PHYSICS – CLASS XI

Chapter 10 : Thermal Properties of Matter

SOLUTIONS AND MARKING SCHEME (Step-by-Step)

Marks for each step are shown in brackets. Alternative correct methods carry full marks.

Quick answer key – Section A

Q	1	2	3	4	5	6	7	8
Ans	(c)	(b)	(a)	(a)	16 W	2×10^{-3} m	−273 °C	5800 K

SECTION A

1. **Ans: (c) 122 °F.** **(1)**

$(t_F - 32)/180 = t_C/100 \rightarrow t_F = 32 + 1.8 \times 50 =$ **122 °F**.

2. **Ans: (b) 4 °C.** **(1)**

The volume of a fixed mass is minimum at 4 °C, so the density (mass/volume) is maximum at **4 °C** (anomalous expansion of water).

3. **Ans: (a) 1 : 2 : 3.** **(1)**

$\alpha_A = 2\alpha_l$ and $\alpha_V = 3\alpha_l$, so the ratio is **1 : 2 : 3**.

4. **Ans: (a).** **(1)**

Both are true. Steam at 100 °C releases the latent heat (2.25×10^6 J kg^{-1}) on condensing into water at 100 °C, in addition to the heat given by water, so it burns more severely; R explains A.

5. **Ans: 16 W.** **(1)**

$H = KA(T_1 - T_2)/L = 400 \times 2 \times 10^{-4} \times 100/0.5 =$ **16 W**.

6. **Ans: 2×10^{-3} m.** **(1)**

$\Delta l = \alpha l \Delta T = 2.5 \times 10^{-5} \times 2 \times 40 =$ **2×10^{-3} m** (2 mm).

7. **Ans: −273 °C (absolute zero).** **(1)**

The pressure of an ideal gas at constant volume extrapolates to zero at **−273 °C** (0 K), called the **absolute zero**.

8. **Ans: 5800 K.** **(1)**

Wien's law: $\lambda_m T = 2.9 \times 10^{-3}$ m K $\rightarrow T = 2.9 \times 10^{-3}/(5 \times 10^{-7}) =$ **5800 K**.

SECTION B

9. **(i)** Principle of calorimetry: in an isolated system, heat lost by the hotter body = heat gained by the colder body. (1) **(2)**

(ii) $0.2 \times s \times (80 - T) = 0.3 \times s \times (T - 20) \rightarrow 16 - 0.2T = 0.3T - 6 \rightarrow 0.5T = 22 \rightarrow T =$ **44 °C**. (1)

10. Newton's law: rate of cooling = $K \times$ (average temperature − surroundings). **(2)**

First interval: average temperature = 70 °C, excess = 50 °C: $20/6 = K \times 50$. (1)

Second interval: average = 50 °C, excess = 30 °C: $20/t = K \times 30$. Dividing: $t/6 = 50/30 \rightarrow t =$ **10 min**. (1)

11. Heat to melt the ice: $Q_1 = mL_f = 0.2 \times 3.3 \times 10^5 = 6.6 \times 10^4$ J. (1) **(2)**
Heat to warm the water 0 → 10 °C: $Q_2 = ms\Delta T = 0.2 \times 4200 \times 10 = 8.4 \times 10^3$ J.
Total = **7.44×10^4 J**. (1)

OR

The land has a smaller specific heat capacity than water, so during the day it heats up faster than the sea. The air above the land becomes hot, expands and rises. (1)
Cooler, denser air from the sea moves in to replace it, setting up a convection current: the **sea breeze**. (1)

12. **(i)** Wien's law: $\lambda_m T$ = constant. $T_A/T_B = \lambda_B/\lambda_A = 2.0/1.0 =$ **2 : 1**, so **A is hotter**. (1) **(2)**
(ii) Stefan's law: $H \propto T^4$ for the same area, so $H_A/H_B = 2^4 =$ **16 : 1**. (1)

SECTION C

13. **(i)** If free, the strain would be $\Delta l/l = \alpha\Delta T$. The walls prevent expansion, so the compressive thermal strain = $1.2 \times 10^{-5} \times 50 =$ **6×10^{-4}**. (1) **(3)**
(ii) Thermal stress = $Y \times$ strain = $2 \times 10^{11} \times 6 \times 10^{-4} =$ **1.2×10^8 N m^{-2}**. (1)
(iii) Force = stress × $A = 1.2 \times 10^8 \times 4 \times 10^{-4} =$ **4.8×10^4 N**. (1)

14. **(i)** In the steady state both rods carry the same heat current: $K_1A(100 - T_0)/L = K_2A(T_0 - 0)/L \rightarrow 300(100 - T_0) = 100T_0 \rightarrow T_0 =$ **75 °C**. (1) **(3)**
(ii) $H = K_1A(100 - 75)/L = 300 \times 4 \times 10^{-4} \times 25/0.5 =$ **6 W**. (1)
(iii) $K' = 2K_1K_2/(K_1 + K_2) = 2 \times 300 \times 100/400 =$ **150 W m^{-1} K^{-1}**. (Check: $K'A \times 100/(2L) = 150 \times 4 \times 10^{-4} \times 100/1 = 6$ W.) (1)

OR

(i) $H = \sigma AT^4 = 5.67 \times 10^{-8} \times 0.5 \times (1000)^4 =$ **2.835×10^4 W** ($\approx 2.8 \times 10^4$ W). (1)
(ii) Net rate = $\sigma A(T^4 - T_s^4) = 5.67 \times 10^{-8} \times 0.5 \times (10^{12} - 8.1 \times 10^9) \approx$ **2.81×10^4 W**. (1)
(iii) $\lambda_m = 2.9 \times 10^{-3}/1000 =$ **2.9×10^{-6} m** (2.9 μm). (1)

15. Temperature rise of water and calorimeter = 25 − 20 = 5 °C; fall of the block = 100 − 25 = 75 °C. **(3)**
(i) Heat gained by water = $0.4 \times 4200 \times 5 =$ **8400 J**. (1)
(ii) Heat gained by calorimeter = (water equivalent) × 4200 × 5 = $0.1 \times 4200 \times 5 =$ **2100 J**. (1)
(iii) Heat lost by block = heat gained: $0.2 \times s \times 75 = 8400 + 2100 = 10500 \rightarrow 15s = 10500 \rightarrow s =$ **700 J kg^{-1} K^{-1}**. (1)

SECTION D

16. **(a)** Latent heat is the heat absorbed or released per unit mass of a substance during a change of state at constant temperature. (1) **(5)**
(b) AB (ice −10 → 0 °C): $Q = ms_{ice}\Delta T = 0.1 \times 2100 \times 10 =$ **2100 J**. (1)
(c) BC (melting at 0 °C): $Q = mL_f = 0.1 \times 3.3 \times 10^5 =$ **3.3×10^4 J**. (1)
(d) CD (water 0 → 100 °C): $Q = 0.1 \times 4200 \times 100 =$ **4.2×10^4 J**. (1)
(e) DE (vaporisation): $Q = mL_v = 0.1 \times 2.25 \times 10^6 =$ **2.25×10^5 J**. Total = 2100 + 33000 + 42000 + 225000 = **3.02×10^5 J**. (1)

OR

(a) $PV = \mu RT$ (μ = number of moles, R = universal gas constant). (1)
(b) $P = \mu RT/V = 2 \times 8.3 \times 300/(8.3 \times 10^{-3}) =$ **6×10^5 Pa**. (1)
(c) At constant volume $P \propto T$: doubling P doubles $T \rightarrow$ **600 K** (327 °C). (1)
(d) At constant temperature PV is constant: doubling V halves $P \rightarrow$ **3×10^5 Pa**. (1)
(e) For an ideal gas $\alpha_V = 1/T = 1/300 =$ **3.3×10^{-3} K^{-1}**. (1)

17. **(a)** $H = KA(T_1 - T_2)/L$, where K is the thermal conductivity, A the area, $(T_1 - T_2)$ the temperature difference and L the thickness. (1) **(5)**

(b) $H = 0.02 \times 0.55 \times (50 - 0)/0.05 =$ **11 W**. (1)

(c) Time = $5 \times 3600 = 18000$ s; heat entering = $11 \times 18000 =$ **1.98×10^5 J**. (1)

(d) $m = Q/L_f = 1.98 \times 10^5/(3.3 \times 10^5) =$ **0.6 kg**. (1)

(e) Thermocole contains many tiny pockets of trapped air; air has a very low thermal conductivity and cannot set up convection in such small pockets, so heat flows through it very slowly. (1)

OR

(a) $(t_F - 32)/180 = t_C/100$, i.e. $t_F = (9/5)t_C + 32$. (1)

(b) $t_C = (98.6 - 32) \times 5/9 = 66.6 \times 5/9 =$ **37 °C**. (1)

(c) Put $t_F = t_C = t$: $t = 9t/5 + 32 \rightarrow -4t/5 = 32 \rightarrow t =$ **−40** (−40 °C = −40 °F). (1)

(d) $t_C = T - 273 = 300 - 273 =$ **27 °C**. (1)

(e) 180 °F interval = 100 °C interval, so 18 °F = 10 °C. The Kelvin and Celsius intervals are equal, so the rise is **10 °C = 10 K**. (1)

— END OF SOLUTIONS —