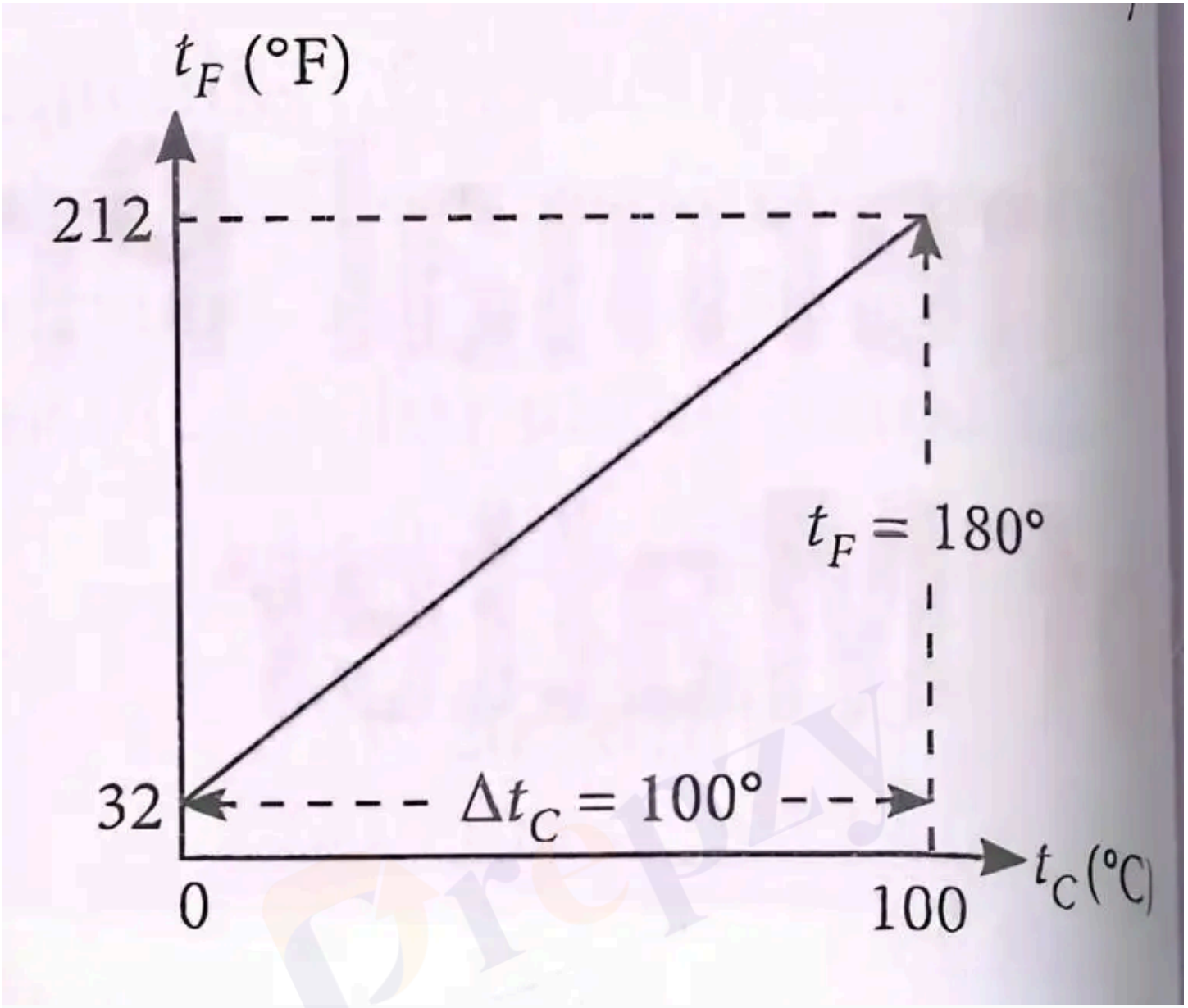
- A thermometer measures temperature using physical properties that change with temperature.
- Commonly used property: volume variation of liquids like mercury or alcohol in glass thermometers.
- Volume of these liquids changes linearly with temperature over a wide range.

Temperature Scales and Fixed Points

- Two fixed reference points define temperature scales: ice point (freezing) and steam point (boiling) of water.
- Ice point = 0°C (32°F), Steam point = 100°C (212°F).
- Common scales: Celsius (°C) and Fahrenheit (°F).

Relation Between Celsius and Fahrenheit

- Formula: $\frac{t_F - 32}{180} = \frac{t_C}{100}$
- Where t_F = temperature in Fahrenheit, t_C = temperature in Celsius.



Solved Examples

- **Ex 1:** Convert 25°C to Fahrenheit.
  - Use formula: $t_F = \frac{180}{100} \times t_C + 32$
  - Calculation: $t_F = 1.8 \times 25 + 32 = 45 + 32 = 77^\circ F$
- **Ex 2:** Convert 95°F to Celsius.
  - Use formula: $t_C = \frac{100}{180}(t_F - 32)$
  - Calculation: $t_C = \frac{100}{180}(95 - 32) = \frac{100}{180} \times 63 = 35^\circ C$

Practice Set

- **Q1:** What is the freezing point of water in Fahrenheit?
  - A) 0°F

    - B) 32°F
    - C) 100°F
    - D) 212°F
- **Q2:** Convert 40°C to Fahrenheit.
    - A) 104°F
    - B) 72°F
    - C) 90°F
    - D) 68°F
- **Q3:** If the temperature is 86°F, what is it in Celsius?
    - A) 30°C
    - B) 32°C
    - C) 28°C
    - D) 25°C

Answer Key

- **Q1:** B) 32°F - Freezing point of water is 32°F on Fahrenheit scale.
- **Q2:** A) 104°F - Using formula: $1.8 \times 40 + 32 = 104^\circ F$.
- **Q3:** A) 30°C - Using formula: $\frac{100}{180}(86 - 32) = 30^\circ C$.

Memory Aids

- Freezing point: 0°C = 32°F
- Boiling point: 100°C = 212°F
- Conversion formula: $t_F = 1.8t_C + 32$, $t_C = \frac{5}{9}(t_F - 32)$
- Volume of mercury/alcohol changes linearly with temperature in thermometers.

Thermal Expansion

Concepts

- Thermal expansion: Increase in dimensions due to temperature rise.
- Occurs in solids (length, area, volume), liquids and gases (volume only).
- Gases can expand at constant volume or pressure.
- Expansion depends on material and state (solid, liquid, gas).

The increase in the dimensions of a body due to the increase in its temperature is called thermal expansion. It is present in solids, liquid and gases.

Coefficient of linear expansion, $\alpha = \frac{\alpha_T - L_0}{L_0 \times \Delta T}$

Coefficient of area expansion, $\beta = \frac{A_T - A_0}{A_0 \times \Delta T}$

Coefficient of volume expansion, $\gamma = \frac{V_T - V_0}{V_0 \times \Delta T}$

Relation between α, β and γ: $\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$



Solved Examples

- **Ex 1:** Calculate length increase of a rod of length 1 m heated by 10°C with linear expansion coefficient $\alpha = 1 \times 10^{-5} \backslash \text{degree} C^{-1}$.
  - Use $\Delta L = L_0 \alpha \Delta T = 1 \times 1 \times 10^{-5} \times 10 = 0.0001 \text{ m} = 0.1 \text{ mm}$

Practice Set

- Q1: Thermal expansion occurs in which states of matter?
  - A. Solids only
  - B. Liquids only
  - C. Solids, liquids, and gases
  - D. Gases only
- Q2: Which dimension expands in liquids on heating?
  - A. Length
  - B. Area
  - C. Volume
  - D. None
- Q3: A gas is heated at constant volume. Which property changes?
  - A. Volume
  - B. Pressure
  - C. Temperature
  - D. Both B and C

Answer Key

- Q1: C - Thermal expansion occurs in solids, liquids, and gases.

- Q2: C - Liquids expand only in volume as they have no fixed shape.
- Q3: D - At constant volume, pressure and temperature change.

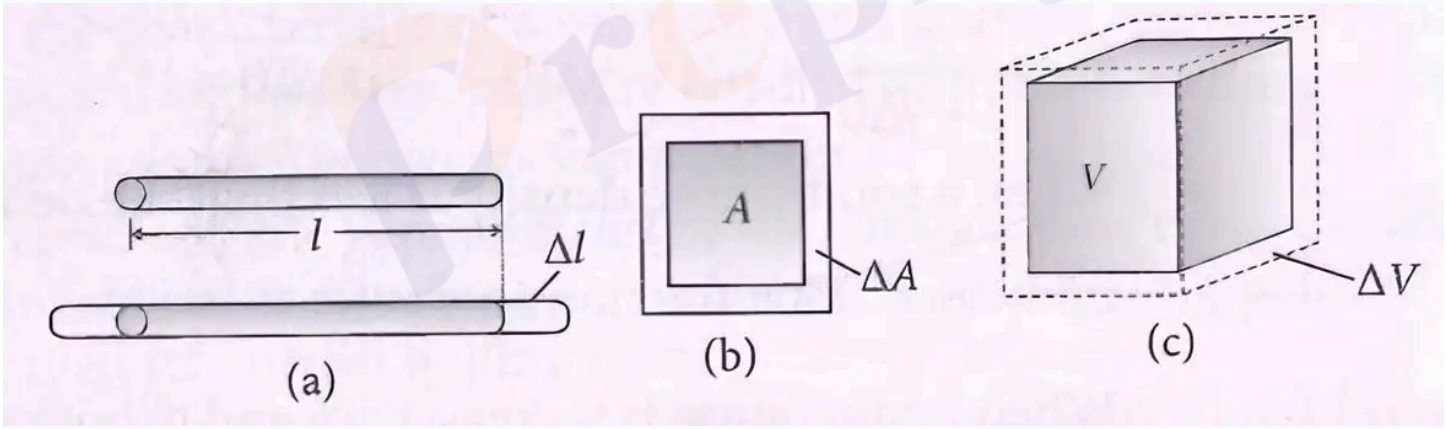
Memory Aids

- Thermal expansion = size increase with temperature.
- Solids: length, area, volume expand.
- Liquids & gases: volume expands only.

Thermal Expansion in Solids

Types

- Linear expansion: Increase in length ΔL.
- Area expansion: Increase in surface area ΔA.
- Volume expansion: Increase in volume ΔV.



Solved Examples

- **Ex 1:** Rod length $l = 2m$, $\alpha = 1.2 \times 10^{-5} \backslash \text{degree} C^{-1}$, temperature rise $\Delta T = 50 \backslash \text{degree} C$.
  - New length $L_T = L_0(1 + \alpha \Delta T) = 2(1 + 1.2 \times 10^{-5} \times 50) = 2.0012m$

Practice Set

- Q1: Linear expansion changes which dimension?

    - A. Length
    - B. Area
    - C. Volume
    - D. Density
- Q2: Area expansion coefficient β relates to increase in?
    - A. Length
    - B. Surface area
    - C. Volume
    - D. Mass
- Q3: Volume expansion coefficient γ is defined as?
    - A. Increase in volume per unit volume per degree rise
    - B. Increase in length per unit length per degree rise
    - C. Increase in area per unit area per degree rise
    - D. None

Answer Key

- Q1: A - Linear expansion changes length.
- Q2: B - Area expansion relates to surface area increase.
- Q3: A - Volume expansion coefficient defines volume increase per unit volume per degree.

Memory Aids

- α: linear expansion coefficient.
- $\beta = 2\alpha, \gamma = 3\alpha$.
- Use $L_T = L_0(1 + \alpha\Delta T)$ for length.

Coefficients of Thermal Expansion

Definitions & Relations

- Coefficient of linear expansion $\alpha = \frac{\Delta L}{L_0 \Delta T}$.
- Coefficient of area expansion $\beta = \frac{\Delta A}{A_0 \Delta T}$.
- Coefficient of volume expansion $\gamma = \frac{\Delta V}{V_0 \Delta T}$.
- Relation: $\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$.
- Units: $\backslash \text{degree} C^{-1}$ or K^{-1}.

Solved Examples

- **Ex 1:** Given $\alpha = 1 \times 10^{-5} \backslash \text{degree} C^{-1}$, find β and γ.
  - $\beta = 2\alpha = 2 \times 10^{-5} \backslash \text{degree} C^{-1}$
  - $\gamma = 3\alpha = 3 \times 10^{-5} \backslash \text{degree} C^{-1}$

Practice Set

- Q1: If $\alpha = 2 \times 10^{-5} \backslash \text{degree} C^{-1}$, then $\beta =$?
  - A. 1×10^{-5}
  - B. 2×10^{-5}
  - C. 4×10^{-5}
  - D. 6×10^{-5}
- Q2: Relation between coefficients is?
  - A. $\alpha = \beta = \gamma$
  - B. $\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$
  - C. $\alpha = 2\beta = 3\gamma$
  - D. None
- Q3: Units of α, β, γ are?
  - A. m
  - B. $\backslash \text{degree} C^{-1}$
  - C. kg/m³
  - D. N/m²

Answer Key

- Q1: C - $\beta = 2\alpha = 4 \times 10^{-5} \backslash \text{degree} C^{-1}$.
- Q2: B - $\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$ is correct relation.
- Q3: B - Units are per degree Celsius or Kelvin.

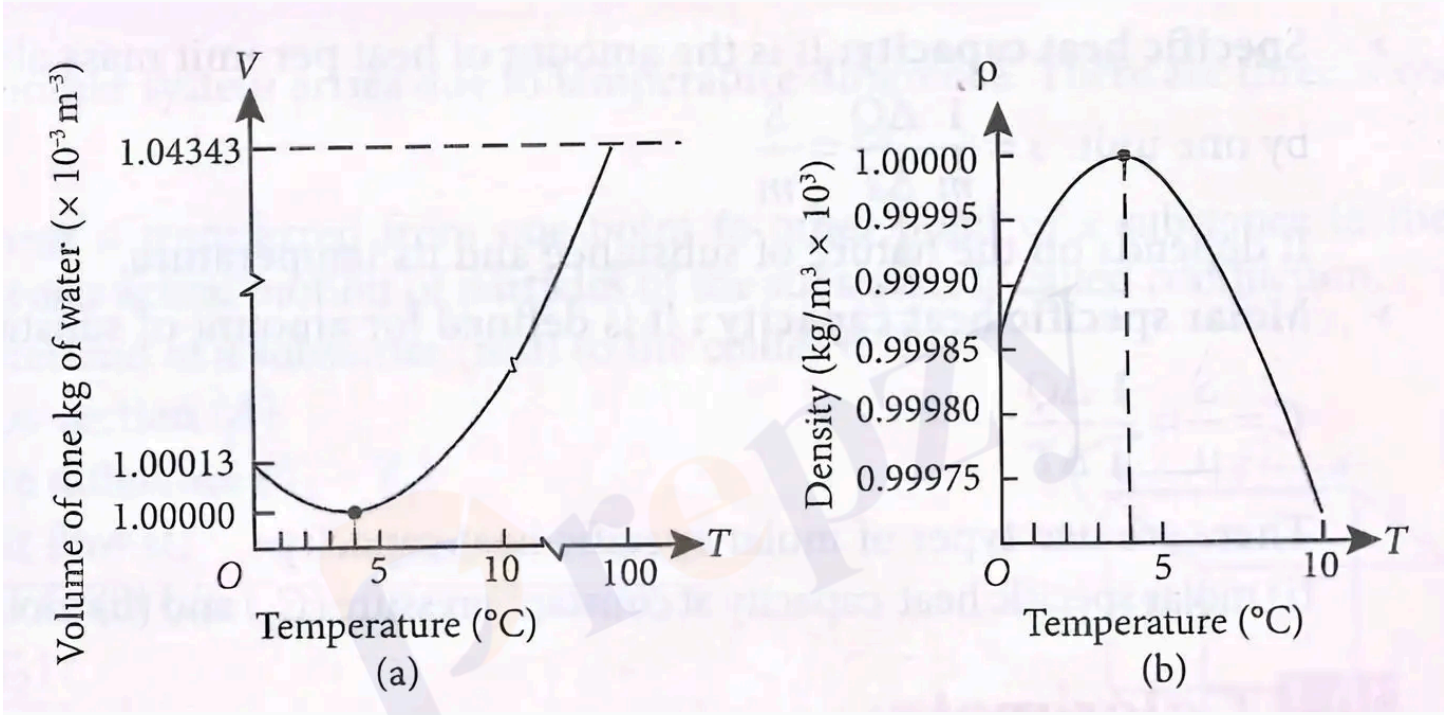
Memory Aids

- Remember: $\beta = 2\alpha$, $\gamma = 3\alpha$.
- All coefficients have same units.

Anomalous Expansion of Water

Key Points

- Water contracts on heating from 0°C to 4°C (negative volume expansion).
- Water expands on heating above 4°C.
- Maximum density at 4°C.
- Explains ice floating and freezing from top.



Solved Examples

- **Ex 1:** Explain why ice floats on water.
  - Due to anomalous expansion, water is densest at 4°C; ice is less dense and floats.

Practice Set

- Q1: Water has maximum density at?
  - A. 0°C
  - B. 4°C
  - C. 100°C
  - D. -4°C
- Q2: Between 0°C and 4°C, water volume?

    - A. Increases on heating
    - B. Decreases on heating
    - C. Remains constant
    - D. Expands on cooling
- Q3: Anomalous expansion means?
    - A. Normal expansion
    - B. Expansion only in solids
    - C. Contraction on heating in 0-4°C range
    - D. No expansion

Answer Key

- Q1: B - Water is densest at 4°C.
- Q2: B - Water contracts on heating from 0°C to 4°C.
- Q3: C - Anomalous expansion means contraction on heating in 0-4°C.

Memory Aids

- Water densest at 4°C.
- Volume decreases on heating 0-4°C.
- Ice floats due to lower density.

Thermal Stress

Concepts & Formulas

- Thermal stress arises when expansion is prevented.
- Thermal strain $= \frac{\Delta L}{L} = \alpha \Delta T$.
- Thermal stress $= Y \times \text{thermal strain} = Y \alpha \Delta T$, where Y is Young's modulus.
- Force developed $= YA\alpha\Delta T$, A is cross-sectional area.

Solved Examples

- **Ex 1:** Rod with $Y = 2 \times 10^{11} \text{Pa}$, $\alpha = 1 \times 10^{-5} \backslash \text{degree} C^{-1}$, $\Delta T = 50 \backslash \text{degree} C$, $A = 0.01 m^2$.

- Thermal stress $= 2 \times 10^{11} \times 1 \times 10^{-5} \times 50 = 1 \times 10^{8}\text{Pa}$
- Force $= 1 \times 10^{8} \times 0.01 = 1 \times 10^{6}\text{N}$

Practice Set

- Q1: Thermal stress occurs when?
  - A. Expansion is free
  - B. Expansion is prevented
  - C. Temperature decreases
  - D. No temperature change
- Q2: Thermal strain formula is?
  - A. $\alpha\Delta T$
  - B. $\frac{\Delta L}{L}$
  - C. Both A and B
  - D. None
- Q3: Force developed depends on?
  - A. Young's modulus, area, α, ΔT
  - B. Only temperature
  - C. Only area
  - D. None

Answer Key

- Q1: B - Stress arises when expansion is prevented.
- Q2: C - Thermal strain = $\alpha\Delta T = \frac{\Delta L}{L}$.
- Q3: A - Force = $YA\alpha\Delta T$.

Memory Aids

- Stress = Young's modulus × strain.
- Strain = $\alpha\Delta T$.
- Force = stress × area.

Specific Heat Capacity

Definition and Formula

- Heat capacity (S) = $\frac{\Delta Q}{\Delta T} = ms$
- ΔQ: heat supplied to change temperature from T to $T + \Delta T$
- m: mass of the substance
- s: specific heat capacity

Specific Heat Capacity

- Heat absorbed or released per unit mass to change temperature by 1 unit
- Formula: $s = \frac{1}{m}\frac{\Delta Q}{\Delta T} = \frac{S}{m}$
- Depends on substance nature and temperature

Molar Specific Heat Capacity

- Heat capacity per mole of substance (in gram moles)
- Formula: $C = \frac{S}{\mu} = \frac{1}{\mu}\frac{\Delta Q}{\Delta T}$
- Two types:
  - At constant pressure: C_p
  - At constant volume: C_V

Solved Examples

- **Ex 1:** Calculate specific heat capacity if $\Delta Q = 500\ \text{J}$, $m = 2\ \text{kg}$, $\Delta T = 5\ \text{K}$.
  - Use $s = \frac{\Delta Q}{m\Delta T} = \frac{500}{2\times5} = 50\ \text{J/kg K}$
- **Ex 2:** Find molar specific heat capacity if $S = 100\ \text{J/K}$, $\mu = 4\ \text{mol}$.
  - Use $C = \frac{S}{\mu} = \frac{100}{4} = 25\ \text{J/mol K}$

Practice Set

- Q1: Heat capacity S is defined as:

- A) $\frac{\Delta T}{\Delta Q}$
- B) $\frac{\Delta Q}{\Delta T}$
- C) $m \times s$
- D) $\frac{1}{m}\frac{\Delta Q}{\Delta T}$

- Q2: Specific heat capacity s depends on:
  - A) Mass only
  - B) Nature of substance and temperature
  - C) Volume only
  - D) Pressure only
- Q3: Molar specific heat capacity at constant volume is denoted by:
  - A) C_p
  - B) C_V
  - C) s
  - D) S

Answer Key

- Q1: B - Heat capacity is heat supplied per unit temperature change $\frac{\Delta Q}{\Delta T}$.
- Q2: B - Specific heat depends on the substance's nature and temperature.
- Q3: B - C_V denotes molar specific heat at constant volume.

Memory Aids

- Heat capacity $S = ms$
- Specific heat $s = \frac{S}{m}$
- Molar heat $C = \frac{S}{\mu}$
- C_p at constant pressure, C_V at constant volume

Calorimetry

Concept and Device

- Calorimetry measures specific heat or latent heat of substances.
- A calorimeter is the device used for heat measurement.
- Heat transfer occurs between bodies at different temperatures until thermal equilibrium.

Principle

- Based on the law of conservation of energy.
- Heat lost by hot body = Heat gained by cold body (no heat loss to surroundings).
- Formula: **Heat Lost = Heat Gained**

Solved Examples

- **Ex 1:** A 100 g hot metal at 100°C is placed in 200 g water at 25°C. Find final temperature if no heat loss occurs. Use specific heat of metal = 0.4 J/g°C, water = 4.2 J/g°C.
  - Heat lost by metal = Heat gained by water
  - $100 \times 0.4 \times (100 - T) = 200 \times 4.2 \times (T - 25)$
  - Solve for T: $T \approx 28.6$°C

Practice Set

- Q1: What is the principle of calorimetry?
  - A) Heat lost = Heat gained
  - B) Heat lost > Heat gained
  - C) Heat lost < Heat gained
  - D) No heat transfer
- Q2: A 50 g metal at 150°C is dropped into 100 g water at 20°C. Final temperature is 30°C. If specific heat of water is 4.2 J/g°C, find specific heat of metal.
  - A) 0.84 J/g°C
  - B) 0.42 J/g°C
  - C) 1.68 J/g°C
  - D) 0.21 J/g°C
- Q3: In a calorimeter, 200 g of water at 25°C is mixed with 100 g of ice at 0°C. What is the final temperature? (Latent heat of fusion of ice = 336 J/g, specific heat of water = 4.2 J/g°C)
  - A) 0°C
  - B) 5°C
  - C) 10°C
  - D) 15°C

Answer Key

- Q1: A - Principle states heat lost equals heat gained in calorimetry.
- Q2: B - Using heat lost = heat gained, specific heat of metal = $\frac{100 \times 4.2 \times (30-20)}{50 \times (150-30)} = 0.42$ J/g°C.
- Q3: A - Ice melts absorbing heat, final temperature remains 0°C until all ice melts.

Memory Aids

- Heat lost = Heat gained (No heat loss to surroundings).
- Use formula: $mc\Delta T$ for heat transfer.
- Latent heat involved during phase change, no temperature change.

Heat Transfer

Overview

- Heat transfer occurs due to temperature difference between systems.
- Three modes: Conduction, Convection, Radiation.

Solved Examples

- **Ex 1:** Heat flows from hot to cold due to temperature difference.

Practice Set

- Q1: Which mode of heat transfer requires no medium?
  A. Conduction
  B. Convection
  C. Radiation
  D. None
- Q2: Heat transfer by actual motion of particles occurs in:
  A. Conduction
  B. Convection

C. Radiation
D. All

- Q3: Heat transfer due to temperature difference is called:
  A. Work
  B. Heat Transfer
  C. Energy Transfer
  D. Power

Answer Key

- Q1: C - Radiation transfers heat without a medium.
- Q2: B - Convection involves motion of heated particles.
- Q3: B - Heat transfer occurs due to temperature difference.

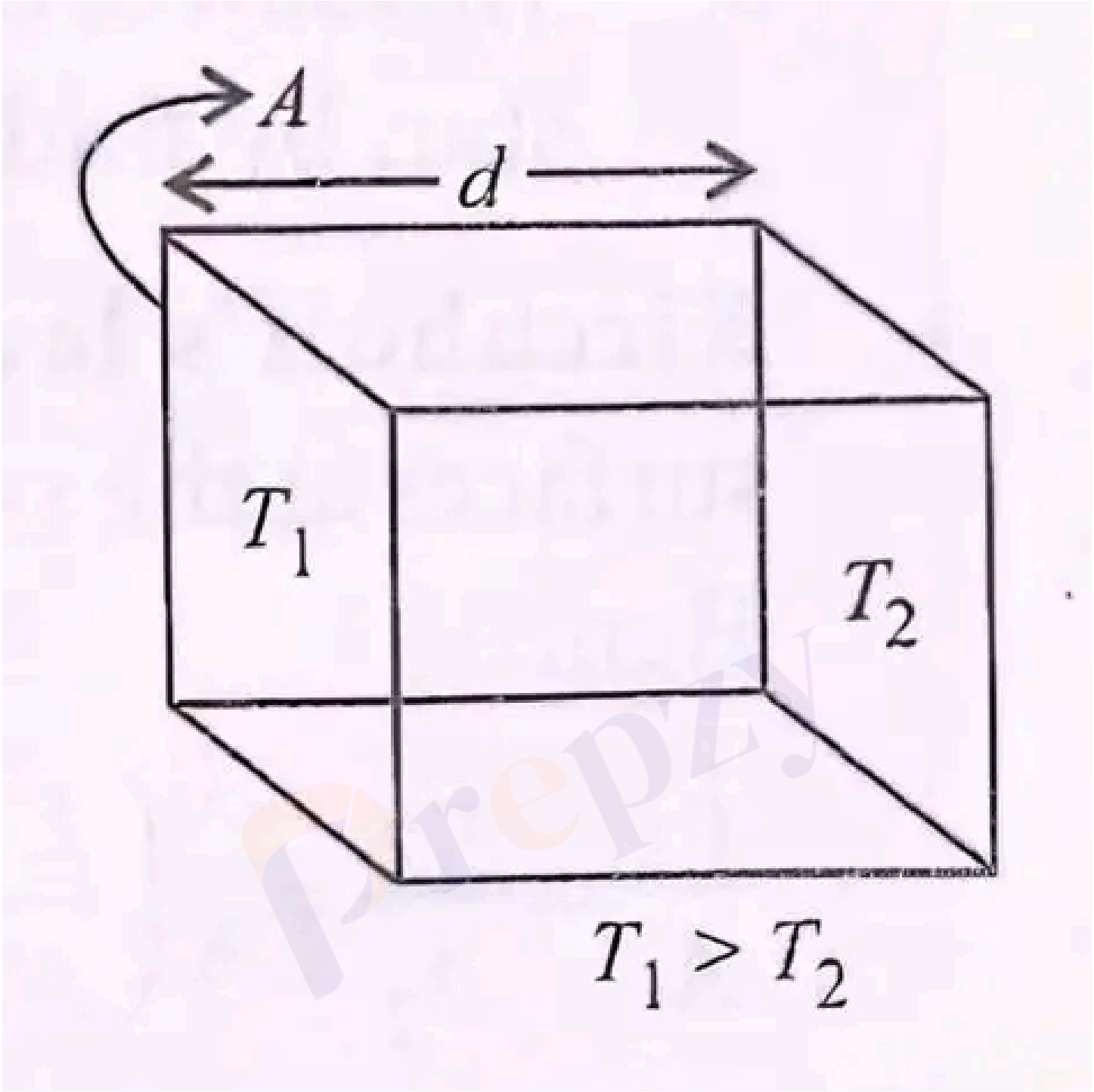
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- Heat transfer modes: Conduction (solid), Convection (fluid), Radiation (vacuum).
- Heat flows from hot to cold.

Conduction

Key Points

- Heat transfer through a substance without particle motion.
- Heat flow rate: $Q \propto \frac{A(T_1-T_2)t}{d}$
- Formula: $Q = \frac{KA(T_1-T_2)t}{d}$, where K is thermal conductivity.
- Rate of heat flow: $\frac{dQ}{dt} = -KA\frac{dT}{dx}$
- Negative sign indicates heat flows opposite to temperature gradient.



Solved Examples

- **Ex 1:** Calculate heat flow through rod with area A, thickness d, temperature difference $T_1 - T_2$, time t, and conductivity K.
  Use $Q = \frac{KA(T_1 - T_2)t}{d}$.

Practice Set

- Q1: Heat conduction depends on:
  A. Area
  B. Temperature difference
  C. Thickness
  D. All
- Q2: If thickness doubles, heat flow:
  A. Doubles
  B. Halves
  C. Unchanged
  D. Quadruples
- Q3: Rate of heat flow formula is:
  A. $\frac{dQ}{dt} = KA\frac{dT}{dx}$
  B. $\frac{dQ}{dt} = -KA\frac{dT}{dx}$
  C. $Q = KA(T_1 - T_2)t$
  D. None

Answer Key

- Q1: D - All factors affect conduction.
- Q2: B - Heat flow inversely proportional to thickness.
- Q3: B - Correct formula includes negative sign.

Memory Aids

- Conduction formula: $Q = \frac{KA\Delta Tt}{d}$.
- Heat flows opposite to temperature gradient.

Convection

Key Points

- Heat transfer by actual motion of heated particles in liquids and gases.
- Causes natural phenomena: trade winds, monsoons, land and sea breezes.

Solved Examples

- **Ex 1:** Identify convection in atmospheric phenomena like monsoons.

Practice Set

- Q1: Convection occurs in:
  A. Solids
  B. Liquids and gases
  C. Vacuum
  D. None
- Q2: Which causes monsoons?
  A. Conduction
  B. Convection
  C. Radiation
  D. Reflection
- Q3: Heat transfer by particle motion is:
  A. Radiation
  B. Conduction
  C. Convection
  D. None

Answer Key

- Q1: B - Convection occurs in fluids.
- Q2: B - Monsoons caused by convection.
- Q3: C - Particle motion heat transfer is convection.

Memory Aids

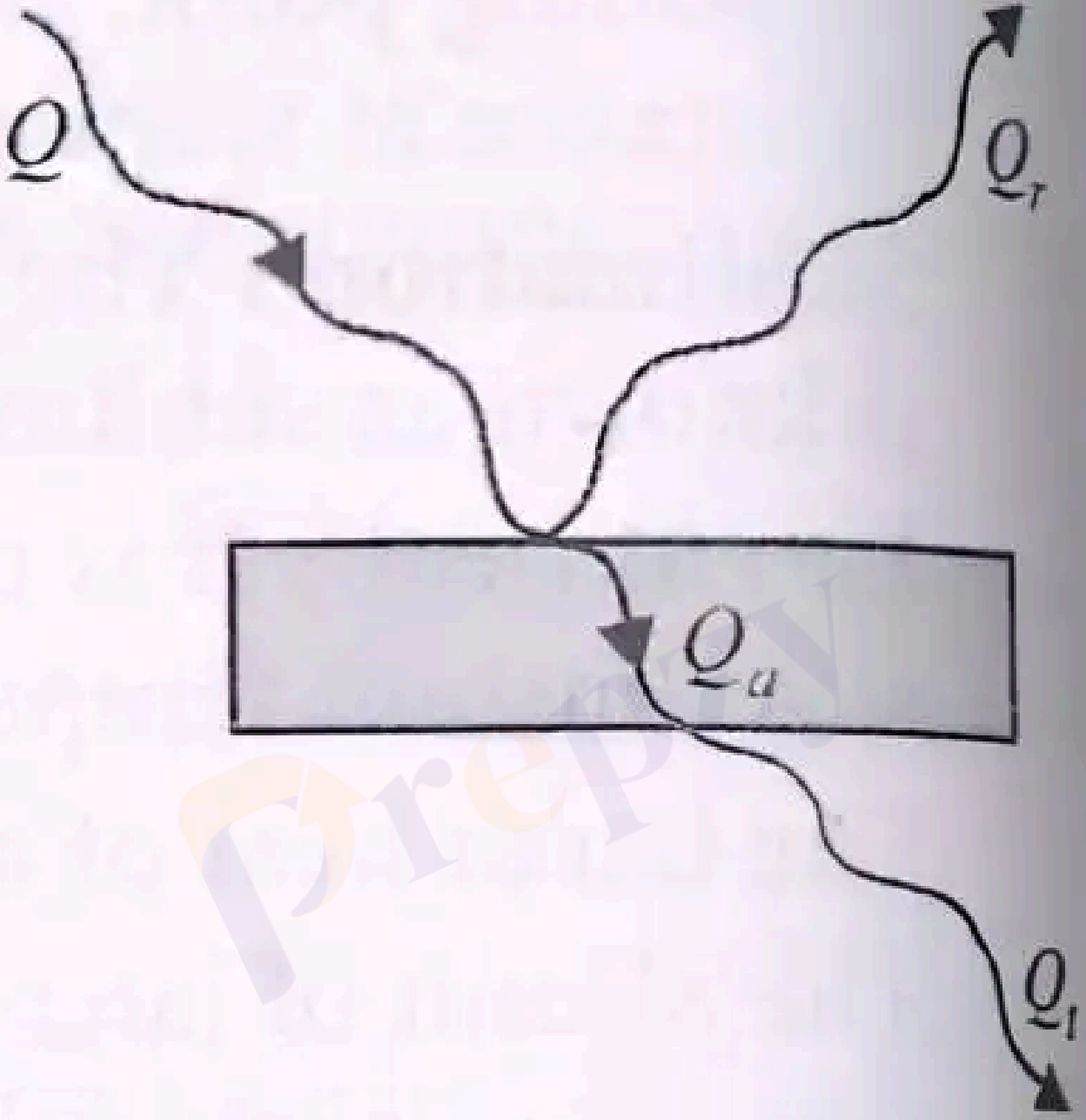
- Convection = fluid motion heat transfer.
- Think of wind and water currents.

Radiation

Key Points

- Heat transfer without heating the medium.
- Heat radiations (Q) on a body are partly reflected (Q_r), absorbed (Q_a), and transmitted (Q_t).
- Energy balance: $Q = Q_a + Q_r + Q_t$
- Coefficients: absorptance $a = \frac{Q_a}{Q}$, reflectance $r = \frac{Q_r}{Q}$, transmittance $t = \frac{Q_t}{Q}$
- Sum: $a + r + t = 1$
- Perfect bodies: reflector (r=1), absorber (a=1), transmitter (t=1).
- Perfect black body: $a = 1, r = 0, t = 0$

Prepzy


Q
Q_r
Q_a
Q_t

Solved Examples

- **Ex 1:** Calculate absorptance if $Q_a = 50J$ and total radiation $Q = 100J$.
  Use $a = \frac{Q_a}{Q} = 0.5$.

Practice Set

- Q1: Sum of absorptance, reflectance, transmittance is:
  A. 0
  B. 1
  C. Depends
  D. None
- Q2: A perfect absorber has:
  A. a=1, r=0, t=0
  B. a=0, r=1, t=0
  C. a=0, r=0, t=1
  D. a=1, r=1, t=1
- Q3: Radiation heat transfer requires:
  A. Medium
  B. Vacuum
  C. Solid
  D. Liquid

Answer Key

- Q1: B - Sum of coefficients equals 1.
- Q2: A - Perfect absorber absorbs all radiation.
- Q3: B - Radiation can occur in vacuum.

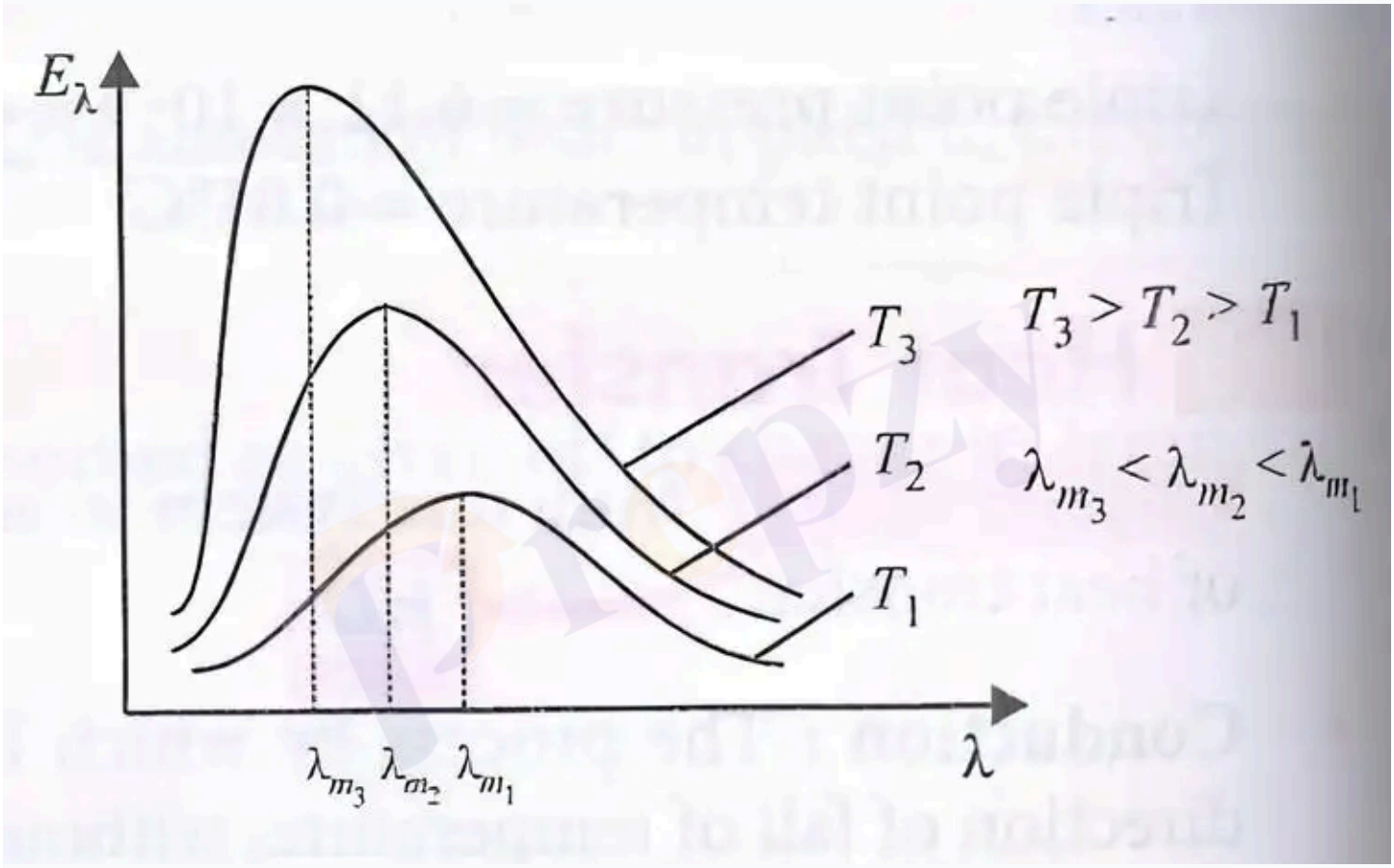
Memory Aids

- Radiation = no medium needed.
- Sum of a, r, t = 1.
- Black body absorbs all.

Wien’s Displacement Law

Key Points

- Product of wavelength of max intensity and temperature is constant:
  $\lambda_m T = b = 2.89 \times 10^{-3}\ \text{mK}$
- As temperature increases, peak wavelength shifts to shorter wavelengths.
- Used to find star temperature: $T = \frac{b}{\lambda_m}$



Solved Examples

- **Ex 1:** Find temperature if peak wavelength $\lambda_m = 500\ \text{nm}$.
  Use $T = \frac{2.89 \times 10^{-3}}{500 \times 10^{-9}} = 5780\ \text{K}$.

Practice Set

- Q1: Wien’s constant b value is:
  A. $2.89 \times 10^{-3}\ \text{mK}$

B. $3.0 \times 10^8\ \mathrm{m/s}$
C. $5.67 \times 10^{-8}\ \mathrm{W/m^2K^4}$
D. None

- Q2: Peak wavelength shifts when temperature:
  A. Increases
  B. Decreases
  C. Constant
  D. None
- Q3: Temperature of star with $\lambda_m = 1\mu m$ is:
  A. 2890 K
  B. 5780 K
  C. 1000 K
  D. 2000 K

Answer Key

- Q1: A - Wien's constant is $2.89 \times 10^{-3}\ \mathrm{mK}$.
- Q2: A - Peak wavelength decreases as temperature increases.
- Q3: A - $T = \frac{2.89 \times 10^{-3}}{1 \times 10^{-6}} = 2890K$.

Memory Aids

- Wien's law: $\lambda_m T = \text{constant}$.
- Hotter objects peak at shorter wavelengths.

Kirchhoff's Law

Key Points

- Ratio of emissive power to absorptive power is same for all surfaces at same temperature.
- Equal to emissive power of a perfect black body at that temperature.
- Mathematically: $\frac{E_1}{A_1} = \frac{E_2}{A_2} = \cdots = \frac{E}{A}$ (perfect black body)

Solved Examples

- **Ex 1:** For two surfaces at same temperature, $\frac{E_1}{A_1} = \frac{E_2}{A_2}$.

Practice Set

- Q1: Kirchhoff’s law relates:
  A. Emissive and absorptive powers
  B. Reflectance and transmittance
  C. Temperature and wavelength
  D. None
- Q2: Emissive power ratio is equal to:
  A. Absorptive power ratio
  B. Reflective power ratio
  C. Transmittance ratio
  D. None
- Q3: Kirchhoff’s law applies to:
  A. Different temperatures
  B. Same temperature
  C. Vacuum only
  D. None

Answer Key

- Q1: A - Kirchhoff’s law relates emissive and absorptive powers.
- Q2: A - Ratios of emissive and absorptive powers are equal.
- Q3: B - Applies at same temperature.

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- Emissive/absorptive power ratio constant at given temperature.
- Perfect black body reference.

Stefan's Law

Key Points

- Radiant energy emitted per unit area by perfect black body $E \propto T^4$.
- Formula: $E = \sigma T^4$, $\sigma = 5.67 \times 10^{-8}\ \mathrm{W/m^2K^4}$.
- For ordinary body: $E = e\sigma T^4$, where e is emissivity.
- Stefan-Boltzmann law: $E = eA\sigma(T^4 - T_0^4)t$ when surrounded by body at T_0.

Solved Examples

- **Ex 1:** Calculate radiant energy for body with emissivity e, area A, temperature T, time t. Use $Q = eA\sigma T^4 t$.

Practice Set

- Q1: Stefan's constant σ value is:
  A. $5.67 \times 10^{-8}\ \mathrm{W/m^2K^4}$
  B. $2.89 \times 10^{-3}\ \mathrm{mK}$
  C. $3.0 \times 10^{8}\ \mathrm{m/s}$
  D. None
- Q2: Radiant energy E is proportional to:
  A. T
  B. T^2
  C. T^4
  D. T^3
- Q3: Stefan-Boltzmann law includes:
  A. $T^4 - T_0^4$
  B. $T - T_0$
  C. $T^2 - T_0^2$
  D. None

Answer Key

- Q1: A - Stefan's constant value is $5.67 \times 10^{-8}\ \mathrm{W/m^2K^4}$.

- Q2: C - Radiant energy proportional to T^4.
- Q3: A - Stefan-Boltzmann law uses difference of fourth powers.

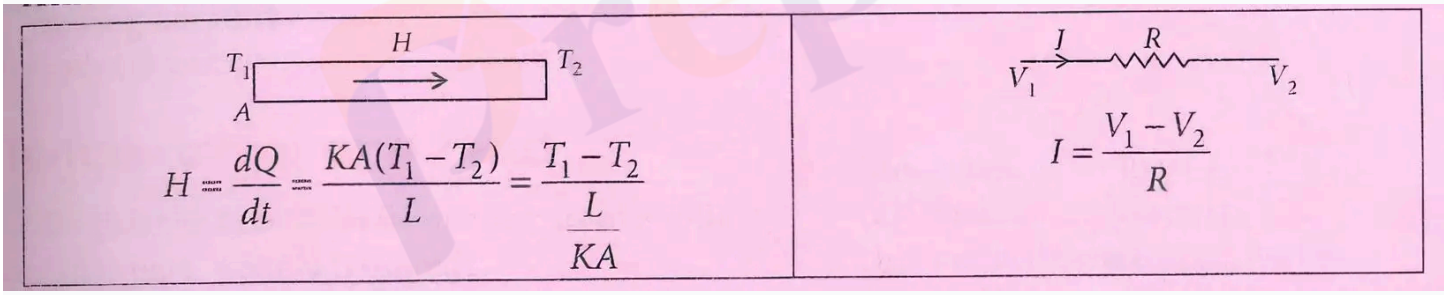
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- Stefan's law: $E = \sigma T^4$.
- Emissivity e modifies for ordinary bodies.

Ohm's Law for Thermal Conduction

Key Points

- Thermal current: $\frac{dQ}{dt} = \frac{T_1 - T_2}{R_{th}}$
- Thermal resistance: $R_{th} = \frac{L}{KA}$
- Equivalent to Ohm's law with temperature as potential difference.
- Rate of heat flow: $H = \frac{\Delta T}{R_{th}}$



Solved Examples

- **Ex 1:** Calculate thermal current for rod with T_1, T_2, L, K, A.
  Use $H = \frac{KA(T_1 - T_2)}{L}$.

Practice Set

- Q1: Thermal resistance R_{th} is:
  A. $\frac{L}{KA}$
  B. $\frac{KA}{L}$

C. LKA

D. None

- Q2: Thermal current is analogous to:

  A. Voltage

  B. Resistance

  C. Electric current

  D. Power

- Q3: Rate of heat flow formula:

  A. $H = \frac{\Delta T}{R_{th}}$

  B. $H = R_{th}\Delta T$

  C. $H = \Delta T R_{th}$

  D. None

Answer Key

- Q1: A - Thermal resistance formula.
- Q2: C - Thermal current analogous to electric current.
- Q3: A - Rate of heat flow formula.

Memory Aids

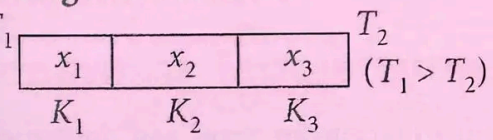
- Thermal resistance $R_{th} = \frac{L}{KA}$.
- Heat flow like current, temperature like voltage.

Thermal Conduction in Slabs

Key Points

- **Series arrangement:** Slabs stacked one after another.
- Heat flow: $Q = \frac{A(T_1 - T_2)t}{\frac{x_1}{K_1} + \frac{x_2}{K_2} + \frac{x_3}{K_3}}$
- Equivalent conductivity: $\frac{1}{K} = \left(\frac{x_1}{K_1} + \frac{x_2}{K_2} + \frac{x_3}{K_3}\right)\frac{1}{x_1 + x_2 + x_3}$
- **Parallel arrangement:** Slabs side by side.
- Heat flow: $Q = (K_1A_1 + K_2A_2 + K_3A_3)\frac{(T_1 - T_2)}{x}t$
- Equivalent conductivity: $K = \frac{K_1A_1 + K_2A_2 + K_3A_3}{A_1 + A_2 + A_3}$

Conducting slabs in series



$$Q = \frac{A(T_1 - T_2)t}{\frac{x_1}{K_1} + \frac{x_2}{K_2} + \frac{x_3}{K_3}}$$

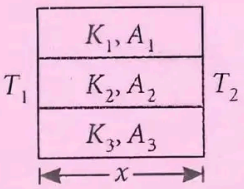
Equivalent thermal conductivity (K)

$$\frac{1}{K} = \left(\frac{x_1}{K_1} + \frac{x_2}{K_2} + \frac{x_3}{K_3}\right)\frac{1}{(x_1 + x_2 + x_3)}$$

In general, $K = \dfrac{(\Sigma x_i)}{\left(\Sigma \dfrac{x_i}{K_i}\right)}$

Conducting slabs in parallel

$$Q = (K_1A_1 + K_2A_2 + K_3A_3)\left(\frac{T_1 - T_2}{x}\right)t$$



Equivalent thermal conductivity

$$K = \frac{K_1A_1 + K_2A_2 + K_3A_3}{A_1 + A_2 + A_3}$$

In general, $K = \dfrac{(\Sigma K_i A_i)}{\Sigma A_i}$

Solved Examples

- **Ex 1:** Calculate heat flow through series slabs using given thickness and conductivity.
- **Ex 2:** Calculate equivalent conductivity for parallel slabs.

Practice Set

- Q1: In series slabs, total resistance is:
  A. Sum of individual resistances
  B. Product of resistances
  C. Average resistance
  D. None
- Q2: Equivalent conductivity in parallel slabs is:
  A. Weighted average
  B. Sum
  C. Difference
  D. None
- Q3: Heat flow in series slabs depends on:
  A. Total thickness
  B. Individual conductivities
  C. Both
  D. None

Answer Key

- Q1: A - Resistances add in series.
- Q2: A - Weighted average by area.
- Q3: C - Both thickness and conductivity affect heat flow.

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- Series: resistances add, conductivity inverse sum.
- Parallel: conductivity weighted average.

Ice Layer Growth Time

Key Points

- Time to grow ice layer from thickness x_1 to x_2:
- $t = \frac{\rho L}{2KT}(x_2^2 - x_1^2)$, where T is atmosphere temperature.
- Time intervals ratio for thickness changes: $\Delta t_1 : \Delta t_2 : \Delta t_3 = 1 : 3 : 5$.

Solved Examples

- **Ex 1:** Calculate time to grow ice from 0 to x using given parameters.

Practice Set

- Q1: Time to grow ice layer depends on:
  A. Thickness squared difference
  B. Temperature
  C. Thermal conductivity
  D. All
- Q2: Ratio of time intervals for thickness growth is:
  A. 1:2:3
  B. 1:3:5

C. 2:4:6

D. 1:1:1

- Q3: Ice growth time formula includes:

A. ρL

B. K

C. T

D. All

Answer Key

- Q1: D - All factors affect ice growth time.
- Q2: B - Time intervals ratio is 1:3:5.
- Q3: D - Formula includes density, latent heat, conductivity, temperature.

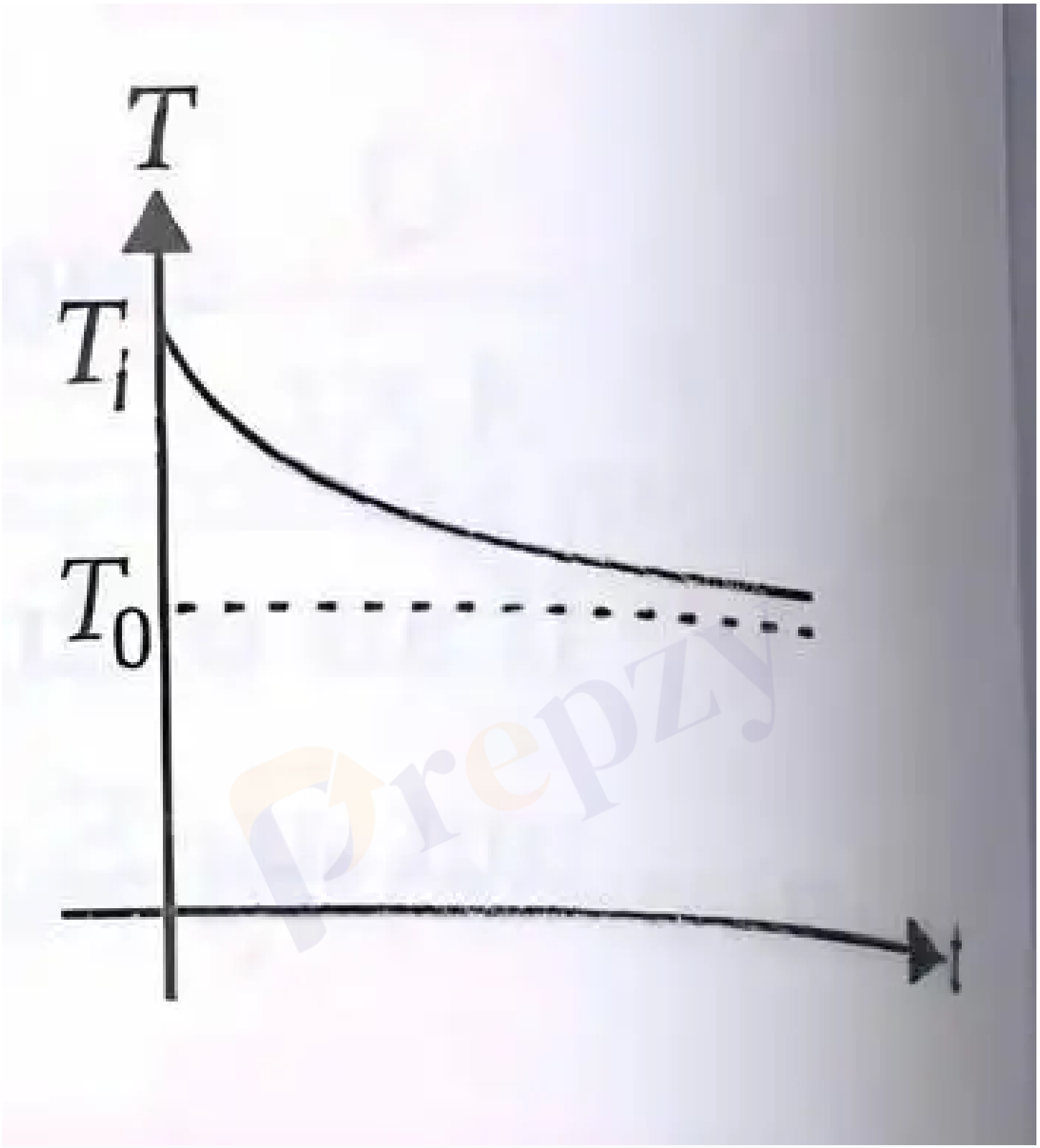
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- Ice growth time $\propto (x_2^2 - x_1^2)$.
- Time intervals increase as odd numbers.

Newton's Law of Cooling

Explanation

- Rate of cooling $-\frac{dQ}{dt}$ is proportional to temperature difference $(T_2 - T_1)$ if difference < 40°C.
- Mathematically, $\frac{dQ}{dt} = k(T_2 - T_1)$, where k depends on surface area and nature.
- Temperature decreases exponentially: $T = T_0 + (T_i - T_0)e^{-kt}$, k = constant.
- Plot of $\ln(T - T_0)$ vs time t is a straight line with slope $-k$ and intercept $\ln(T_i - T_0)$.
- Shortcut formula: $\frac{T_1 - T_2}{t} = k\left(\frac{T_1 + T_2}{2} - T_0\right)$ to avoid calculating e^{-kt}.



Solved Examples

- **Ex 1:** Find temperature after time t if $T_i = 80^\circ C$, $T_0 = 30^\circ C$, $k = 0.1$ min^{-1}.
  - Use $T = T_0 + (T_i - T_0)e^{-kt}$
  - Calculate $T = 30 + (80 - 30)e^{-0.1t}$
- **Ex 2:** Given $\ln(T - T_0)$ vs t graph slope $= -0.05$, find k.
  - From slope $m = -k$, so $k = 0.05$

Practice Set

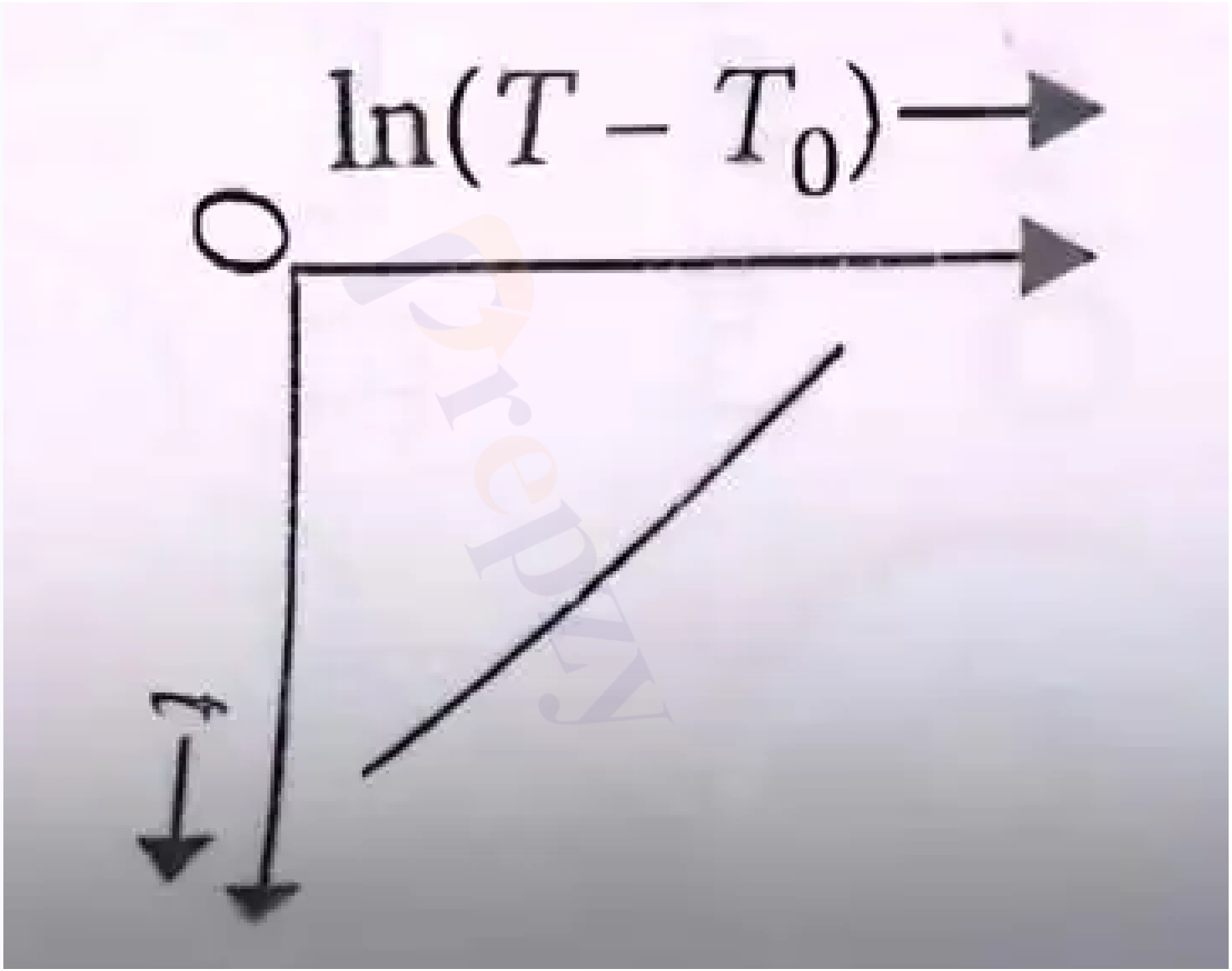
- Q1: If initial temperature $T_i = 90^\circ C$, surrounding $T_0 = 30^\circ C$, and $k = 0.2$ min^{-1}, temperature after 5 min is?
  - A) 40°C
  - B) 50°C
  - C) 60°C
  - D) 70°C
- Q2: The plot of $\ln(T - T_0)$ vs time is a straight line with slope -0.1. What is the value of k?
  - A) 0.1
  - B) -0.1
  - C) 1
  - D) -1
- Q3: Using shortcut formula, if $T_1 = 80^\circ C$, $T_2 = 60^\circ C$, $T_0 = 30^\circ C$, and time $t = 10$ min, find k.
  - A) 0.05
  - B) 0.1
  - C) 0.15
  - D) 0.2

Answer Key

- Q1: B) 50°C - Use $T = 30 + 60e^{-0.2\times5} = 30 + 60e^{-1} \approx 50^\circ C$.
- Q2: A) 0.1 - Slope $m = -k$, so $k = 0.1$.
- Q3: A) 0.05 - Using $\frac{T_1 - T_2}{t} = k\left(\frac{T_1 + T_2}{2} - T_0\right)$, solve for k.

Memory Aids

- Cooling rate ∝ temperature difference (small difference).
- Temperature formula: $T = T_0 + (T_i - T_0)e^{-kt}$.
- Plot $\ln(T - T_0)$ vs t is straight line with slope $-k$.
- Shortcut: $\frac{T_1 - T_2}{t} = k\left(\frac{T_1 + T_2}{2} - T_0\right)$.


$\ln(T - T_0)$
O
t