SAMPLE CONTENT

MHT-CET

TRIUMPH

PHYSICS

SOLUTIONS to MCQs

Target Publications® Pvt. Ltd.

Written in accordance with the latest MHT-CET Paper Pattern prescribed by
State Common Entrance Test Cell, Maharashtra State

TRIUMPH

MHT-CET PHYSICS SOLUTIONS to MCQs

Salient Features

- Detailed solutions provided for difficult MCQs as per the concepts emphasized in the syllabus
- **Smart Keys** (Shortcuts, Mindbenders, Caution, Thinking Hatke) - Multiple Study Techniques to enhance understanding of concepts and problem solving skills
- Solutions to Evaluation Test for each chapter
- Solutions to Model Question Papers
- Solutions to MHT-CET 2023 Question Papers (12th May Shift - 1 & 15th May Shift - 1)

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PREFACE

Target's **Triumph MHT-CET Physics Solutions to MCQs** book provides students comprehensive understanding of physics through solutions to MCQs based on the concepts emphasized in the syllabus.

It includes **Smart Keys** (Shortcuts, Mindbenders, Caution and Thinking Hatke), which offer supplemental explanations for the tricky questions and are intended to help students approaching problems in novel ways in the shortest possible time with accuracy.

- **Shortcuts** incorporate important theoretical or formula based short tricks that are beneficial in solving MCQs
- **Mindbenders** present thought provoking snippets of concepts
- **Caution** apprises students about mistakes often made while solving MCQs.
- **Thinking Hatke** reveals quick witted approach to crack the specific question.

Solutions to **Model Question Papers** and **MHT-CET 2023 Question Papers** (12^{th} May Shift - 1 & 15^{th} May Shift - 1) are also included in this book.

All the features of this book are designed keeping the following elements in mind:
Time management, easy memorization or revision, and non-conventional yet simple methods for MCQ solving.

We hope the book benefits the learner as we have envisioned.

Publisher
Edition: First

The journey to create a complete book is strewn with triumphs, failures and near misses. If you think we've nearly missed something or want to applaud us for our triumphs, we'd love to hear from you.

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CONTENTS

Chapter 7

Thermal Properties of Matter

Shortcuts

1. To convert Celsius temperature into Fahrenheit, apply the relation $t_f = \frac{9}{5} t_c + 32$ and to convert Fahrenheit temperature to Celsius apply, $t_c = \frac{5}{9}(t_f - 32)$
2. When a metallic body with a hole of diameter (d) is heated then size of hole increases. Increase in diameter of the hole = $d\,\alpha\,(t_2 - t_1)$
3. When two conductors of same length and same cross-section area but having thermal conductivities K_1 and K_2 are connected in **series**, then temperature of interface is given as, $\theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$. This can also be applied in case of a single slab made from layers of two different materials.

Mindbenders

1. Both heat and light are electromagnetic radiations. The only difference is that the heat radiations have larger wavelength as compared to visible light. All phenomena which are present in light, will also be present in heat, such as reflection, interference etc.
2. A solid and hollow sphere of same radius and material are heated to the same temperature then expansion of both will be equal. It means the expansion of cavity is same as if it has been a solid body of the same material. But if same heat is given to the two spheres, due to lesser mass, rise in temperature of hollow sphere will be more.
3. It is possible to boil water without supplying any heat. Below the room temperature, when the pressure is made low, water starts boiling.

Classical Thinking

7.1 Introduction

1. (A) 2. (B) 3. (D)
4. (C) 5. (B) 6. (B)

7.2 Temperature and Heat

1. (A) 2. (D) 3. (C)
4. (A)

7.3 Measurement of Temperature

1. (C) 2. (C) 3. (D)
4. (A)
5. (D) $t_k = 27 + 273 = 300$ K
6. (C) $t_k = 6400 + 273 = 6673$ K
7. (C) $\frac{t_c - 0}{100} = \frac{t_f - 32}{180}$

$\therefore \frac{20 - 0}{100} = \frac{t_f - 32}{180}$

$\therefore t_f = 36 + 32 = 68$ °F

Alternate Method:

Using ***Shortcut 1***,

$t_f = \frac{9}{5} t_c + 32 = \left(\frac{9}{5} \times 20\right) + 32 = 68$ °F

8. (D) Relation between any two scales can be found as follows –

$$\frac{T'_{scale} - (\text{Freezing point})'}{(\text{Parts between boiling and freezing})'} = \frac{T''_{scale} - (\text{Freezing point})''}{(\text{Parts between boiling and freezing})''}$$

$\therefore \frac{T_x - 40°}{80} = \frac{T_y - (-30°)}{160}$

$\therefore \frac{50° - 40°}{1} = \frac{T_y + 30°}{2} \Rightarrow T_y = -10°$

7.4 Absolute Temperature and Ideal Gas Equation

1. (A) 2. (A) 3. (A)
4. (D) 5. (C) 6. (D)

7. (B) $\frac{P_1}{P_2} = \frac{T_1}{T_2}$

$\therefore$ $P_2 = \frac{T_2}{T_1} P_1 = \frac{(273+198)}{(273+41)} \times 1$

$\therefore$ P_2 = 1.5 atmosphere

8. (C) Since $\frac{PV}{T}$ = constant

$\therefore$ $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Here T_1 = 27 °C = 300 K

$\therefore$ $\frac{P_1V_1}{300} = \frac{3P_1 \times 3V_1}{T_2}$

$\therefore$ T_2 = 2700 K

9. (C) $\frac{P_1}{P_2} = \frac{T_1}{T_2}$

$T_2 = \frac{P_2}{P_1} T_1 = \frac{90 \times 300}{72}$ = 375 K = 102 °C

10. (D) At constant pressure,

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\therefore$ $T_2 = \frac{V_2}{V_1} T_1$

$T_1 = \frac{67}{47.5} \times 273$ = 385.07 K

T_2 = 385.07 – 273 = 112.07 °C

11. (B) At constant pressure,

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Here T_1 = 27 °C = 300 K,

T_2 = 297 °C = 570 K

$\therefore$ $\frac{1}{300} = \frac{V_2}{570}$

V_2 = 1.9 litre

12. (C) PV = nRT

50 × 100 = 1RT and 100 V = 3RT

$\therefore$ $\frac{100V}{50 \times 100} = \frac{3RT}{1RT}$

$\therefore$ V = 150 m*l*

13. (D) Using ideal gas equation: $P = \frac{RT}{V} = \frac{\rho RT}{M}$

$\therefore$ $\frac{P_1}{P_2} = \frac{\rho_1}{M_2} \times \frac{M_2}{\rho_2}$

$\therefore$ $\frac{4}{3} = \frac{\rho_1}{\rho_2} \times \frac{3}{2}$

$\therefore$ $\frac{\rho_1}{\rho_2} = \frac{8}{9}$

7.5 Thermal Expansion

1.	(D)	**2.**	(D)	**3.**	(B)
4.	(C)	**5.**	(D)	**6.**	(A)
7.	(B)	**8.**	(B)		

9. (A) $L_2 = L_1(1 + \alpha t)$

$\therefore$ $50 = L_1 (1 + 16 \times 10^{-6} \times 65)$

$\therefore$ $50 = L_1 (1 + 1040 \times 10^{-6}) = L_1 (1.001)$

$\therefore$ L_1 = 49.95 cm

10. (C) $L_2 - L_1 = L_1 \alpha (t_2 - t_1)$

$\therefore$ $0.5 \times 10^{-2} = 12 \times 11 \times 10^{-6} \times (t_2 - 10)$

$\therefore$ t_2 = 47.8 °C

11. (D) Initial length of combination = L + 2L = 3L

Increase in length of first rod = $L\alpha\Delta t$

Increase in length of second rod = (2L) (Δt) (2α)

$= 4L\alpha\Delta t$

Total increase in the length of the rod

$= 4L\alpha\Delta t + L\alpha\Delta t = 5L\alpha\Delta t$

Coefficient of linear expansion of the rod

$= \frac{\text{Change in length}}{\text{Initial length} \times \text{change in temperature}}$

$= \frac{5L\ \alpha\ \Delta t}{3L\ \Delta t} = \frac{5\alpha}{3}$

12.	(A)	**13.**	(C)

14. (C) $\beta = \frac{A_2 - A_1}{A_1(t_2 - t_1)}$

$0.000036 = \frac{A_2 - 110}{110(200 - 20)}$

$0.7128 = A_2 - 110$

$A_2 = 110.71\ cm^2$

15.	(C)	**16.**	(B)	**17.**	(C)

18. (A) $\gamma = \frac{\text{change in volume}}{\text{original volume} \times \text{change in temperature}}$

$= \frac{0.84}{100 \times 200} = 42 \times 10^{-6}/\ °C$

19. (D) Increase in volume,

$\Delta V = V \gamma (\Delta T)$

$= a^3 \times 3\alpha \times (\Delta T)$

$= 3a^3\alpha\Delta T$

20.	(C)	**21.**	(C)	**22.**	(D)
23.	(D)				

7.6 Specific Heat Capacity

1.	(B)	**2.**	(A)

3. (C) $c = \frac{Q}{m\Delta T} = \frac{1200}{500 \times (90 - 10)}$ = 0.03 cal/g °C

7.7 Calorimetry

1. (C) 2. (B) 3. (B)
4. (A)

7.8 Change of State

1. (C) 2. (D) 3. (D)
4. (C) 5. (B) 6. (A)
7. (B)

8. (D) Heat required to melt the ice

$= m_{ice}L_{mett} = 1 \times 80 = 80$ cal

Heat required to change the temperature of water to 100 °C

$= m_w c_w \Delta T = 1 \times 1 \times (100 - 0) = 100$ cal

Total heat required $Q_1 = 180$ cal

Now, heat to be given out for 1 g of steam to condense into liquid $Q_2 = 540$ cal

As $Q_2 > Q_1$, the whole system is not condensed.

∴ Temperature remains 100 °C.

7.9 Heat transfer

1. (C) 2. (D) 3. (A)
4. (A) 5. (B) 6. (B)
7. (B) 8. (C) 9. (C)
10. (D) 11. (C) 12. (C)
13. (D) 14. (A) 15. (D)
16. (D) 17. (A) 18. (C)
19. (B) 20. (C)

21. (D) Rate of flow of heat ∝ temperature difference

....(∵ K, A and Δx being unchanged)

∴ $\frac{4}{Q} = \frac{10}{10}$

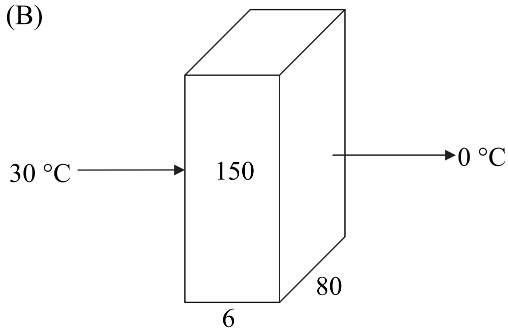
∴ Q = 4 J/s

22. (D) $\left(\frac{\Delta Q}{t}\right) \propto \Delta\theta$

$$\frac{\left(\frac{\Delta Q}{t}\right)_1}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{\Delta\theta_1}{\Delta\theta_2}$$

$$\frac{60}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{80-20}{40-20} = 20 \text{ cal/s}$$

23. (B)



K = 0.0005 cal/cm s °C

$\frac{Q}{t} = KA\frac{\Delta\theta}{\Delta x}$

Here, A = area of cross-section of refrigerator

$= 150 \times 80$ cm^2

Δx = length of (conductor) refrigerator door through which heat is lost

= 6 cm

Δθ = 30 °C

∴ $\frac{Q}{t} = \frac{0.0005 \times 150 \times 80 \times 30}{6}$

∴ $\frac{Q}{60} = 30 \Rightarrow Q$ = heat loss per min = 1800 cal

7.10 Newton's Law of Cooling

1. (C) 2. (D) 3. (C)

4. (C) $R_1 \propto (\theta_1 - \theta_0)$ and $R_2 \propto (\theta_2 - \theta_0)$

∴ $\frac{R_1}{R_2} = \frac{k(\theta_1 - \theta_0)}{k(\theta_2 - \theta_0)}$

∴ $\frac{1.5}{1} = \frac{30}{(\theta_2 - \theta_0)}$

∴ $(\theta_2 - \theta_0) = 20$ °C.

5. (C) $R_1 = \frac{64 - 55}{10} = \frac{9}{10}$

$R_2 = \frac{55° - 42°}{10} = \frac{13}{10}$

∴ $\frac{R_1}{R_2} = \frac{9/10}{13/10} = \frac{9}{13}$

6. (A) $\frac{R_1}{R_2} = \frac{\left(\frac{100° + 70°}{2} - 15°\right)}{\left(\frac{70° + 40°}{2} - 15°\right)}$

$= \frac{(85° - 15°)}{(55° - 15°)} = \frac{7}{4}$

$R_1 t_1 = R_2 t_2$

∴ $t_2 = \frac{R_1}{R_2} t_1 = \frac{7}{4} \times 4$

= 7 minute

Critical Thinking

7.2 Temperature and Heat

1. (A) **2.** (D)

7.3 Measurement of Temperature

1. (B)

2. (B) t = required temperature then

$$\frac{t}{100} = \frac{t-32}{180}$$

$$\frac{t}{10} = \frac{t-32}{18}$$

$18t = 10t - 320$

$\therefore$ $t = -40$ °C

3. (D) Let reading of celsius scale be x °C

$\therefore$ reading of fahrenheit scale will be 2x °F

$\because$ $\dfrac{t_f - 32}{180} = \dfrac{t_c - 0}{100}$

$\therefore$ $\dfrac{2x - 32}{180} = \dfrac{x}{100}$

$\therefore$ $10x - 160 = 9x$

$\therefore$ $x = 160$ °C and $2x = 320$ °F

4. (A) $\dfrac{t_f - 32}{180} = \dfrac{t_k - 273.15}{100}$

Since $t_f = t_k$

$$\frac{t_f - 32}{18} = \frac{t_f - 273.15}{10}$$

$10t_f - 320 = 18t_f - 4916.7$

$8t_f = 4596.7$

$\therefore$ $t_f = 574.58$ °F

7.4 Absolute Temperature and Ideal Gas Equation

1. (D) **2.** (B)

3. (A) PV = constant, $\Rightarrow V \propto \dfrac{1}{P}$

$$\frac{V_2}{V_1} = \frac{P_1}{P_2}$$

$\therefore$ $V_2 = V_1 \dfrac{P_1}{P_2} = 60 \times \dfrac{1}{4} = 15\ \text{cm}^3$

4. (C) Comparing with PV = nRT

Here, n = 3

Hence V represents volume of 3 moles of gas.

5. (C) On mixing, $n_1 + n_2 = n$

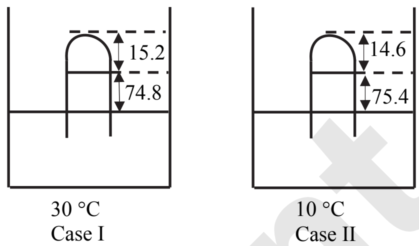
$$\frac{P_1V_1}{RT_1} + \frac{P_2V_2}{RT_2} = \frac{P(V_1 + V_2)}{RT}$$

$$T = \frac{P(V_1 + V_2)(T_1T_2)}{P_1V_1T_2 + P_2V_2T_1}$$

$P_1V_1 + P_2V_2 = P(V_1 + V_2)$ (From Boyle's law)

$$T = \frac{(P_1V_1 + P_2V_2)T_1T_2}{(P_1V_1T_2 + P_2V_2T_1)}$$

6. (C)



In first case:

When atmospheric pressure is P_a and barometric pressure is P_b, pressure difference $P_1 = P_a - P_b = 76 - 74.8 = 1.2$ cm

In second case, let atmospheric pressure be P_a' and corresponding barometric pressure P_b'.

$\therefore$ Pressure difference $P_2 = P_a' - P_b' = P_a' - 75.4$

Volumes in both cases will be equivalent to the length of air column in the barometer.

$\therefore$ $V_1 = 90 - 74.8 = 15.2$ units

and $V_2 = 90 - 75.4 = 14.6$ units.

As number of moles of gas in the barometer tube is constant,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{1.2 \times 15.2}{303} = \frac{P_2 \times 14.6}{283} \Rightarrow P_2 = 1.166\ \text{cm}$$

$\therefore$ $P_a' = 75.4 + 1.166 = 76.566$ cm

7. (C) Assuming the graph for a gas of given mass, we have,

PV = nRT

$\therefore$ $\dfrac{V}{T} \propto \dfrac{1}{P}$

From the graph, $\dfrac{V}{T} = \tan\theta$

$\therefore$ $\dfrac{1}{P} \propto \tan\theta$

$\therefore$ as angle θ increases, tan θ increases and pressure decreases.

$\therefore$ $P_1 > P_2$

8. (A) Since the relation between t_c and t_f is given by

$$t_f = \frac{9}{5}t_c + 32$$

At $t_c = 0$, $t_f = 32$ °F and

At $t_f = 0$,

$$t_c = -\frac{32 \times 5}{9}\ \text{°C} = -17.7\ \text{°C}$$

1st graph satisfies the above condition.

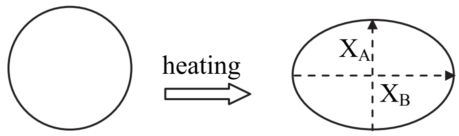
7.5 Thermal Expansion

1. (B)

2. (B) In summer alcohol expands, density decreases, so 1 litre of alcohol will weigh less in summer than in winter.

3. (A) Boiling occurs when the vapour pressure of liquid becomes equal to the atmospheric pressure. At the surface of moon, atmospheric pressure is zero, hence boiling point decreases and water begins to boil at 30 °C.

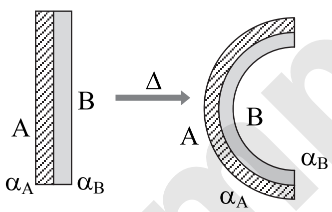
4. (D) The plate is made up of anisotropic material with different coefficients of thermal expansion. Hence, upon heating, plate will not remain circular. Also, as coefficients of thermal expansion are in mutually perpendicular direction, it will become elliptical in shape.



5. (A) 6. (B)

7. (D) Since, the coefficient of linear expansion of brass is greater than that of steel. On cooling, the brass contracts more, so it get loosened.

8. (C) A bimetallic strip upon heating bends in the form of an arc with more expandable metal (A) outside as shown.



9. (B) Using ***Shortcut 2***,

$d_2 = d_1 [1 + \alpha(t_2 - t_1)]$

$= 10[1 + 12 \times 10^{-6} (90 - 10)]$

$\therefore$ $d_2 = 10.0096$ cm

10. (C) Given $\Delta l_1 = \Delta l_2 \Rightarrow l_1\alpha_a t = l_2\alpha_s t$

$\therefore \quad \frac{l_1}{l_2} = \frac{\alpha_s}{\alpha_a} \Rightarrow \frac{l_1}{l_1 + l_2} = \frac{\alpha_s}{\alpha_a + \alpha_s}$.

11. (B) Diameter of sphere = Diameter of ring

$10.01 [1 + 12 \times 10^{-6}(t_2 - 10)]$

$= 10[1 + 18 \times 10^{-6}(t_2 - 10)]$

$1.001 + 1.001 \times 12 \times 10^{-6} (t_2 - 10)$

$= 1 + 18 \times 10^{-6} (t_2 - 10)$

$1.001 - 1 = 18 \times 10^{-6} (t_2 - 10) - 1.001 \times 12 \times 10^{-6} (t_2 - 10)$

$10^{-3} = (t_2 - 10) \times 10^{-6} [18 - 12.012]$

$\therefore \quad t_2 - 10 = \frac{10^{-3}}{5.988 \times 10^{-6}} \approx 167$

$\therefore \quad t_2 = 177$ °C

12. (A) The actual length of metal scale at $T_2 = 25$ °C is given by,

$L = L_0 (1 + \alpha \Delta T)$

$\therefore \quad L = L_0 [1 + \alpha (T_2 - T_1)]$

$\therefore \quad L = 1[1 + 20 \times 10^{-6} (25 - 0)]$

....($\because \alpha_{metal} = 20 \times 10^{-6}$/ °C)

$\therefore \quad L = 1[1 + 5 \times 10^{-4}]$

$\therefore \quad L = 1.0005$ m

Now for the steel rod, $L_2 = 1.0005$ at 25 °C,

L_1 is the length at 0 °C

$\therefore \quad L_2 = L_1 [1 + \alpha (T_2 - T_1)]$

$\therefore \quad 1.0005 = L_1 [1 + 12 \times 10^{-6} (25 - 0)]$

....($\because \alpha_{steel} = 12 \times 10^{-6}$/ °C)

$\therefore \quad L_1 = \frac{1.0005}{1.0003}$

$\therefore \quad L_1 \approx 1.0002$ m

13. (D) $(OR)^2 = (PR)^2 - (PO)^2$

$$l^2 - \left(\frac{l}{2}\right)^2 = [l(1+\alpha_2 t)]^2 - \left[\frac{l}{2}(1+\alpha_1 t)\right]^2$$

$$l^2 - \frac{l^2}{4} = l^2(1 + \alpha_2^2 t^2 + 2\alpha_2 t) - \frac{l^2}{4}(1 + \alpha_1^2 t^2 + 2\alpha_1 t)$$

Neglecting $\alpha_2^2 t^2$ and $\alpha_1^2 t^2$

$$0 = l^2(2\alpha_2 t) - \frac{l^2}{4}(2\alpha_1 t) \Rightarrow 2\alpha_2 = \frac{2\alpha_1}{4} \Rightarrow \alpha_1 = 4\alpha_2$$

14. (A) Due to thermal expansion both the alloy and cylinder will expand. In order to fit the alloy piston into the cylinder, the difference between both the linear thermal expansion of cylinder and alloy has to be equal to twice of the clearance.

$\therefore$ Total clearance $\Delta x = 0.08 \times 2 = 0.16$ mm

$= 0.16 \times 10^{-1}$ cm

Let the temperature to which the system will be heated be T.

$\therefore$ Temperature difference = (T – 30) °C

Thus the equation becomes,

$L_0 \alpha_1 \Delta T = L_0 \alpha_2 \Delta T + \Delta x$

$L_0 \alpha_1 \Delta T - L_0 \alpha_2 \Delta T = \Delta x$

$\therefore \quad L_0 \Delta T (\alpha_1 - \alpha_2) = \Delta x$

$\therefore \quad 15 \times (T - 30) (1.6 \times 10^{-5} - 1.2 \times 10^{-5}) = 0.16 \times 10^{-1}$

$\therefore \quad 6 \times 10^{-5} \times (T - 30) = 0.16 \times 10^{-1}$

$\therefore \quad T - 30 = 266.67$

$\therefore \quad T = 266.67 + 30$

$T \approx 297°$ C

15. (B) $\beta = 2\alpha$

$\therefore$ $\beta = 4 \times 10^{-6} / °C$

$A_2 = A_1 (1+ \beta \Delta t) = 0.32 (1 + 4 \times 10^{-6} \times 80)$

$A_2 = 0.3201 \text{ m}^2$

16. (D) $\beta = \left(\frac{\Delta A}{A_0}\right)\frac{1}{\Delta t} = \left(\frac{\Delta l}{l} + \frac{\Delta b}{b}\right)\frac{1}{\Delta t}$

$= \frac{\Delta l}{l \Delta t} + \frac{\Delta b}{b \Delta t} = \alpha_1 + \alpha_2$

17. (A) **18.** (C)

19. (C) Since the expansion of isotropic solids is in all directions, on heating the system, x, r, d all increase.

20. (C) When a copper ball is heated, its size increases. As volume $\propto$ (radius)^3 and area $\propto$ (radius)^2, so percentage increase will be largest in its volume. Density will decrease with rise in temperature.

21. (B) Due to volume expansion of both liquid and vessel, the change in volume of liquid relative to container is given by $\Delta V = V_0[\gamma_L - \gamma_g]\Delta\theta$

Also,

$\gamma_g = 3\alpha_g = 3 \times 0.1 \times 10^{-4} / °C = 0.3 \times 10^{-4} / °C$

$\therefore$ $\Delta V = 1000 [1.82 \times 10^{-4} - 0.3 \times 10^{-4}] \times 100$

$= 15.2$ cc

22. (C) Initial diameter of tyre = 1000 – 6 = 994 mm, so initial radius of tyre $R = \frac{994}{2} = 497 \text{ mm}$

and change in diameter ΔD = 6 mm so $\Delta R = \frac{6}{2} = 3 \text{ mm}$

After increasing temperature by $\Delta\theta$ tyre will fit onto wheel

Increase in the length (circumference) of the iron tyre

$\Delta L = L \times \alpha \times \Delta\theta = L \times \frac{\gamma}{3} \times \Delta\theta$ [As $\alpha = \frac{\gamma}{3}$]

$2\pi \Delta R = 2\pi R \left(\frac{\gamma}{3}\right)\Delta\theta$

$\Rightarrow \Delta\theta = \frac{3}{\gamma}\frac{\Delta R}{R} = \frac{3 \times 3}{3.6 \times 10^{-5} \times 497} = 503 °C$

23. (D) Change in volume of flask = Change in volume of mercury.

$V(3\alpha)\Delta r = V'\gamma\Delta t$

$V' = \frac{V(3\alpha)}{\gamma}$

$= \frac{2000 \times 3 \times 9 \times 10^{-6}}{1.8 \times 10^{-4}}$

$= 300$ c.c

24. (C) Let the original temperature be 0 °C;

Volume of A = $V_1 = l \times \pi(2r)^2$;

After heating volume of A will become,

$V'_1 = V_1(1 + \gamma\Delta T)$

$\frac{(V'_1 - V_1)}{V_1} = \gamma\Delta T \Rightarrow V'_1 - V_1 \propto V_1$

Similarly for rod B,

$\frac{(V'_2 - V_2)}{V_2} = \gamma\Delta T \Rightarrow V'_2 - V_2 \propto V_2$

$\therefore$ $\frac{\Delta V_1}{\Delta V_2} = \frac{l(2r)^2}{2l(r/2)^2} = \frac{2}{1} \times 4 = \frac{8}{1}$

25. (C) $\rho_2 = \frac{\rho_1}{(1 + \gamma\Delta T)}$

Fractional changes

$= \frac{\rho_1 - \rho_2}{\rho_1} = 1 - \frac{\rho_2}{\rho_1} = 1 - (1 + \gamma\Delta T)^{-1}$

$= 1 - (1 - \gamma\Delta T)$ …[$\because (1 + x)^n \approx 1 + nx$]

$= \gamma\Delta T = 5 \times 10^{-4} \times 40$

$= 0.020$

26. (B) Change in the temperature,

$\Delta T = 30 °C - 10 °C = 20 °C$

Volume of gasoline = Volume of steel tank = 100 L

$\gamma_{gasoline} = 95 \times 10^{-5} /°C$

The change in the volume of gasoline

$\Delta V_g = \gamma_{gasoline} V \Delta T$

$\therefore$ $\Delta V_g = 95 \times 10^{-5} \times 100 \times 20$

$\therefore$ $\Delta V_g = 1.9$ L

The change in the volume of steel tank

$\Delta V_s = \alpha_{steel} V \Delta T$

$\therefore$ $\Delta V_s = 12 \times 10^{-6} \times 100 \times 20$

$\therefore$ $\Delta V_s = 0.024$ L

Volume of gasoline that overflows

$= \Delta V_g - \Delta V_s = 1.9 - 0.024 = 1.876$ L

27. (C) The volume expansion is given by

$V = V_0 (1 + \gamma \Delta\theta)$ …(i)

The linear expansion is given by

$L^3 = L_0 (1 + \alpha_1 \Delta\theta) L_0^2 (1 + \alpha_2 \Delta\theta)^2$

$\therefore$ $L^3 = L_0^3 (1 + \alpha_1 \Delta\theta)(1 + \alpha_2 \Delta\theta)^2$

Also, $L^3 = V$ and $L_0^3 = V_0$

$V = V0 (1 + \alpha_1 \Delta\theta)(1 + \alpha_2 \Delta\theta)^2$ …(ii)

Comparing (i) and (ii),

$\therefore$ $(1 + \gamma \Delta\theta) = (1 + \alpha_1 \Delta\theta)(1 + \alpha_2 \Delta\theta)^2$

…[Using binomial expansion on the term $(1 + \alpha_2 \Delta\theta)^2$ i.e., $(1 + x)^n = 1 + nx$ + …. + negligible terms]

$\therefore$ $(1 + \gamma \Delta\theta) = (1 + \alpha_1 \Delta\theta)(1 + 2\alpha_2 \Delta\theta)$

$\therefore$ $(1 + \gamma \Delta\theta) = (1 + 2\alpha_2 \Delta\theta + \alpha_1 \Delta\theta + 2\alpha_1\alpha_2 \Delta\theta^2)$

The values of α_1 and α_2 are less than 1,

∴ neglecting the higher powers of α_1 and α_2.

∴ $(1 + \gamma\,\Delta\theta) = (1 + \alpha_1\,\Delta\theta + 2\alpha_2\,\Delta\theta)$

$= 1 + (\alpha_1 + 2\alpha_2)$

∴ $\gamma = \alpha_1 + 2\alpha_2$

28. (B) Force developed = $\alpha AY\Delta T$
⇒ force is independent of length of the bar.

29. (C) Water will overflow, both when heated or cooled because water has maximum density or minimum volume at 4 °C.

30. (A) Freezing point of water decreases when pressure increases, because water expands on solidification while "except water" for other liquid freezing point increases with increase in pressure. Since the liquid in question is water. Hence, it expands on freezing.

7.6 Specific Heat Capacity

1. (C) The value of specific heat will depend upon nature of substance and will vary for different substances. Also, it depends on the state of the substance. For example, specific heat of ice, water and steam is 0.5 cal/g °C, 1 cal/g °C and 0.47 cal/g °C respectively.

2. (C) **3.** (A)

4. (C) Using $Q = mc\,\Delta T = mc(T_1 - T_2)$

$c = \frac{Q}{m(T_1 - T_2)}$

In this case, $T_1 = T_2 = 100$ °C

$c = \frac{Q}{m(0)} = \infty$

5. (C)

6. (A) $Q = mc\Delta T$
For copper,
$Q = 420 \times 50 \times 10^{-3} \times 10 = 210$ calories
For water,

$\Delta T = \frac{Q}{cm} = \frac{210}{4200 \times 10 \times 10^{-3}} = 5$ ºC

7. (A) The heat supplied is given by,
$Q = mc\Delta T$ ….(i)

Rate of heat supplied $Q' = \frac{Q}{t}$

∴ $Q = Q'\,t$
Substituting the value of Q in equation (i).

∴ $Q'\,t = m \times c \times \Delta T$

∴ $\Delta T = \frac{Q'}{mc} \times t$

Temperature (ΔT) is along y axis and time (t) is along x-axis

∴ $y = \frac{Q'}{mc} \times x$ ….(ii)

Comparing equation (ii) with the equation of a straight line
$y = mx + \text{constant}$

Thus, the slope of the equation = $\frac{Q'}{mc}$

The slope of the equation $\propto \frac{1}{c}$

…(∵ Q and m are constant)

Thus, the specific heat of the substance is inversely proportional to the slope.
Also, the slope of substance = $\tan\theta$
Therefore, the slope of A is highest and hence its specific heat capacity is lowest.

7.7 Calorimetry

1. (C)

2. (B) Let the final temperature be T °C.
Total heat supplied by the three liquids in coming down to 0 °C
$= m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3$ ....(i)
Total heat used by three liquids in raising temperature from 0 °C to T °C
$= m_1c_1T + m_2c_2T + m_3c_3T$ ....(ii)
By equating (i) and (ii),
$(m_1c_1 + m_2c_2 + m_3c_3)\,T$
$= m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3$

$\Rightarrow T = \frac{m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3}{m_1c_1 + m_2c_2 + m_3c_3}$.

3. (D) Heat lost by boiling water
= Heat gained by cold water

∴ $100 \times 1 \times (100 - 20) = (300 + W) \times (20 - 10)$
where, W = water equivalent of calorimeter

∴ $8000 = 3000 + 10W$

∴ $W = 500$ g
When the metallic block is added,
Heat lost by the water = Heat gained by block

∴ $(100 + 300 + 500) \times 1 \times (20 - 19)$
$= 1000 \times c \times (19 - 10)$
where, c = specific heat of the metal

∴ $900 = 1000 \times 9 \times c$

∴ $c = 0.1$ cal/g °C.

4. (C) Mixing A and B:
Heat gained by A = Heat lost by B

∴ $m_A\,c_A\,\Delta T_A = m_B\,c_B\,\Delta T_B$
$\Rightarrow m\,c_A(16 - 12) = m\,c_B\,(19 - 16)$
$\Rightarrow 4c_A = 3c_B$ ….(i)
Mixing B and C :

∴ $m_B\,c_B\,\Delta T_B = m_C\,c_C\,\Delta T_C$
$\Rightarrow m\,c_B(23 - 19) = m\,c_C\,(28 - 23)$
$\Rightarrow 4c_B = 5c_C$ ….(ii)
Multiplying equation (i) by 4 and equation (ii) by (3),
$16c_A = 12\,c_B$ and $12\,c_B = 15\,c_C$

$\therefore \quad 16c_A = 15c_C \Rightarrow c_A = \frac{15}{16} c_C$

Mixing A and C:

$\therefore \quad m_A c_A \Delta T_A' = m_C c_C \Delta T_C'$

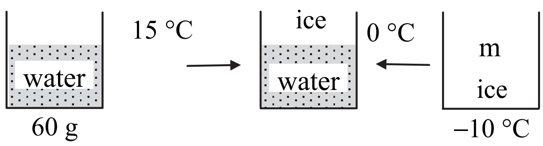
$m\, c_A(x - 12) = m\, c_C (28 - x)$

where, x is final temperature of mixture

$\therefore \quad \frac{15}{16} c_C (x - 12) = c_C (28 - x)$

$\therefore \quad x = 20.26\ °C$

5. (C)



$$60\text{ g} + \frac{m}{2}\text{ (water)} + \frac{m}{2}\text{ (ice)}$$

Heat gained by ice of mass m to change its temperature from –10 °C to 0 °C + Heat gained by ice of mass $\frac{m}{2}$ to convert into water = Heat lost by water to change its temperature from 15 °C to 0 °C

$$m \times \frac{1}{2} \times 10 + \frac{m}{2} \times 80 = 60 \times 1 \times 15$$

$$m = \frac{60 \times 15}{45} = 20\text{ g}$$

7.8 Change of State

1. (A) **2.** (C) **3.** (B)

4. (B)

5. (A) For same mass and material, latent heat is independent of configuration.

6. (A) The latent heat of vaporization is always greater than latent heat of fusion because in liquid to vapour phase change there is a large increase in volume. Hence more heat is required as compared to solid to liquid phase change.

7. (D) Suppose m g ice is melted, then heat required for its melting = mL = m × 80 cal

Heat available with steam for being condensed and then brought to 0°C

$= 1 \times 540 + 1 \times 1 \times (100 - 0) = 640$ cal

$\Rightarrow$ Heat lost = Heat taken

$\Rightarrow 640 = m \times 80 \Rightarrow m = 8$ g

Thinking Hatke - Q.7

You can remember that amount of steam (m′) at 100 °C required to melt m g ice at 0 °C is $m' = \frac{m}{8}$.

Here, $m = 8 \times m' = 8 \times 1 = 8$ g

8. (B) Initially ice will absorb heat to raise its temperature to 0 °C then its melting takes place.

If m_i = Initial mass of ice, m_i' = Mass of ice that melts and m_W = Initial mass of water

Heat gained by ice = Heat lost by water

$\Rightarrow m_i \times c \times (20) + m_i' \times L = m_W c_W (20)$

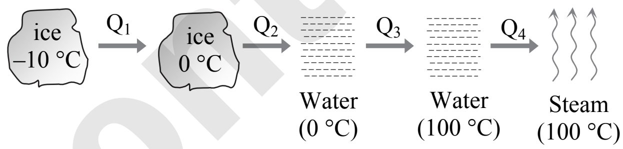
$\Rightarrow 2 \times 0.5(20) + m_i' \times 80 = 5 \times 1 \times 20$

$\Rightarrow m_i' = 1$ kg

So final mass of water = Initial mass of water + Mass of ice that melts = 5 + 1 = 6 kg.

9. (A) Ice (–10 °C) converts into steam as follows

(c_i = Specific heat of ice, c_W = Specific heat of water, L_f = Latent heat of fusion and L_V = Latent heat of vaporization)



Total heat required

$Q = Q_1 + Q_2 + Q_3 + Q_4$

$= mc_i\Delta\theta_1 + mL_f + mc_W\Delta\theta_2 + mL_V$

$= 1 \times 0.5(10) + 1 \times 80 + 1 \times 1 \times (100 - 0) + 1 \times 540$

$= 725$ cal

Work done $W = JQ = 4.2 \times 725 = 3045$ J

10. (A) Heat required to melt ice $= m_i L_i$

$= 60 \times 80$

$= 4800$ cal

Heat required to change the temperature of water at 100 °C (steam)

$= m_s c_w \Delta\theta$

$= 60 \times 1 \times (100 - 0) = 6000$ cal

$\therefore$ Total heat $Q_1 = 6000 + 4800 = 10800$ cal

Now, heat required to condense 60 g of steam

$Q_2 = 60 \times 540 = 32400$ cal

As $Q_2 > Q_1$, whole 60 g of steam does not get condensed.

Hence, temperature of mixture remains 100 °C.

But Q_1 amount of heat will condense M g of steam,

$\therefore \quad M = \frac{Q_1}{L_s} = \frac{10800}{540} = 20$ g

Hence, out of 60 g , 20 g of steam is converted into water.

$\therefore$ mixture contains 40 g of steam and

120 – 40 = 80 g of water.

11. (B) $m_w = 150$ g = 0.15 kg
The heat required to evaporate 'm' grams of water,
$\Delta Q_{required} = mL_v$ ....(i)
(0.15 – m) is the amount of mass that converts into ice
∴ $\Delta Q_{released} = (0.15 - m)\ L_f$ ....(ii)

Amount of heat required = Amount of heat released

From (i) and (ii),
$mL_v = (0.15 - m)\ L_f$
∴ $m\ (L_f + L_v) = 0.15\ L_f$
∴ $m = \dfrac{0.15\ L_f}{L_f + L_v}$
$= \dfrac{0.15 \times 3.36 \times 10^5}{2.10 \times 10^6 + 3.36 \times 10^5}$
∴ m = 0.0206 kg ≈ 20 g

7.9 Heat transfer

1.	(D)	**2.**	(A)	**3.**	(C)
4.	(D)	**5.**	(B)	**6.**	(A)
7.	(D)	**8.**	(A)		

9. (C) $\dfrac{\Delta Q}{t} = \dfrac{KA\Delta\theta}{\Delta x}$
Thermal gradient
$\dfrac{\Delta\theta}{\Delta x} = \dfrac{(\Delta Q/At)}{K} = \dfrac{20}{0.8} = 25\ °C/cm$

10. (C) $\dfrac{Q}{At} = K\dfrac{\Delta\theta}{\Delta x}$
∵ $K\dfrac{\Delta\theta}{\Delta x} = \text{constant} \Rightarrow \dfrac{\Delta\theta}{\Delta x} \propto \dfrac{1}{K}$
Hence If $X_c = X_m = X_g$, then
$\left(\dfrac{\Delta\theta}{\Delta x}\right)_c < \left(\dfrac{\Delta\theta}{\Delta x}\right)_m < \left(\dfrac{\Delta\theta}{\Delta x}\right)_g$
$(T_g)_c < (T_g)_m < (T_g)_g$
because higher K implies lower value of the temperature gradient.

11. (D) $\dfrac{Q}{t} = \dfrac{KA\Delta\theta}{\Delta x}$
$\dfrac{Q}{t} \propto \dfrac{A}{\Delta x} \propto \dfrac{d^2}{\Delta x}$ (d = Diameter of rod)
$\dfrac{(Q/t)_1}{(Q/t)_2} = \left(\dfrac{d_1}{d_2}\right)^2 \times \dfrac{\Delta x_2}{\Delta x_1} = \left(\dfrac{1}{2}\right)^2 \times \left(\dfrac{1}{2}\right) = \dfrac{1}{8}$

12. (B)

13. (B) Heat passes quickly from the body into the metal which leads to a cold feeling

14. (B) $\dfrac{Q}{t} \propto \dfrac{r^2}{x}$; from the given options, option (B) has higher value of $\dfrac{r^2}{x}$.

15. (A) $\dfrac{dQ}{dt} = \dfrac{KA\Delta\theta}{l}$, For both rods K, A and Δθ are same $\Rightarrow \dfrac{dQ}{dt} \propto \dfrac{1}{l}$
So $\dfrac{(dQ/dt)_{semi\ circular}}{(dQ/dt)_{straight}} = \dfrac{l_{straight}}{l_{semicircular}} = \dfrac{2r}{\pi r} = \dfrac{2}{\pi}$.

16. (D) $\dfrac{Q}{t} = \dfrac{KA\ \Delta\theta}{l}$
All the four rods are kept at same temperature difference.
∴ $\dfrac{Q}{t} \propto \dfrac{A}{l}$
∴ $\dfrac{Q}{t} \propto \dfrac{r^2}{l}$
Hence, the rod to conduct maximum heat, should have largest r and smallest l
i.e., largest $\dfrac{r^2}{l}$ ratio
Ratio $\dfrac{r^2}{l}$ is maximum in option (D).

17. (B) The amount of heat flow in time t through a cylindrical metallic rod of length x and uniform area of cross-section A with its ends maintained at temperatures θ_1 and θ_2 is given by
$Q = \dfrac{KA(\theta_1 - \theta_2)t}{x}$
where K is the thermal conductivity of the material of the rod.
Area of cross-section of new rod
$A' = \pi\left(\dfrac{R}{2}\right)^2 = \dfrac{\pi R^2}{4}$
$\Rightarrow A' = \dfrac{A}{4}$
As the volume of the rod remains unchanged
$Ax = A'x'$
where x′ is the length of the new rod
$x' = x\dfrac{A}{A'} = 4x$
Now, the amount of heat flows in same time t in the new rod with its ends maintained at the same temperatures θ_1 and θ_2 is given by
$Q' = \dfrac{K(A/4)(\theta_1 - \theta_2)t}{4x} = \dfrac{1}{16}\ \dfrac{KA\ (\theta_1 - \theta_2)t}{x} = \dfrac{1}{16}Q$

18. (B) The rods are identical and are of same material, ie. $l_1 = l_2 = l$
And $K_1 = K_2 = K$ ….K = thermal conductivity
also, $A_1 = A_2 = A$
Case I :
When rods are connected end to end (series),
∴ $\dfrac{Q}{t_s} = \dfrac{\Delta\theta}{R_s}$

$\therefore \quad t_s = \dfrac{Q R_s}{\Delta\theta}$

Where, R_s = Thermal resistivity

i.e. $t_s = \dfrac{Q}{\Delta\theta}\left[\dfrac{l_1}{K_1A_1} + \dfrac{l_2}{K_2A_2}\right]$

$\therefore \quad 8 = \dfrac{Q}{\Delta\theta}\left[\dfrac{2l}{KA}\right]$ ….(i)

Case II :

When rods are connected in parallel,

$t_p = \dfrac{QR_p}{\Delta\theta} = \dfrac{Q}{\Delta\theta}\dfrac{1}{\left[\dfrac{2KA}{l}\right]}$ ….(ii)

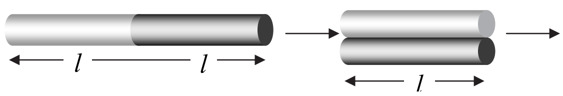
Dividing equation (i) by equation (ii),

$\therefore \quad \dfrac{8}{t_p} = \dfrac{QR_s}{\Delta\theta} \times \dfrac{\Delta\theta}{QR_p}$

$= 2\left[\dfrac{l}{KA}\right] \times 2\left[\dfrac{KA}{l}\right] = 4$

$\therefore \quad t_p = 2$ s

19. (B) Let the heat transferred be Q.



When rods are joined end to end. Heat transferred by each rod

$= Q = \dfrac{KA\Delta\theta}{2l} \times 12$ ....(i)

When rods are joined lengthwise,

$Q = \dfrac{K2A\Delta\theta}{l}t$ ....(ii)

From equation (i) and (ii), t = 3 s

20. (A) Using formula, $\dfrac{Q}{t} = \dfrac{\Delta T}{(\Delta x / KA)}$

For first configuration, blocks are arranged in series combination.

$\therefore \quad \dfrac{\Delta x}{KA} = \dfrac{l}{KA} + \dfrac{l}{2KA}$

Thus $\dfrac{Q}{t} = \dfrac{T_1 - T_2}{\left[\dfrac{l}{KA} + \dfrac{l}{2KA}\right]}$ ….(i)

For second configuration, arrangement of blocks resemble parallel combination.

$\therefore \quad \left(\dfrac{\Delta x}{KA}\right)^{-1} = \dfrac{KA}{l} + \dfrac{2KA}{l}$

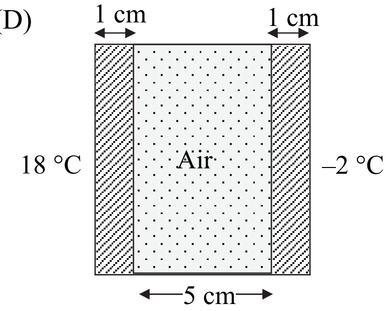
Thus $\dfrac{Q}{t'} = (T_1 - T_2)\left(\dfrac{KA}{l} + \dfrac{2KA}{l}\right)$ ….(ii)

Dividing equation (i) by equation (ii),

$\therefore \quad \dfrac{t'}{t} = \dfrac{2}{9}$

$\therefore \quad t' = \dfrac{2}{9} \times t = \dfrac{2}{9} \times 9 = 2$ s

21. (D)



The window can be considered to be a series combination of three layers, such that,

$K_1 = K_3 = 0.8$ Wm^{-1} K^{-1}, $K_2 = 0.08$ Wm^{-1} K^{-1}

$A_1 = A_2 = A_3 = 2.6$ m^2,

$l_1 = l_3 = 1$ cm and $l_2 = 5$ cm

$\therefore$ Equivalent thermal resistance,

$R_{eq} = R_1 + R_2 + R_3$

$= \dfrac{l_1}{K_1A_1} + \dfrac{l_2}{K_2A_2} + \dfrac{l_3}{K_3A_3}$

$= \dfrac{1 \times 10^{-2}}{0.8 \times 2.6} + \dfrac{5 \times 10^{-2}}{0.08 \times 2.6} + \dfrac{1 \times 10^{-2}}{0.8 \times 2.6}$

$= \dfrac{2 \times 10^{-2} + 5 \times 10^{-1}}{0.8 \times 2.6}$

$= \dfrac{0.52}{0.8 \times 2.6} = \dfrac{1}{4}$

$\therefore \quad \dfrac{Q}{t} = \dfrac{\Delta\theta}{R} = \dfrac{[18 - (-2)]}{\left(\dfrac{1}{4}\right)} = 20 \times 4 = 80$ W.

22. (A) The rods are connected in parallel.

$\therefore$ In parallel, $\dfrac{1}{R_P} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

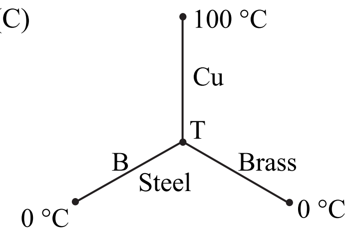
But, $R = \dfrac{l}{KA}$ and l is same for both rods i.e.,

$l_1 = l_2 = d$

$\therefore \quad \dfrac{K_P(2A)}{d} = \dfrac{K_1A}{d} + \dfrac{K_2A}{d}$

$\therefore \quad K_P = \dfrac{K_1 + K_2}{2}$

23. (C)



$Q = Q_1 + Q_2 \quad \ldots\left[\because Q = KA\left(\dfrac{\Delta\theta}{\Delta x}\right)t\right]$

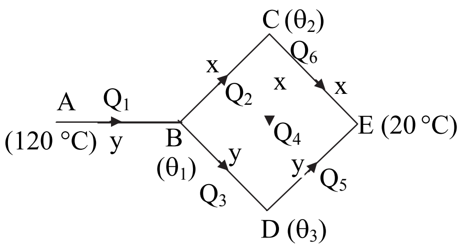
$\dfrac{0.92 \times 4(100 - T)}{46} = \dfrac{0.26 \times 4 \times (T - 0)}{13} + \dfrac{0.12 \times 4 \times T}{12}$

$\Rightarrow 200 - 2T = 2T + T$

$\Rightarrow T = 40$ °C

$\Rightarrow Q = \dfrac{0.92 \times 4 \times 60}{46} = 4.8$ cal/s

24. (A) Let L be the length of each rod.
Temperature of A = 120 °C,
Temperature of E = 20 °C



Quantity of heat, $Q = \frac{kA(T_1 - T_2)t}{x}$

Let θ_1, θ_2, θ_3 be respective temperatures of B, C, D. If Q_1, Q_2, Q_3, Q_4, Q_5, Q_6 are the amounts of heat flowing per second respectively from A to B; B to C; B to D; C to D; D to E and C to E then

$Q_1 = \frac{0.45\,A(120 - \theta_1)t}{x}$, $Q_2 = \frac{0.92\,A(\theta_1 - \theta_2)t}{x}$

$Q_3 = \frac{0.46\,A(\theta_1 - \theta_3)t}{x}$, $Q_4 = \frac{0.92A(\theta_2 - \theta_3)t}{x}$

$Q_5 = \frac{0.46\,A(\theta_3 - 20)t}{x}$, $Q_6 = \frac{0.92\,A(\theta_2 - 20)t}{x}$

As $Q_1 = Q_2 + Q_3$

$\frac{0.46A(120 - \theta_1)}{x} = \frac{0.92A(\theta_1 - \theta_2)}{x} + \frac{0.46A(\theta_1 - \theta_3)}{x}$

$120 - \theta_1 = 2(\theta_1 - \theta_2) + \theta_1 - \theta_3$

$\therefore$ $4\theta_1 - 2\theta_2 - \theta_3 = 120$ °C ….(i)

$Q_2 = Q_4 + Q_6$ gives

$\theta_1 - 3\theta_2 + \theta_3 = -20$°C ….(ii)

Again, $Q_5 = Q_3 + Q_4$ gives

$\theta_1 + 2\theta_2 - 4\theta_3 = -20$°C ….(iii)

Solving (i), (ii) and (iii),

$\theta_1 = 60$ °C, $\theta_2 = 40$ °C, $\theta_3 = 40$ °C

7.10 Newton's Law of Cooling

1. (A) For same mass, volume and material, rate of cooling will depend upon area of the body. Smaller the area, lesser will be rate of cooling.

2. (A) For both spheres, surface area, material and temperature difference are same hence rate of cooling $\frac{d\theta}{dt} \propto \frac{1}{m}$ and $m_{solid} > m_{hollow}$.
Hence hollow sphere will cool fast.

3. (B)

4. (A) According to Newton's law of cooling, the body whose rate of cooling is more, its specific heat will be less.

5. (A)

6. (C) The temperature of the metal will decrease exponentially with time to θ_0.

7. (B) For θ-t plot,
rate of cooling $= \frac{d\theta}{dt} =$ slope of the curve.

At P, $\frac{d\theta}{dt} = \tan\phi_2 = k(\theta_2 - \theta_0)$,
where k = constant.

At Q $\frac{d\theta}{dt} = \tan\phi_1 = k(\theta_1 - \theta_0) \Rightarrow \frac{\tan\phi_2}{\tan\phi_1} = \frac{\theta_2 - \theta_0}{\theta_1 - \theta_0}$

8. (D)

9. (C) According to Newton's law of cooling,
Rate of cooling $\propto$ Mean temperature difference

$\Rightarrow \frac{\text{Fall in temperature}}{\text{Time}} \propto \left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right)$

$\because \left(\frac{\theta_1 + \theta_2}{2}\right)_1 > \left(\frac{\theta_1 + \theta_2}{2}\right)_2 > \left(\frac{\theta_1 + \theta_2}{2}\right)_3$

$\Rightarrow$ $T_1 < T_2 < T_3$

10. (A) $\frac{d\theta}{dt} = k(\theta - \theta_0)$

$k = \frac{0.2}{20} = 0.01$/min

11. (C) According to Newton's law of cooling
Rate of cooling $\propto$ mean temperature difference.
Initially, mean temperature difference

$= \left(\frac{70 + 60}{2} - \theta_0\right) = (65 - \theta_0)$

Finally, mean temperature difference

$= \left(\frac{60 + 50}{2} - \theta_0\right) = (55 - \theta_0)$

In second case mean temperature difference decreases, so rate of fall of temperature decreases, so it takes more time to cool through the same range.

12. (D) $R_1 = 0.5$ °C/s, $R_2 = x$,
R = k (temp. difference)

$\therefore$ $R_1 = k\,(50°)$, $R_2 = k\,(30°)$

$\therefore$ $0.5 = k \times 50°$

$\therefore$ $x = k\,(30°)$

$\therefore$ $\frac{x}{0.5} = \frac{k(30°)}{k(50°)}$

$\therefore$ $x = 0.3$ °C/s

13. (D) According to Newton's law of cooling

$\frac{\theta_1 - \theta_2}{t} = k\left[\frac{\theta_1 + \theta_2}{2} - \theta_s\right]$

$\frac{80 - 70}{5} = k\left[\frac{80 + 70}{2} - 40\right]$

$2 = 35\,k$ …(i)

$$\frac{80-60}{t} = k\left[\frac{80+60}{2} - 40\right]$$

$$\frac{20}{t} = 30\text{ k} \qquad \text{…(ii)}$$

Dividing equation (i) by (ii),

$$\frac{t}{10} = \frac{35}{30}$$

$$t = \frac{35}{30} \times 10 = 12\text{ minute}$$

14. (C) Using $\frac{dQ}{dt} \propto \Delta T$,

$$\frac{60-40}{7} = k(60-10) \quad \therefore\ k = \frac{2}{35}$$

$$\frac{40-28}{t} = k\,(40-10) = \frac{2}{35}(30)$$

$$t = \frac{12\times 35}{60} = 7\text{ minutes}$$

15. (A) According to Newton's law of cooling,

$$\frac{d\theta}{dt} = K(\theta - \theta_0)$$

Case I:

$$\therefore\ \frac{90-80}{t} = K\left[\left(\frac{90+80}{2}\right) - 20\right]$$

$$\therefore\ \frac{10}{t} = K(85-20) \qquad \text{….(i)}$$

Case II:

$$\therefore\ \frac{80-60}{t'} = K\left[\left(\frac{80+60}{2}\right) - 20\right]$$

$$\therefore\ \frac{20}{t'} = K(70-20) \qquad \text{….(ii)}$$

From equations (i) and (ii),

$$\frac{10/t}{20/t'} = \frac{(85-20)}{(70-20)}$$

$$\therefore\ \frac{t'}{2t} = \frac{65}{50}$$

$$\therefore\ \frac{t'}{t} = \frac{65\times 2}{50}$$

$$\therefore\ \frac{t'}{t} = \frac{130}{50}$$

$$\therefore\ t' = \frac{13}{5}\,t$$

16. (B) According to Newton's law of cooling,

$$\frac{\theta_1-\theta_2}{t} = k\left[\frac{\theta_1+\theta_2}{2} - \theta_0\right]$$

Case 1:

$$\frac{60-50}{10} = k\left[\frac{60+50}{2} - \theta_0\right]$$

$$1 = k(55-\theta) \qquad \text{….(i)}$$

Case 2:

$$\frac{50-42}{10} = k\left[\frac{50+42}{2} - \theta_0\right]$$

$$0.8 = k(46-\theta_0) \qquad \text{….(ii)}$$

Dividing equation (i) by equation (ii),

$$\frac{1}{0.8} = \frac{55-\theta}{46-\theta}$$

$$46 - \theta_0 = 44 - 0.8\,\theta_0$$

$$\theta_0 = 10\ °C$$

17. (A) According to Newton's law of cooling,

$$\frac{\theta_1-\theta_2}{\Delta t} = k\left[\frac{\theta_1+\theta_2}{2} - \theta_0\right]$$

$$\text{First} \Rightarrow \frac{70-60}{5} = k\left[65-\theta_0\right]$$

$$\Rightarrow 2 = k[65-\theta_0]$$

$$\text{Next} \Rightarrow \frac{60-54}{5} = k\left[57-\theta_0\right]$$

Dividing (i) and (ii)

$$\frac{5}{3} = \frac{65-\theta_0}{57-\theta_0}$$

$$\Rightarrow 285 - 5\theta_0 = 195 - 3\theta_0$$

$$\Rightarrow 2\theta_0 = 90$$

$$\theta_0 = 45\ °C$$

Concept Fusion

1. (C)

2. (D) For cooking utensils, low specific heat is preferred for its material as it should need less heat to raise its temperature and it should have high conductivity, because, it should transfer heat quickly.

3. (B)

4. (B) Substances are classified into two categories

i. water like substances which expand on solidification.

ii. CO_2 like (Wax, Ghee etc.) which contract on solidification.

Their behaviour regarding solidification is opposite.

Melting point of ice decreases with rise of temperature but that of wax etc increases with increase in temperature. Similarly ice starts forming from top downwards whereas wax starts its formation from bottom.

5. (B) Heat lost in t seconds = mL

Heat lost per second = $\frac{mL}{t}$.

This must be the heat supplied for keeping the substance in molten state per second.

$\therefore \frac{mL}{t} = P \Rightarrow L = \frac{Pt}{m}$

6. (C) Heat delivered by burner in first 10 mins,
$H_1 = Pt_1$
where, P is power delivered by burner.
Let mass of water in the beaker be m then,
$Pt_1 = mc\Delta T$
Since settings of burner are unchanged, same power will be used for evaporation process.
If t_2 is time taken to evaporate the water,
$Pt_2 = mL$

$t_2 = \frac{mL}{P} = \frac{mLt_1}{mc\Delta T} = \frac{Lt_1}{c\Delta T}$

$= \frac{2.3\times10^6\times10}{4.2\times10^3\times(100-20)} = 68.45$ min. ≈ 68 min

= 1 hr 8 min.

7. (D) $\frac{dQ}{dt}$ = 50% of input P

$\therefore P_{out} = \frac{dQ}{dt} = \frac{15\times10^3}{2}$ W

Also, $\frac{dQ}{dt} = mc\frac{d\theta}{dt}$

$\therefore \frac{15\times10^3}{2} = 10\times0.91\times10^3\times\frac{d\theta}{2\times60}$

$\therefore d\theta = \frac{15\times10^3\times2\times60}{2\times10\times0.91\times10^3} = 98.9$ °C

8. (A) $\left(KA\frac{dT}{dx}\right)t = mL$,

$K \propto \frac{1}{t}$ So, $\frac{K_1}{K_2} = \frac{t_2}{t_1}$

9. (B) $\frac{dQ}{dt} = \frac{KA}{l}d\theta = \frac{0.01\times1}{0.05}\times30 = 6$ J/s

Heat transferred in one day (86400 s)
$\theta = 6\times86400 = 518400$ J

Now $Q = mL \Rightarrow m = \frac{Q}{L} = \frac{518400}{334\times10^3}$

= 1.552 kg = 1552 g

10. (D) $Q = KA\left(\frac{\Delta\theta}{\Delta x}\right)dt$

Now, Q = mL

$\therefore mL = KA\left(\frac{\Delta\theta}{\Delta x}\right)dt$

$\therefore mL = \frac{KA[0-(-26)]dt}{x}$

$\therefore (\rho A\,dx)L = KA\frac{[0-(-26)]}{x}dt$

$\therefore \frac{dx}{dt} = \frac{26K}{x\rho L}$

11. (C) $\frac{Q}{t} = \frac{KA\Delta\theta}{\Delta x}$

$\frac{mL}{t} = \frac{K(\pi r^2)\Delta\theta}{\Delta x}$

For 1st rod

$\left(\frac{m}{t}\right)_1 = \frac{K_1r_1^2}{x_1}$ ….(i)

For 2nd rod

$\left(\frac{m}{t}\right)_2 = \frac{K_2r_2^2}{x_2}$ ….(ii)

But $K_2 = \frac{K_1}{4}$, $r_2 = 2r_1$, $x_2 = \frac{x_1}{2}$

$\therefore$ Dividing (ii) by (i)

$\therefore \frac{\left(\frac{m}{t}\right)_2}{\left(\frac{m}{t}\right)_1} = \frac{\frac{K_1}{4}(2r_1)^2}{\frac{x_1}{2}}\times\frac{x_1}{K_1r_1^2} = \frac{\left(\frac{K_1}{4}\right)4r_1^2}{x_1}\times\frac{x_1}{K_1r_1^2}$

$\left(\frac{m}{t}\right)_2 = \left(\frac{m}{t}\right)_1\times2$

$\left(\frac{m}{t}\right)_2 = 0.1\times2 = 0.2$ g/s

12. (A) From Newton's law of cooling,

$\frac{dQ}{dt} = K(\theta-\theta_0)$

When the liquid is maintained at θ = 57 °C by heater of power 30 W,
$30 = K(57-27)$

$\therefore K = 1$ ….(i)

Also, $Q = mc\theta$

$\therefore \frac{dQ}{dt} = \frac{mc\,d\theta}{dt} = K(\theta-\theta_0)$

As temperature difference is too small, θ can be considered as 47 °C.

$\therefore \frac{250\times10^{-3}\times c\times(47-46.9)}{10} = K(47-27)$

$\therefore 0.0025\times c = 20K$

$\therefore 0.0025\times c = 20$ ….[From (i)]

$\therefore c = \frac{20}{0.0025} = 8000$ J kg^{-1} K^{-1}

13. (A) Frictional force, $f = \mu mg = 0.1\times20\times10 = 20$ N
The work done in dragging the block is converted into heat energy.

$\therefore f\times ut = mc\Delta T$

$\therefore 20\times0.5\times2.1 = 20\times0.1\times4.2\times10^3\times\Delta T$

$\therefore \Delta T = 0.0025$ °C

14. (B) Using the ideal gas equation,
PV = nRT

$\therefore$ $\frac{1}{T} = \frac{nR}{PV}$

Since pressure (P) is constant
$P\Delta V = nR\Delta T$

$\therefore$ $\frac{\Delta V}{\Delta T} = \frac{nR}{P}$

The coefficient of volume expansion,

$\alpha_v = \frac{\Delta V}{V\Delta T}$

$\therefore$ $\alpha_v = \frac{nR}{PV} = \frac{1}{T} \Rightarrow \alpha_v \propto \frac{1}{T}$

Thus, graph (B) represents correct graph.

15. (C) From ideal gas equation $PV = nRT \Rightarrow P = \frac{nRT}{V}$

Given $PT^2 = K \Rightarrow \frac{nRT}{V} \cdot T^2 = K = nRT^3 = KV$ ….(i)

Differentiating both sides,
$3n\,RT^2\,dT = K\,dV$ ….(ii)
Dividing equation (ii) by equation (i),

$\frac{3}{T}dT = \frac{dV}{V}$

Coefficient of volume expansion = $\frac{dV}{V\,dT} = \frac{3}{T}$

16. (C) When external pressure is applied on the cube, the compression produced in volume is

$\frac{\Delta V}{V} = \frac{P}{K}$ ....(i)

When heated, the cube will expand through,
$\Delta V = V(\gamma\,\Delta T)$

$\therefore$ $\frac{\Delta V}{V} = 3\alpha\Delta T$ ....(ii) ($\because \gamma = 3\alpha$)

Hence, equating equations (i) and (ii),

$3\alpha\Delta T = \frac{P}{K}$

$\therefore$ $\Delta T = \frac{P}{3\alpha K}$

17. (C) As the coefficient of cubical expansion of metal is less as compared to the coefficient of cubical expansion of liquid, we may neglect the expansion of metal ball. So when the ball is immersed in alcohol at 0 ºC, it displaces some volume V of alcohol at 0 °C and has weight W_1.
$W_1 = W_0 - V\rho_0 g$
where W_0 = weight of ball in air
Similarly, $W_2 = W_0 - V\rho_{50} g$
where, ρ_0 = density of alcohol at 0 ºC
and ρ_{50} = density of alcohol at 50 ºC
As $\rho_{50} < \rho_0$, $\Rightarrow W_2 > W_1$ or $W_1 < W_2$

18. (A) When the piece of ice falls from the height h, it possesses potential energy, mgh.
This P.E. is converted to heat energy.

$\therefore$ Q = mgh

But only $\frac{1}{4}^{th}$ of it is absorbed by ice which is used to change the state.

$\therefore$ $\frac{mgh}{4} = mL$

$\therefore$ $\frac{10 \times h}{4} = 3.4 \times 10^5$

$\therefore$ $h = 13.6 \times 10^4\ m = 136\ km$

19. (A) When a bullet is fired it has

K.E. = $\frac{1}{2}mv^2$

This K.E. is converted into heat energy. Out of which $\frac{1}{4}$ th of heat is absorbed hence remaining energy is used to melt the bullet.

$\therefore$ $\frac{3}{4}\left(\frac{1}{2}mv^2\right) = mc\Delta\theta + mL$

$\therefore$ $\frac{3}{8}v^2 = c\Delta\theta + L$

$\therefore$ $\frac{3}{8}v^2 = 0.03 \times 4200 \times (600 - 300) + 6 \times 4200$

$\therefore$ $v^2 = 8\,(0.01 \times 4200 \times 300) + 8\,(2 \times 4200)$

$= 8 \times 4200\,(3 + 2)$
$= 168000$
$v = \sqrt{168000} \approx 410$ m/s

20. (A) For two identical ice blocks,

$m_1 = m_2 \Rightarrow \mu = \frac{m}{2}$

Relative velocity $(v_{rel}) = u_1 - (-u_2) = u_1 + u_2 = 2u$

$\therefore$ K.E. = $\frac{1}{2}\mu v_{rel}^2 = \frac{1}{2} \times \frac{m}{2} \times (2u)^2 = mu^2$

Also this K.E. is used to completely melt both the blocks.

$\therefore$ $mu^2 = Q = (mL + mc\,\Delta\theta) \times 2$

$\therefore$ $u^2 = 2\,(L + c\Delta\theta)$
$= (2 \times 3.36 \times 10^5) + \{(2 \times 2100 \times [0 - (-8)]\}$
$= 2 \times (336000 + 16800)$
$= 705600$

$\therefore$ u = 840 m/s

21. (D) Period of pendulum,

$T = 2\pi\sqrt{\frac{L}{g}}$

$\therefore$ $T \propto \sqrt{L}$

But, $L = L_0(1 + \alpha\,\Delta t)$

$\therefore$ $T \propto \sqrt{L_0(1 + \alpha\Delta t)}$

As L_0 is constant,

$\Rightarrow T \propto (1 + \alpha\,\Delta t)^{1/2}$

Calculating fractional change in time period of pendulum,

$$\frac{\Delta T}{T} = \frac{1}{2}(\alpha \Delta t)$$

For the given pendulum,

$T = 24 \times 60 \times 60 = 86400$ s

When $t_1 = 40$ °C, $\Delta T = 12$ s,

$$\frac{\Delta T}{T} = \frac{1}{2}\,\alpha\,(40 - t_0)$$

Where, t_0 is temperature at which the clock will show correct time.

$\therefore \quad \frac{12}{86400} = \frac{1}{2}\,\alpha\,(40 - t_0) \qquad ….(i)$

Similarly, when $t_2 = 20$ °C, $\Delta T = 4$ s

$\therefore \quad \frac{4}{86400} = \frac{1}{2}\,\alpha\,(t_0 - 20) \qquad ….(ii)$

Dividing equation (i) by (ii),

$$\frac{12}{4} = \frac{(40 - t_0)}{(t_0 - 20)}$$

$\therefore \quad 3t_0 - 60 = 40 - t_0$

$\therefore \quad t_0 = 25$ °C

Substituting it in equation (i),

$$\frac{12}{86400} = \frac{1}{2}\,\alpha\,(40 - 25)$$

$\therefore \quad \alpha = \frac{12 \times 2}{15 \times 86400}$

$= 18.5 \times 10^{-6}$

$= 1.85 \times 10^{-5}$ /°C

Thinking Hatke - Q.21

After finding out the value temperature of t_0, the only option which satisfies the condition is option (D).

MHT-CET Previous Years' Questions

1. (A)

2. (C) $\left(\frac{d\theta}{dt}\right)_1 = k(\theta_1 - \theta_0)$

$\left(\frac{62 - 50}{10}\right) = k(62 - 26)$

$\therefore \quad k = \frac{12}{10 \times 36} = \frac{1}{30}$ / min

$\left(\frac{d\theta}{dt}\right)_2 = k(\theta_2 - \theta_0)$

$\frac{50 - 42}{dt} = \frac{1}{30}(50 - 26)$

$\therefore \quad dt = \frac{8 \times 30}{24} = 10$ min

3. (C) $F = \alpha\,AY\Delta T$

$= 1.2 \times 10^{-5} \times 2.5 \times 10^{-6} \times 2 \times 10^{11} \times 40$

$= 240$ N

4. (B) According to Newton's law of cooling

$\frac{d\theta}{dt} = K(\theta - \theta_0)$

Where, K is constant of proportionality.

Integrating

$$\int_{\theta}^{\theta_0} \frac{d\theta}{\theta - \theta_0} = \int_0^t K dt$$

$$-\int_{\theta_0}^{\theta} \frac{d\theta}{\theta - \theta_0} = \int_0^t K dt$$

$$\int_{\theta_0}^{\theta} \frac{d\theta}{\theta - \theta_0} = -\int_0^t K dt$$

$\log_e(\theta - \theta_0) = -Kt + c$

$2.303 \log_{10}(\theta - \theta_0) = -Kt + c$

As 2.303 is constant above equation can be equated to, $\log(\theta - \theta_0) = -Kt + c$.

5. (C)

6. (A) Elongation $l = \alpha\Delta\theta L = \alpha t L \qquad ….(\because \Delta\theta = t)$

Force = $Y\,\alpha\,t\,A$

Work done = $\frac{1}{2} \times$ Force $\times$ elongation

$\therefore \quad W = \frac{1}{2} \times Y\,\alpha\,t\,A \times \alpha\,t\,L = \frac{1}{2}\,Y\,\alpha^2\,t^2\,AL$

7. (A) Force $F = AY\,\alpha\,\Delta T$

$\therefore \quad mg = AY\,\alpha\,\Delta T$

$m = \frac{AY\,\alpha\,\Delta T}{g} = \frac{3 \times 10^{-6} \times 10^{11} \times 10^{-5} \times 100}{10} = 30$ kg

8. (B) Thermal resistance = $\frac{\text{Temp. difference}}{\text{Conduction rate}}$

$\frac{|T_1 - T_2|}{P_{cond}} = \frac{28}{1400} = 0.02$ °C/s cal

9. (C) Let the required temperature be P_T

Using relation between temperature and thermodynamic property,

$T = \frac{100(P_T - P_1)}{P_2 - P_1}$

In this case, $P_2 = 239$ °W, $P_1 = 39$ °W and $T = 39$ °C

$\therefore \quad 39 = \frac{100(P_T - 39)}{239 - 39} = \frac{100(P_T - 39)}{200}$

$\therefore \quad P_T = (2 \times 39) + 39 = 117$ °W

10. (B) Temperature in kelvin = –197 + 273 = 76 K

11. (A) $\frac{Q}{At} = \frac{k\Delta T}{x}$

$\therefore$ $10 = k \times \frac{9}{1.8 \times 10^{-2}}$

$\therefore$ $k = \frac{18 \times 10^{-2}}{9} = 2 \times 10^{-2}$ kcal/ms °C

12. (D) $\gamma = \frac{\Delta V}{V(\Delta T)} = \frac{0.3}{100 \times 50} = 6 \times 10^{-5}$ /°C

$\alpha = \frac{\gamma}{3} = 2 \times 10^{-5}$ /°C

13. (D) V = 500 cm^3, $\alpha = 12 \times 10^{-6}$ /°C

$\gamma = 3\alpha = 36 \times 10^{-6}$ /°C

$\Delta V = V\alpha\Delta T = 500 \times 36 \times 10^{-6} \times 100 = 1.8\ cm^3$

14. (C)

15. (D) Let T be the temperature of the junction then we have

$\frac{Q}{t} = \frac{K_1A(T_1 - T)}{d_1} = \frac{K_2A(T - T_2)}{d_2}$

$\therefore$ $(K_1T_1 - K_1 T) d_2 = (K_2T - K_2 T_2)d_1$

Solving the equation for T

$T = \frac{K_1T_1d_2 + K_2T_2d_1}{K_1d_2 + K_2d_1}$

16. (B) Let l_1 be the initial length of the rod and r_1 be the radius of the rod. Then

$H_1 = \frac{kA_1(T_2 - T_1)}{l_1}$

After doubling the dimensions,

$H_2 = \frac{kA_2(T_2 - T_1)}{l_2}$

$\therefore$ $\frac{H_2}{H_1} = \frac{A_2}{A_1} \times \frac{l_1}{l_2}$

If $r_2 = 2r_1$, then $A_2 = 4A_1$

Also, $l_2 = 2l_1$

$\therefore$ $\frac{H_2}{H_1} = 4 \times \frac{1}{2} = 2$

$\therefore$ $H_2 = 2H_1$

17. (A) Only 25% of the energy is absorbed by ice and it melts completely.

$\therefore$ 0.25 mgh = mL

$\therefore$ $h = \frac{L}{0.25 \times g} = \frac{3.5 \times 10^5}{0.25 \times 10} = 1.4 \times 10^5$ m = 140 km

18. (C)

19. (D) Coefficient of cubical expansion of liquid = γ

Coefficient of linear expansion of copper = $\frac{\gamma}{3}$

$\therefore$ coefficient of cubical expansion of copper

$= 3 \times \frac{\gamma}{3} = \gamma$

Since the coefficient of cubical expansion of liquid and the container is same, they will expand by almost same amount. As a result, liquid level will remain almost the same.

20. (D) If R is the thermal resistance of each rod, then in series, their equivalent resistance will be $R_S = 2R$ and in parallel it will be $R_P = \frac{R}{2}$

Hence the ratio $\frac{R_P}{R_S} = \frac{1}{4}$

Since thermal resistance becomes one fourth, the rate of transfer of heat will become four times.

This means time required will be $\frac{t}{4}$ s.

21. (B) Length of brass rod at temp. t = $l_1 + l_1 \alpha_1 \Delta t$

Length of steel rod at temp. t = $l_2 + l_2 \alpha_2 \Delta t$

Length of steel rod – length of brass rod

$= (l_2 - l_1) + (l_2 \alpha_2 - l_1 \alpha_1) \Delta t$

For difference in the length to be constant coefficient of Δt must be zero.

$\therefore$ $l_2 \alpha_2 - l_1 \alpha_1 = 0$

$\therefore$ $l_1 \alpha_1 = l_2 \alpha_2$

22. (D) $R_{eq} = R_1 + R_2$

$\because$ $R_1 = \frac{x}{KA}, R_2 = \frac{4x}{2KA}$

$\therefore$ $R_{eq} = \frac{x}{KA} + \frac{2x}{KA} = \frac{3x}{KA}$

Rate of heat transfer of composite slab is given by,

$\frac{dQ}{dt} = \frac{T_2 - T_1}{R_{eq}} = \frac{KA(T_2 - T_1)}{3x}$

$\therefore$ $f = \frac{1}{3}$

23. (B) In volumetric expansion for a cube

$\Delta V = V3\alpha\ \Delta T$

$\Delta V = 1 \times 3 \times 18 \times 10^{-6} \times 100$

$\Delta V = 54 \times 10^{-4}\ m^3$

24. (C) Let the original temperature be 0 °C;
Volume of A = $V_1 = l \times \pi(2r)^2$;
After heating volume of A will become,
$V'_1 = V_1(1 + \gamma\Delta T)$
$\frac{(V_1' - V_1)}{V_1} = \gamma\Delta T$
As r and ΔT are constant here,
$V'_1 - V_1 \propto V_1$
Similarly for rod B,
$\frac{(V_2' - V_2)}{V_2} = \gamma\Delta T \Rightarrow V'_2 - V_2 \propto V_2$
$\therefore \quad \frac{\Delta V_1}{\Delta V_2} = \frac{l\pi(2r)^2}{2l\pi r^2} = \frac{2}{1}$

25. (C) Coefficient of cubical expansion is related to coefficient of superficial expansion as
$\frac{\gamma}{3} = \frac{\beta}{2}$
$\therefore \quad \beta = \frac{2}{3}\gamma$
Given: $\beta = \frac{1}{x}\gamma$
$\therefore \quad x = \frac{3}{2}$

Evaluation Test

1. (A) In steady state the quantity of heat absorbed and quantity of heat radiated is same.

2. (A) According to Newton's law of cooling,
$\frac{\theta_1 - \theta_2}{t} = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$
where, θ_0 = tempeature of surrounding
$\therefore \quad \frac{60 - 50}{8} = K\left[\frac{60 + 50}{2} - 30\right]$
$\frac{10}{8} = K \times 25$ ….(i)
After another 20 min, let the temperature be θ.
$\therefore \quad \frac{50 - \theta}{20} = K\left[\frac{50 + \theta}{2} - 30\right]$ ….(ii)
$\frac{50 - \theta}{20} = \frac{10}{8 \times 25}\left[\frac{50 + \theta}{2} - 30\right]$ using (i)
$\frac{50 - \theta}{20} = \frac{1}{20}\left[\frac{50 + \theta - 60}{2}\right]$
$2(50 - \theta) = 50 + \theta - 60$
$100 - 2\theta = -10 + \theta$
$3\theta = 110$
$\theta = \frac{110}{3} = 36.67$ °C.

3. (B) Let 'm' grams be the mass of the steam.
Heat lost by the steam = m × L + m × 1 × (100 – 0)
= m × 540 + 100m
= 640m
Heat gained by ice = $m_i \times c \times \Delta T + m_i L$
= 1600 × 0.5 × [0 – (–8)] + 1600 × 80
= 134400 cal.
According to principle of calorimetry,
640m = 134400 ⇒ m = 210 g.

4. (A) Coefficient of linear expansion for brass (1.8×10^{-5} °C) > coefficient of linear expansion for steel (1.1×10^{-5} °C). On cooling the disc shrinks to a greater extent than the hole and hence it will get loose.

5. (D) Let the temperature of junction be θ
$\left(\frac{\Delta Q}{\Delta t}\right)_{copper} = \left(\frac{\Delta Q}{\Delta t}\right)_{steel}$
$K_1A\frac{(100 - \theta)}{20} = \frac{K_2A(\theta - 2.5)}{5}$
$9K_2\frac{(100 - \theta)}{4} = K_2(\theta - 2.5)$ $(\because K_1 = 9K_2)$
$900 - 9\theta = 4\theta - 10$
$\therefore \quad 13\theta = 910$
$\therefore \quad \theta = 70$ ° C.

6. (C) Density of water is maximum at 4 °C. In both heating and cooling of water from this temperature, level of water rises due to decrease in density, i.e., water will overflow in both A and B.

7. (C) If l is the original length of wire, then change in length of first wire, $\Delta l_A = (l_A - l)$
Change in length of second wire, $\Delta l_B = (l_B - l)$
Now Young's Modulus,
$Y = \frac{T_A}{A} \times \frac{l}{\Delta l_A} = \frac{T_B}{A} \times \frac{l}{\Delta l_B}$
$\Rightarrow \frac{T_A}{\Delta l_A} = \frac{T_B}{\Delta l_B} \Rightarrow \frac{T_A}{l_B - l} = \frac{T_B}{l_B - l}$
$\therefore \quad T_A l_B - T_A l = T_B l_A - T_B l$
$\therefore \quad l = \frac{T_B l_A - T_A l_B}{T_B - T_A}$

8. (A) Increase in volume of flask
$= 40 \times 10^{-6} \times 4000 \times 80$
$= 12.8$ cc
Increase in volume of mercury
$= 180 \times 10^{-6} \times 4000 \times 80 = 57.6$ cc
$\therefore$ Volume of mercury overflow
$= 57.6 - 12.8 = 44.8$ cc

9. (B) Using standard gas equation,
$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$
$$V_2 = \frac{P_1V_1T_2}{P_2T_1}$$
$$= \frac{1\times 600\times(273-13)}{0.8\times(273+37)} \approx 629 \text{ m}^3$$

10. (A) Colour is an indication of temperature of the body. If two pieces of same substance appear of different colours, then their temperatures must be different. In this case, $T_A < T_B$

11. (A) Number of moles of gas in two flasks are
$n_1 = \frac{P_1V_1}{RT}$ and $n_2 = \frac{P_2V_2}{RT}$
$\because$ $n = n_1 + n_2$
$\therefore$ $P = \frac{(n_1+n_2)RT}{V_1+V_2} = \frac{P_1V_1+P_2V_2}{V_1+V_2}$

12. (D)

13. (C) Fahrenheit scale and Absolute scale are related as
$$\frac{T_F - 32}{180} = \frac{T_K - 273\cdot15}{100} \quad \text{....(i)}$$
For another set of temperature T_F' and T_K',
$$\frac{T_F' - 32}{180} = \frac{T_K' - 273\cdot15}{100} \quad \text{....(ii)}$$
Subtracting (i) from (ii)
$$\frac{T_F' - T_F}{180} = \frac{T_K' - T_K}{100}$$
$$T_F' - T_F = \frac{180}{100}(T_K' - T_K)$$
If $T_K' - T_K = 1$ K then, $T_F' - T_F = \frac{180}{100}\times 1 = \frac{9}{5}$
For a temperature of triple point i.e., 273.16 K, the temperature on the new scale is
$$= 273\cdot16\times\frac{9}{5} \approx 491.69$$

14. (C) At absolute zero temperature, pressure P of gas would reduce to zero. The volume V of the gas would also become zero. If we were to imagine going below this temperature, volume of gas would be negative, which is impossible. That suggests that the lowest attainable temperature is absoulate zero.
At absolute zero, the translatory motion of molecules ceases but other forms of molecular energy (like inter molecular potential energy) do not become zero. Therefore absolute zero temperature is not the temperature of zero-energy.

15. (C)

16. (B) Using $\frac{dQ}{dt} = \frac{KA\Delta\theta}{\Delta x}$,
$$\Delta\theta = \frac{dQ}{dt} \times \frac{\Delta x}{KA}$$
$$= \frac{6000\times 1}{200\times 0.75}$$
$\therefore$ $\Delta\theta = 40$ °C

17. (C)

18. (C) $\frac{C_p}{C_v} = \frac{3}{2} \Rightarrow \frac{C_v + R}{C_v} = \frac{3}{2}$
This gives $C_v = 2R$, and hence $C_p = 3R$

19. (B)

20. (A) Heat lost by hot ball = Heat gained by water
$m_1 \times c_1 (t_2 - t_0) = m_2 \times c_2 (t_0 - t_1)$
$200 \times 0.08 \times (t - 22.8) = 500 \times 1 \times (22.8 - 10)$
$\therefore$ $t = 422.8$ °C

21. (B) $\frac{50-49.9}{5} = k\left[\frac{50+49.9}{2} - 30\right]$ ....(i)
$\frac{40-39.9}{t} = k\left[\frac{40+39.9}{2} - 30\right]$ ....(ii)
from equations (i) and (ii) $t \approx 10$ s

22. (C)

23. (B) At constant volume of a gas
$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$
$\therefore$ $\frac{20}{273.15} = \frac{14}{T_2}$
$\therefore$ $T_2 = 191.21$ K

24. (C)

25. (B) $\left(\frac{Q}{t}\right) = \frac{K\pi r^2(\theta_1 - \theta_2)}{\Delta x} \propto \frac{r^2}{\Delta x}$
$\therefore$ $\frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^2\left(\frac{\Delta x_2}{\Delta x_1}\right) = \left(\frac{1}{2}\right)^2 \times \left(\frac{2}{1}\right) = \frac{1}{2}$
$Q_2 = 2Q_1$