

Thermal Properties of Matter — Assignment 2

Class 11 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Temperature and Temperature Scales

2 Mark Questions

1. Convert 98.6°F (normal body temperature) to the Celsius scale.
2. Write the relation between the Celsius, Fahrenheit and Kelvin scales and define each.

3 Mark Questions

1. At what temperature do the Celsius and Fahrenheit scales read the same numerical value? Derive your answer.

Thermal Expansion of Solids and Liquids

2 Mark Questions

1. A steel rod of length 1 m and coefficient of linear expansion $1.1 \times 10^{-5} \text{ K}^{-1}$ is heated from 20°C to 120°C . Find its increase in length.

3 Mark Questions

1. A copper plate has a hole of diameter 1 cm at 20°C . Find the new diameter of the hole when the plate is heated to 220°C . ($\alpha = 1.7 \times 10^{-5} \text{ K}^{-1}$.)

Calorimetry and Specific Heat

2 Mark Questions

1. How much heat is required to raise the temperature of 500 g of water from 20°C to 40°C ? ($c = 4200 \text{ J kg}^{-1} \text{ K}^{-1}$.)

3 Mark Questions

1. A piece of metal of mass 100 g at 100°C is placed in 200 g of water at 20°C in a calorimeter of negligible heat capacity. If the final temperature is 25°C , find the specific heat of the metal. ($c_{\text{water}} = 4200 \text{ J kg}^{-1} \text{ K}^{-1}$.)

Change of State and Latent Heat

2 Mark Questions

1. How much heat is needed to convert 100 g of ice at 0°C to water at 0°C ? ($L_f = 3.34 \times 10^5 \text{ J kg}^{-1}$.)

3 Mark Questions

1. Find the heat required to convert 200 g of ice at -10°C to steam at 100°C . ($c_{\text{ice}} = 2100$, $c_{\text{water}} = 4200$, $L_f = 3.34 \times 10^5$, $L_v = 2.26 \times 10^6 \text{ J kg}^{-1}$, all in $\text{J kg}^{-1} \text{ K}^{-1}$.)

Heat Transfer: Conduction, Convection and Radiation**2 Mark Questions**

1. A metal rod of length 0.5 m and cross-section 10^{-4} m^2 has a temperature difference of 100°C across its ends. If $k = 200 \text{ W m}^{-1} \text{ K}^{-1}$, find the rate of heat flow.

3 Mark Questions

1. A window pane is 1 cm thick, $1 \text{ m} \times 1 \text{ m}$ in area, with a temperature difference of 20°C between its faces. Find the heat conducted per second. ($k_{\text{glass}} = 0.8 \text{ W m}^{-1} \text{ K}^{-1}$.)

Black-Body Radiation and Newton's Law of Cooling**2 Mark Questions**

1. A body of surface area 0.1 m^2 at temperature 500 K radiates as a black body. Find the power radiated. ($\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$.)

3 Mark Questions

1. A black-body sphere of radius 5 cm at 1000 K radiates energy. Find the rate of energy radiated. ($\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$.)

Part B — Integrated problems (multi-topic)

- Convert 300 K to the Celsius and Fahrenheit scales. Also convert normal body temperature 98.6°F to the Celsius scale.
- A steel rod of length 1 m and coefficient of linear expansion $1.1 \times 10^{-5} \text{ K}^{-1}$ is heated from 20°C to 120°C . Find its increase in length, and explain why gaps are left between successive sections of railway tracks.
- A piece of metal of mass 100 g at 100°C is placed in 200 g of water at 20°C in a calorimeter of negligible heat capacity. If the final temperature is 25°C , find the specific heat of the metal. ($c_{\text{water}} = 4200 \text{ J kg}^{-1} \text{ K}^{-1}$)
- Find the heat required to convert 200 g of ice at -10°C to steam at 100°C . ($c_{\text{ice}} = 2100$, $c_{\text{water}} = 4200$, $L_f = 3.34 \times 10^5$, $L_v = 2.26 \times 10^6 \text{ J kg}^{-1}$)
- A body cools from 80°C to 70°C in 5 minutes when the room is at 20°C . Using Newton's law of cooling, estimate how long it will take to cool from 70°C to 60°C .

Answer Key**Temperature and Temperature Scales**

2M(0): $T = (98.6 - 32) \times 5/9 = 37^\circ\text{C}$. 2M(1): $C/100 = (F - 32)/180 = (K - 273.15)/100$ on a Celsius-sized degree: $1 \text{ K} = 1^\circ\text{C} = 1.8^\circ\text{F}$. 3M(1): Set $C = F = x$: $x = 5/9(x - 32)$ $\Rightarrow x = 5x - 160$ $\Rightarrow -40$. So $-40^\circ\text{C} = -40^\circ\text{F}$, the one temperature where the two scales agree.

Thermal Expansion of Solids and Liquids

2M(0): $\Delta l = \alpha l \Delta T = 1.1 \times 10^{-5} \times 1 \times 100 = 1.1 \times 10^{-3} \text{ m} = 1.1 \text{ mm}$. 3M(1): The hole expands with the plate: $\Delta d = \alpha d \Delta T = 1.7 \times 10^{-5} \times 1 \times 200 = 3.4 \times 10^{-3} \text{ cm}$, so the new diameter $\approx 1.0034 \text{ cm}$.

Calorimetry and Specific Heat

2M(0): $Q = mc\Delta T = 0.5 \times 4200 \times (40 - 20) = 4.2 \times 10^4 \text{ J}$. 3M(1): Heat lost by metal = heat gained by water: $0.1 c (100 - 25) = 0.2 \times 4200 \times (25 - 20)$ $\Rightarrow 5c = 4200$ $\Rightarrow c = 560 \text{ J kg}^{-1} \text{ K}^{-1}$.

Change of State and Latent Heat

2M(0): $Q = mL_f = 0.1 \times 3.34 \times 10^5 = 3.34 \times 10^4 \text{ J}$. 3M(1): $Q = mc_{\text{ice}}\Delta T + mL_f + mc_{\text{water}}\Delta T + mL_v = 0.2 \times 2100 \times 10 + 0.2 \times 3.34 \times 10^5 + 0.2 \times 4200 \times 100 + 0.2 \times 2.26 \times 10^6 = 4200 + 66800 + 84000 + 452000 = 6.07 \times 10^5 \text{ J}$.

Heat Transfer: Conduction, Convection and Radiation

2M(0): $H = kA\Delta T/l = 200 \times 10^{-4} \times 100 / 0.5 = 4 \text{ W}$. 3M(1): $H = kA\Delta T/l = 0.8 \times 1 \times 20 / 0.01 = 1600 \text{ W}$.

Black-Body Radiation and Newton's Law of Cooling

2M(0): $P = \sigma AT^4 = 5.67 \times 10^{-8} \times 0.1 \times (500)^4 \approx 354 \text{ W}$. 3M(1): $A = 4\pi r^2 = 4\pi \times (0.05)^2 \approx 0.0314 \text{ m}^2$; $P = \sigma AT^4 = 5.67 \times 10^{-8} \times 0.0314 \times (1000)^4 \approx 1.78 \times 10^3 \text{ W}$.

Integrated problems

1: $T_C = 300 - 273.15 = 26.85^\circ\text{C}$; $T_F = 9/5 \times 26.85 + 32 \approx 80.3^\circ\text{F}$; $98.6^\circ\text{F} = (98.6 - 32) \times 5/9 = 37^\circ\text{C}$. 2: $\Delta l = 1.1 \times 10^{-3} \text{ m} = 1.1 \text{ mm}$; gaps let tracks expand freely in summer and contract in winter without buckling. 3: $c = 560 \text{ J kg}^{-1} \text{ K}^{-1}$. 4: $6.07 \times 10^5 \text{ J}$ (see Part A). 5: Average excess in $80 \rightarrow 70$ is $(60 + 50)/2 = 55$; in $70 \rightarrow 60$ it is $(50 + 40)/2 = 45$; rate excess, so $t \approx 5 \times 55/45 \approx 6.1 \text{ min}$.