Class 11 Physics · Chapter 10: Thermal Properties of Matter

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. A beaker of pure water at 0 °C is warmed slowly to 8 °C. Over this range its density [1]

(a) increases throughout (b) decreases throughout
(c) first decreases, then increases (d) first increases, then decreases

Answer: (d) Water contracts on heating from 0 °C to 4 °C, so its density rises; above 4 °C it expands and the density falls. Water is densest at 4 °C.

2. Rods of equal length made of iron ($\alpha_l = 1.2 \times 10^{-5}\ K^{-1}$), aluminium ($2.5 \times 10^{-5}\ K^{-1}$), copper ($1.7 \times 10^{-5}\ K^{-1}$) and brass ($1.8 \times 10^{-5}\ K^{-1}$) are heated through the same rise in temperature. The rod that lengthens the most is the one made of [1]

(a) iron (b) aluminium
(c) copper (d) brass

Answer: (b) $\Delta l = \alpha_l\, l\, \Delta T$, so with l and ΔT the same, the rod with the largest α_l lengthens the most: aluminium, $2.5 \times 10^{-5}\ K^{-1}$.

3. An aluminium rod 2.0 m long is heated from 20 °C to 120 °C ($\alpha_l = 2.5 \times 10^{-5}\ K^{-1}$). Its length increases by [1]

(a) 0.5 mm (b) 2.5 mm
(c) 5.0 mm (d) 50 mm

Answer: (c) $\Delta l = \alpha_l\, l\, \Delta T = 2.5 \times 10^{-5} \times 2.0 \times 100 = 5.0 \times 10^{-3}$ m = 5.0 mm. 2.5 mm forgets the length of 2.0 m; 0.5 mm and 50 mm slip a power of ten.

4. An ideal gas is heated at constant pressure. At 27 °C its coefficient of volume expansion is about [1]

(a) $3.7 \times 10^{-3}\ K^{-1}$ (b) $3.7 \times 10^{-2}\ K^{-1}$
(c) $1.1 \times 10^{-3}\ K^{-1}$ (d) $3.3 \times 10^{-3}\ K^{-1}$

Answer: (d) For an ideal gas at constant pressure $\alpha_v = 1/T$, with T in kelvin: $1/300\ K = 3.3 \times 10^{-3}\ K^{-1}$. $3.7 \times 10^{-3}\ K^{-1}$ is the value at 0 °C; $3.7 \times 10^{-2}\ K^{-1}$ uses 1/27, the Celsius number.

5. The temperature of a room rises from 18 °C to 43 °C. The rise in temperature on the Kelvin scale is [1]

(a) 25 K (b) 298.15 K
(c) 45 K (d) 316.15 K

Answer: (a) The Kelvin and Celsius scales have the same size of unit ($T = t_C + 273.15$), so a rise of 25 °C is a rise of 25 K. 298.15 K and 316.15 K are temperatures, not a rise; 45 is the rise in °F.

6. Equal volumes of ethanol and mercury are warmed through the same rise in temperature. With α_v(ethanol) $= 110 \times 10^{-5}\ K^{-1}$ and α_v(mercury) $= 18.2 \times 10^{-5}\ K^{-1}$, find the ratio of their increases in volume. In two thermometers with identical bulbs and bores, which liquid gives the longer length per degree? [2]

$\Delta V = \alpha_v\, V \Delta T$, so with V and ΔT equal, $\Delta V_{ethanol} / \Delta V_{mercury} = 110/18.2 \approx 6.0$. Ethanol expands about six times as much, so its column moves farther for each degree: the ethanol thermometer has the longer length per degree.

- ratio ≈ 6.0 from $\Delta V = \alpha_v\, V \Delta T$ (1)
- ethanol, with reason (1)

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7. Name two features of a Dewar flask (thermos bottle) and, for each, the mode of heat transfer it reduces. [2]

The inner and outer walls are coated with silver: radiation from the inner wall is reflected back to the contents and incoming radiation is reflected back by the outer wall, which reduces heat transfer by radiation. The space between the double walls is evacuated, which reduces conduction and convection. (The flask also rests on an insulator such as cork, reducing conduction.)

- silvered walls: radiation (1)
- evacuated gap: conduction and convection (1)

8. What is sublimation? Name two substances that sublime at normal atmospheric pressure, and state how the solid and vapour are related while the change takes place. [2]

Sublimation is the change from the solid state directly to the vapour state without passing through the liquid state. Dry ice (solid CO_2) and iodine sublime. During sublimation the solid and the vapour coexist in thermal equilibrium.

- definition of sublimation (1)
- two examples and solid-vapour equilibrium (1)

9. A hot plate of surface area 0.050 m^2 and emissivity 0.80 is kept at 500 K by an electric heater, in a room whose walls are at 300 K. Radiation is the only loss. ($\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}) (a) Find the power the plate radiates. (b) Find the heater power needed to keep the plate at 500 K. (c) By what factor must the heater power rise to keep the plate at 600 K instead? [3]

(a) $H = e\sigma AT^4 = 0.80 \times 5.67 \times 10^{-8} \times 0.050 \times (500)^4 = 2.268 \times 10^{-9} \times 6.25 \times 10^{10} \approx 141.8$ W. (b) The plate also absorbs from the walls, so the heater supplies the net loss: $e\sigma A(T^4 - T_s^4) = 2.268 \times 10^{-9} \times (6.25 \times 10^{10} - 8.1 \times 10^{9}) \approx 123.4$ W. (c) $(600^4 - 300^4)/(500^4 - 300^4) = (12.96 - 0.81)/(6.25 - 0.81) \approx 2.23$.

- radiated power ≈ 141.8 W (1)
- net loss ≈ 123.4 W = heater power (1)
- factor ≈ 2.23 (1)

10. A copper rod and a pyrex glass rod are each 1.000 m long at 20 °C. Both are heated to 120 °C. With α_l(copper) = 1.7×10^{-5} K^{-1} and α_l(pyrex) = 0.32×10^{-5} K^{-1}, find (a) the increase in length of each rod and (b) how many times the copper's increase is the glass's. (c) State why pyrex glassware is preferred for heating in a laboratory. [3]

(a) $\Delta l = \alpha_l l \Delta T$. Copper: $1.7 \times 10^{-5} \times 1.000 \times 100 = 1.7 \times 10^{-3}$ m = 1.7 mm. Pyrex: $0.32 \times 10^{-5} \times 1.000 \times 100 = 0.32 \times 10^{-3}$ m = 0.32 mm. (b) 1.7/0.32 ≈ 5.3: copper expands about five times as much. (c) Pyrex has a very small α_l, so uneven heating sets up little difference in expansion across the glass and it does not crack.

- both increases: 1.7 mm and 0.32 mm (1)
- ratio ≈ 5.3 (1)
- small α_l, little uneven expansion (1)

11. 0.50 kg of a solid is heated by a 200 W heater, all of whose heat goes into the substance. Its temperature rises, then stays at 80 °C for 4.0 minutes, and then rises again, the liquid warming by 20 °C in 50 s. (a) What is happening during the 4.0 minutes? (b) Find the latent heat of fusion of the substance. (c) Find the specific heat capacity of the liquid. [3]

(a) The substance is melting at its melting point, 80 °C; the heat supplied changes its state, solid and liquid coexisting, so the temperature does not rise. (b) $Q = 200 \times 240 = 48000$ J; $L_f = Q/m = 48000/0.50 = 96000$ J $kg^{-1} = 9.6 \times 10^4$ J kg^{-1}. (c) $Q = 200 \times 50 = 10000$ J; $s = Q/(m\Delta T) = 10000/(0.50 \times 20) = 1000$ J kg^{-1} K^{-1}.

- melting at constant temperature (1)
- $L_f = 9.6 \times 10^4$ J kg^{-1} (1)
- s = 1000 J kg^{-1} K^{-1} (1)