Pressure exerted by water column

$$p = h\rho g = 3000 \times 10^3 \times 9.8$$
$$= 29.4 \times 10^6 \text{ Pa} = 2.94 \times 10^7 \text{ Pa}$$

125 (*b*) Given, maximum mass that can be lifted, $m = 3000$ kg

Area of cross-section, $A = 425 \text{ cm}^2 = 4.25 \times 10^{-2} \text{ m}^2$

$\therefore$ Maximum pressure on the bigger piston,

$$p = \frac{F}{A} = \frac{mg}{A}$$
$$= \frac{3000 \times 9.8}{4.25 \times 10^{-2}} = 6.92 \times 10^5 \text{ Pa}$$

According to Pascal's law, the pressure applied on an enclosed liquid is transmitted equally in all directions.

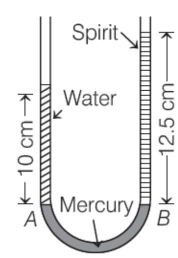
$\therefore$ Maximum pressure on smaller piston = Maximum pressure on bigger piston

$$p' = p = 6.92 \times 10^5 \text{ Pa}$$

126 (*c*) As, the mercury columns in the two arms of the U-tube are at the same level, as shown below therefore

Pressure due to water column = Pressure due to spirit column

$$h_w \rho_w g = h_s \rho_s g \quad \text{or} \quad h_w \rho_w = h_s \rho_s$$



Given, $h_w = 10$ cm

$\rho_w = 1 \text{ gcm}^{-3}$

$h_s = 12.5$ cm

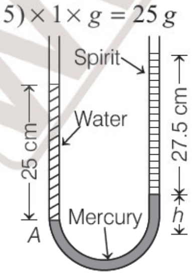
$\therefore$ $10 \times 1 = 12.5 \times \rho_s$

or $\rho_s = \frac{10}{12.5} = 0.8 \text{ gcm}^{-3}$

Specific gravity of spirit $= \frac{\rho_s}{\rho_w} = \frac{0.8 \text{ gcm}^{-3}}{1 \text{ gcm}^{-3}} = 0.8$

127 (*b*) Pressure on mercury level in one arm due to water,

$$p_1 = h_w \rho_w g$$
$$= (10 + 15) \times 1 \times g = 25\, g$$



Pressure on mercury level in another arm due to spirit,

$$p_2 = h_s \rho_s g = (12.5 + 15) \times 0.8 \times g = 22\, g$$

As the pressure in water arm is more, so mercury will rise in spirit arm.

If this pressure difference corresponds to height difference h in the two arms as shown in figure, then

$$p_1 - p_2 = h\rho g$$
$$25g - 22g = h \times 13.6 \times g \quad \text{or} \quad h = \frac{3}{13.6} = 0.221 \text{ cm}$$

Thus, mercury rises in the arm containing spirit and the difference in the levels of mercury in the two columns is 0.221 cm.

128 (*b*) Volume of the liquid flowing per second,

$$V = \frac{\text{Mass collected per second}}{\text{Density}} = \frac{4.0 \times 10^{-3}}{1.3 \times 10^3} \text{ m}^3\text{s}^{-1}$$

But, $V = \frac{\pi p r^4}{8 l \eta}$

$$\therefore \; p = \frac{8 l \eta V}{\pi r^4} = \frac{8 \times 1.5 \times 0.83}{3.14 \times (1.0 \times 10^{-2})^4} \times \frac{4.0 \times 10^{-3}}{1.3 \times 10^3}$$
$$= 9.75 \times 10^2 \text{ Pa}$$

129 (*c*) Let the lower and upper surface of the wing of the aeroplane be at the same height h and speeds of air on the upper and lower surfaces of the wing be v_1 and v_2, respectively.

Speed of air on the upper surface of the wing,

$$v_1 = 70 \text{ ms}^{-1}$$

Speed of air on the lower surface of the wing,

$$v_2 = 63 \text{ ms}^{-1}$$

Density of the air, $\rho = 1.3 \text{ kgm}^{-3}$

Area, $A = 2.5 \text{ m}^2$

According to Bernoulli's theorem,

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h$$

$$\Rightarrow \quad p_2 - p_1 = \frac{1}{2}\rho\,(v_1^2 - v_2^2)$$

$\therefore$ Lifting force acting on the wings,

$$F = (p_2 - p_1) \times A = \frac{1}{2}\rho(v_1^2 - v_2^2) \times A$$
$$\left(\because \text{Pressure} = \frac{\text{Force}}{\text{Area}}\right)$$
$$= \frac{1}{2} \times 1.3 \times [(70)^2 - (63)^2] \times 2.5$$
$$= \frac{1}{2} \times 1.3\,[4900 - 3969] \times 2.5$$
$$= \frac{1}{2} \times 1.3 \times 931 \times 2.5 = 1.51 \times 10^3 \text{ N}$$

The pressure difference between two ends of the tube is 1.51×10^3 N.

130 (*b*) Area of cross-section of tube,

$A = 8.0 \text{ cm}^2 = 8.0 \times 10^{-4} \text{ m}^2$

Number of holes, $N = 40$

Diameter of each hole, $2r = 1.0$ mm

Cross-section area, $A_1 = 8.0\,\text{cm}^2$

$\therefore$ Radius of each hole, $r = 0.5$ mm $= 5 \times 10^{-4}$ m

Velocity of liquid flow in tube $= 1.5$ m/min $= \frac{1.5}{60}\ \text{ms}^{-1}$

$= 2.5 \times 10^{-2}\ \text{ms}^{-1}$

Total area of holes, $A_2 = N \times \pi r^2$

$= 40 \times 3.14 \times (5 \times 10^{-4})^2$

$= 3.14 \times 10^{-5}\ \text{m}^2$

According to equation of continuity, $A_1 v_1 = A_2 v_2$

So, speed of ejection of the liquid through the hole

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{8.0 \times 10^{-4} \times 2.5 \times 10^{-2}}{3.14 \times 10^{-5}}$$

$$= \frac{20}{3.14} \times 10^{-1} = 0.64\ \text{ms}^{-1}$$

131 (*a*) Given, $F = 1.5 \times 10^{-2}$ N and $l = 30\,\text{cm} = 0.3\,\text{m}$

As the soap film has two free surfaces, so the force F acts over the twice the length of the slider.

Hence, surface tension (S),

$$S = \frac{F}{2l} = \frac{1.5 \times 10^{-2}}{2 \times 0.30} = 2.5 \times 10^{-2}\ \text{Nm}^{-1}$$

132 (*d*) Excess pressure inside a liquid drop is given by $\Delta p = \frac{2S}{R}$, where S = surface tension of the liquid and R = radius of the drop.

Given, radius of drop, $R = 3.00$ mm $= 3.00 \times 10^{-3}$ m

Surface tension of mercury, $S = 4.65 \times 10^{-1}\ \text{Nm}^{-1}$

Atmospheric pressure, $p_o = 1.01 \times 10^5$ Pa

Excess pressure inside the drop,

$$\Delta p = \frac{2S}{R} = \frac{2 \times 4.65 \times 10^{-1}}{3.00 \times 10^{-3}}$$

$= 3.10 \times 10^2$

$= 310$ Pa

133 (*b*) Given, $\sigma = 2.50 \times 10^{-2}\ \text{Nm}^{-1}$, $R = 5.00\,\text{mm}$

$= 5.00 \times 10^{-3}$ m,

Relative density $= 1.20$, $h = 40\,\text{cm} = 0.40$ m

Excess pressure inside a soap bubble,

$$p = \frac{4\sigma}{R} = \frac{4 \times 2.50 \times 10^{-2}}{5.00 \times 10^{-3}} = 20\,\text{Pa}$$

Excess pressure inside an air bubble under soap solution, $p' = \frac{2\sigma}{R} = \frac{2 \times 2.50 \times 10^{-2}}{5.00 \times 10^{-3}} = 10$ Pa

Density of soap solution,

ρ = Relative density $\times$ 1000

$= 1.20 \times 1000 = 1200\ \text{kgm}^{-3}$

Total pressure inside air bubble = Atmospheric pressure + Pressure due to 40 cm soap solution + Excess pressure

$= 1.01 \times 10^5 + h\rho g + \rho'$

$= 1.01 \times 10^5 + 0.40 \times 1200 \times 9.8 + 10$

$= 1.06 \times 10^5$ Pa

134 (*a*) **For compartment containing water**

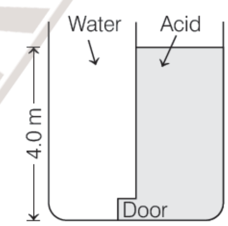
Height of water column, $h = 4.0$ m

Density of water, $\rho = 10^3\ \text{kgm}^{-3}$

Pressure due to water at the door at the bottom,

$p_w = h\rho g = 4.0 \times 10^3 \times 9.8$

$= 39.2 \times 10^3$ Pa



For compartment containing acid

Height of acid column, $h = 4.0$m

Density of acid, ρ = relative density $\times 10^3$

$= 1.7 \times 10^3\,\text{kgm}^{-3}$

Pressure due to acid at the door at the bottom,

$p_a = h\rho g = 4.0 \times 1.7 \times 10^3 \times 9.8$

$= 66.64 \times 10^3$ Pa

$\therefore \quad p_a - p_w = 66.64 \times 10^3 - 39.2 \times 10^3$

$= 27.44 \times 10^3$ Pa

Area of the door, $A = 20\,\text{cm}^2 = 20 \times 10^{-4}\,\text{m}^2$

Force on the door due to difference of pressure on its two sides

$= (p_a - p_w) \times A$

$= 27.44 \times 10^3 \times 20 \times 10^{-4}$

$= 54.88\ \text{N} \approx 55\ \text{N}$

135 (*a*) Atmospheric pressure, $p_0 = 76$ cm of mercury

According to Fig. (a) given in question pressure head, $h_1 = 20$ cm of mercury

$\therefore$ Absolute pressure of the gas, $p = p_0 + h_1\rho g$

= 76 cm of Hg + 20 cm of Hg

= 96 cm of Hg

Gauge pressure = Absolute pressure − Atmospheric pressure

= 96 cm of Hg − 76 cm of Hg = 20 cm of Hg

According to Fig. (b) given in question pressure head, $h_2 = -18$ cm of mercury

$\therefore$ Absolute pressure of the gas, $p' = p_0 + h_2\rho g$

= 76 cm of Hg + (− 18 cm of Hg)

= 58 cm of Hg

Gauge pressure = Absolute pressure − Atmospheric pressure

$= 58$ cm of Hg $-$ 76 cm of Hg

$= -$ 18 cm of Hg

136 (*d*) Given, $p_g = 2000$ Pa and $\rho = 1.06 \times 10^3$ kgm^{-3}

Let h be the height of container at which its blood exerts pressure equal to gauge pressure in vein, then

$$h\rho g = p_g$$

$$\Rightarrow \quad h = \frac{p_g}{\rho g} = \frac{2000}{1.06 \times 10^3 \times 9.8} = 0.1925 \text{ m}$$

The blood will just enter the vein, if the blood container is kept at height slightly greater than 0.1925 m, i.e. at 0.2 m.

137 (*a*) (i) Given, $\rho = 1.06 \times 10^3$ kgm^{-3}

$$D = 2r = 4 \times 10^{-3} \text{m}$$

and $\eta = 2.084 \times 10^{-3}$ Pa-s

The maximum value of Reynold's number for laminar flow is 2000. Hence, the maximum average velocity for laminar flow or critical velocity is given by

$$v_c = \frac{R_e \eta}{\rho \cdot D} = \frac{2000 \times 2.084 \times 10^{-3}}{1.06 \times 10^3 \times 4 \times 10^{-3}} = 0.98 \text{ ms}^{-1}$$

(ii) Volume of blood flowing per second,

$$V = av_c = \pi r^2 v_c$$

$$= \frac{22}{7} \times (2 \times 10^{-3})^2 \times 0.98$$

$$= 1.23 \times 10^{-5} \text{m}^3\text{s}^{-1}$$

138 (*c*) Given, $v_1 = 180$ kmh^{-1} = 50ms^{-1}

$v_2 = 234$ kmh^{-1} = 65 ms^{-1}

Area of the wings, $A = 2 \times 25 = 50$ m^2, $\rho = 1$ kgm^{-3}

For a plane in the level flight, Bernoulli's equation is

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

$$p_1 - p_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

$$= \frac{1}{2} \times 1 \times (65^2 - 50^2) = 862.5 \text{ Nm}^{-2}$$

Upward force on the plane $= (p_1 - p_2) \times A$

$= 862.5 \times 50 = 43125$ N

In level flight, the upward force balances the weight of the plane, so

$$mg = 43125 \text{ N}$$

$\therefore$ Mass of the plane, $m = \frac{43125}{9.8} = 4400$ kg

139 (*b*) Given, radius of drop, $r = 2.0 \times 10^{-5}$ m

Density of oil, $\rho = 1.2 \times 10^3$ kgm^{-3}

Viscosity of air, $\eta = 1.8 \times 10^{-5}$ Pa-s

Terminal velocity, $v = \frac{2}{9}\frac{r^2(\rho - \rho_0)g}{\eta}$

$$= \frac{2}{9} \times \frac{(2.0 \times 10^{-5})^2 \times (1.2 \times 10^3 - 0) \times 9.8}{1.8 \times 10^{-5}}$$

$$= 5.8 \times 10^{-2} \text{ ms}^{-1}$$

Viscous force acting on the drop (according to Stoke's law), $F = 6\pi\eta rv$

$$= 6 \times 3.14 \times 1.8 \times 10^{-5} \times 2.0 \times 10^{-5} \times 5.8 \times 10^{-2}$$

$$= 3.93 \times 10^{-10} \text{ N}$$

140 (*c*) Given, angle of contact, $\theta = 140°$

Radius of tube, $r = 1$ mm $= 1 \times 10^{-3}$ m

Surface tension, $S = 0.465$ Nm^{-1}

Density of mercury, $\rho = 13.6 \times 10^3$ kgm^{-3}

Height of liquid rise or fall due to surface tension,

$$h = \frac{2S\cos\theta}{r\rho g} = \frac{2 \times 0.465 \times \cos 140°}{1 \times 10^{-3} \times 13.6 \times 10^3 \times 9.8}$$

$$= \frac{2 \times 0.465 \times (-0.7660)}{10^{-3} \times 13.6 \times 10^3 \times 9.8}$$

$$= -5.34 \times 10^{-3} \text{ m} = -5.34 \text{ mm}$$

Hence, the mercury level will depressed by 5.34 mm.

141 (*c*) Given, $r_1 = \frac{d_1}{2} = \frac{3.0}{2} = 1.5\text{mm} = 1.5 \times 10^{-3}$ m,

$$r_2 = \frac{d_2}{2} = \frac{6.0}{2} = 3\text{mm} = 3 \times 10^{-3} \text{ m},$$

$$S = 7.3 \times 10^{-2} \text{ Nm}^{-2}$$

$$\rho = 1.0 \times 10^3 \text{ kgm}^{-3}$$

$$g = 9.8 \text{ ms}^{-2}$$

Let h_1 and h_2 be heights to which water rise in the two tubes, then

$$h_1 = \frac{2S\cos\theta}{r_1 \rho g} \text{ and } h_2 = \frac{2S\cos\theta}{r_2 \rho g}$$

Therefore, $h_1 - h_2 = \frac{2S\cos\theta}{\rho g}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$$= \frac{2 \times 7.3 \times 10^{-2} \times \cos 0°}{1.0 \times 10^3 \times 9.8}\left(\frac{1}{1.5 \times 10^{-3}} - \frac{1}{3 \times 10^{-3}}\right)$$

$$= 0.49 \times 10^{-2} \text{ m} = 4.9\text{mm}$$

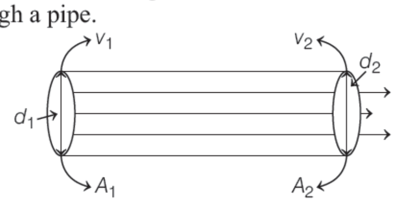
142 (*c*) When the pebble is falling through the viscous oil, the viscous force is $F = 6\pi\eta rv$

where, r is radius of the pebble, v is instantaneous speed and η is coefficient of viscosity. As the force is variable, hence acceleration is also variable, so v-t graph will not be straight line. First velocity increases due to gravity and then becomes constant known as terminal velocity.

143 (*d*) In a streamline flow at any given point, the velocity of each passing fluid particles remains constant. If we consider a cross-sectional area, then a point on the area cannot have different velocities at the same time, hence two streamlines of flow cannot cross each other.

144 (*b*) As we know for a streamline flow of a liquid, velocity of each particle at a particular position is constant, because Av = constant (law of continuity) between two cross-section of a tube of flow.

145 (*a*) Consider the diagram where an ideal fluid is flowing through a pipe.



Given, d_1 = diameter at 1st point is 2.5 cm

d_2 = diameter at 2nd point is 3.75 cm

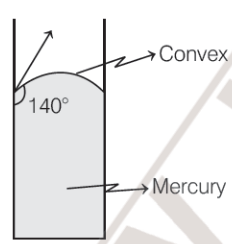
Applying equation of continuity for cross-sections A_1 and A_2.

$$\Rightarrow \quad A_1 v_1 = A_2 v_2$$

$$\Rightarrow \quad \frac{v_1}{v_2} = \frac{A_2}{A_1} = \frac{\pi(r_2^2)}{\pi(r_1^2)} = \left(\frac{r_2}{r_1}\right)^2$$

$$= \left(\frac{\frac{3.75}{2}}{\frac{2.5}{2}}\right)^2 = \left(\frac{3.75}{2.5}\right)^2 = \frac{9}{4} \quad \left(\because r_2 = \frac{d_2}{2} \text{ and } r_1 = \frac{d_1}{2}\right)$$

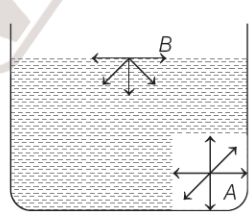
146 (*c*) According to the question, the observed meniscus is of convex shape which is only possible when angle of contact is obtuse as shown below. Hence, the combination will be of mercury-glass is 140°.



147 (*b*) Consider the diagram shown below, where two molecules of a liquid are shown. One is well inside the liquid and other is on the surface. The molecule A which is well inside experiences equal forces from all directions, hence net force on it will be zero.

And molecules on the liquid's surface have some extra energy, as it is surrounded by liquid molecules only from lower half side.

Hence, for a surface molecule, there is a net downward force.



148 (*b*) Pressure is defined as the ratio of magnitude of component of the force normal to the area and the area under consideration. As magnitude of component is considered, hence it will not have any direction.
So, pressure is a scalar quantity.

151 (*b*) When a big drop of radius R breaks into N droplets each of radius r, then in volume remains constant.

$\therefore$ Volume of big drop = $N \times$ Volume of small drop

$$\frac{4}{3}\pi R^3 = N \times \frac{4}{3}\pi r^3$$

$$\Rightarrow \quad R^3 = Nr^3$$

$$\Rightarrow \quad N = \frac{R^3}{r^3}$$

Now, change in surface area ,$\Delta A = 4\pi R^2 - N 4\pi r^2$

$$= 4\pi (R^2 - Nr^2)$$

Energy released $= S \times \Delta A$

$$= S \times 4\pi (R^2 - Nr^2)$$

Due to releasing of this energy, the temperature is lowered.

If ρ is the density and s is specific heat of liquid and its temperature is lowered by $\Delta\theta$, then

Energy released $= ms\Delta\theta$

$$S \times 4\pi(R^2 - Nr^2) = \left(\frac{4}{3}\pi R^3 \times \rho\right) s\,\Delta\theta$$

$$\Delta\theta = \frac{S \times 4\pi (R^2 - Nr^2)}{\frac{4}{3}\pi R^3 \rho \times s}$$

$$= \frac{3S}{\rho s}\left(\frac{R^2}{R^3} - \frac{Nr^2}{R^3}\right)$$

$$= \frac{3S}{\rho s}\left(\frac{1}{R} - \frac{(R^3/r^3) \times r^2}{R^3}\right)$$

$$= \frac{3S}{\rho s}\left(\frac{1}{R} - \frac{1}{r}\right)$$

152 (*b*) Given, surface tension of water,

$$S = 7.28 \times 10^{-2}\ \text{Nm}^{-1}$$

Vapour pressure, $p = 2.33 \times 10^3$ Pa

The drop will evaporate, if the water pressure is greater than the vapour pressure. Let a water droplet of radius R can be formed without evaporating.

$\therefore$ Vapour pressure = Excess pressure in drop

$$p = \frac{2S}{R}$$

$$\Rightarrow \quad R = \frac{2S}{p} = \frac{2 \times 7.28 \times 10^{-2}}{2.33 \times 10^3}$$

$$= 6.25 \times 10^{-5}\ \text{m}$$

CHAPTER > 11

Thermal Properties of Matter

KEY NOTES

Temperature and Heat

- Temperature is the property by virtue of which we predict the hotness or coldness of a body relative to some other body.
- An object that has a higher temperature than another object is said to be **hotter**.
- Heat is the form of energy transferred between two (or more) systems or a system and its surroundings by virtue of temperature difference.
- SI unit of heat is Joule (J), while SI unit of temperature is Kelvin [K] and degree Celsius (°C).
- The devices which are used to measure the temperature are termed as **thermometers**, while the science related to measurement of temperature is termed as **thermometry.**
- Many physical properties of materials change with temperature. Some of these properties are used as the basis for constructing thermometers. The commonly used property is variation of the volume of a liquid with temperature.
- The ice point and the steam point of water are two convenient fixed points and are known as the **freezing** and **boiling points**, respectively.

Ice Point and Steam Point of Different Scales

Scale	Ice point/Lower reference point	Steam point/Upper reference point	Unit
Celsius	0	100	°C
Fahrenheit	32	212	°F
Kelvin	273.15	373.15	K

- A relationship for converting temperature on two scales, for Fahrenheit temperature t_F and Celsius temperature t_C is
$$\frac{t_F - 32}{180} = \frac{t_C}{100}$$

Ideal Gas Equation

- As we know, pV = constant **(Boyle's law)** and $\frac{V}{T}$ = constant **(Charles' law)** for a given quantity of gas, then $\frac{pV}{T}$ should also be constant. This relation is known as **ideal gas law**.
- It can be written in a more general form that applies not just to given quantity of a single gas but to any quantity of a low density gas and is known as **ideal gas** equation.

i.e. $$\frac{pV}{T} = \mu R \text{ or } pV = \mu RT$$

where, p = pressure, T = temperature, V = volume, μ = number of moles in the sample of gas and R is called **universal gas constant**, i.e. $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.

Absolute Temperature

- Absolute temperature of an ideal gas corresponds to that temperature where the gas in nature has the least possible molecular activity.
- Absolute zero temperature on Kelvin scale is 0°K. On Celsius scale, absolute temperature is -273.15°C.
- The size of unit in Kelvin and Celsius temperature scales is same, so the temperature on these scales are related by
$$T = t_C + 273.15$$

Thermal Expansion

- The increase in the dimensions of a body due to the increase in its temperature is called thermal expansion. The expansions in a body are generally of three types
  (i) The expansion in length Δl of a body due to increase in temperature ΔT is called **linear expansion,** i.e. $\frac{\Delta l}{l} = \alpha_l \Delta T$.
  (ii) The expansion in area ΔA of a body due to increase in temperature is called **area expansion,** i.e. $\frac{\Delta A}{A} = 2\alpha_l \Delta T$.
  (iii) The expansion in volume ΔV of a body due to increase in temperature is called **volume expansion,** i.e. $\frac{\Delta V}{V} = 3\alpha_l \Delta T$.

  where, α_l is known as the **coefficient of linear expansion** (or **linear expansivity**) and is characteristics of the material of the body.
- Normally, metals expands more and have relatively high values of α_l.
- For fractional change in volume $\frac{\Delta V}{V}$, of a substance for temperature change ΔT, the **coefficient of volume expansion** (or **volume expansivity**) is $\alpha_V = \left(\frac{\Delta V}{V}\right)\frac{1}{\Delta T}$.
- For ideal gas, $\alpha_V = \frac{1}{T}$

  At 0°C, $\alpha_V = 3.7 \times 10^{-3}\ K^{-1}$, which is much larger than that for solids and liquids.
- Water exhibits an anomalous behaviour, it contracts on heating between 0℃ and 4℃, so volume of water is minimum at 4℃, i.e. density of water is maximum at 4℃.
- When a metal rod whose ends are fixed is heated, then compressive strain is produced in the rod. The stress set up in the rod due to increase of temperature is called **thermal stress**.

  Thermal stress $= Y\frac{\Delta l}{l} = Y\alpha l \Delta T$

  where, Y = Young's modulus, ΔT = change in temperature, Δl = change in length and α = linear expansion coefficient of the material.

Specific Heat Capacity

- The change in temperature of a substance, when given quantity of heat is absorbed or rejected by it, is characterised by a quantity called **heat capacity** of substance. It is given by $S = \frac{\Delta Q}{\Delta T}$, where ΔQ is the amount of heat supplied to the substance to change its temperature from T to $T + \Delta T$.
- Every substance has a unique value for the amount of heat absorbed or given off to change the temperature of unit mass of it by one unit. This quantity is referred to as the **specific heat capacity** of the substance.

  It is given by

$$s = \frac{S}{m} = \frac{1}{m}\cdot\frac{\Delta Q}{\Delta T}$$

- Specific heat capacity of a substance depends on the nature of the substance and its temperature. The SI unit of specific heat capacity is $Jkg^{-1}K^{-1}$.
- **Molar specific heat capacity** is the amount of heat required to raise the temperature of unit mole gas by 1°C and given by $c = \frac{S}{\mu} = \frac{1}{\mu}\cdot\frac{\Delta Q}{\Delta T}$, where μ = number of moles.

  The SI unit of molar specific heat capacity is J mol^{-1} K^{-1}. Molar specific heat capacity is of two types
  (i) **Molar specific heat at constant pressure** is the amount of heat required to raise the temperature of unit mole of gas by 1°C at constant pressure. It is denoted by C_p.
  (ii) **Molar specific heat at constant volume** is the amount of heat required to raise the temperature of unit mole of gas by 1°C at constant volume. It is denoted by C_V.
- Water has the highest specific heat capacity as compared to other substances. For this reason, water is also used as coolant in automobile radiators, as well as a heater in hot water bags.

Calorimetry and Change of State

- Calorimetry means measurement of heat. A device in which heat measurement can be done is called **calorimeter**.

  According to principle of calorimetry,

  Heat lost by hotter body = Heat gained by colder body

$$m_1 s_1 \Delta T = m_2 s_2 \Delta T$$

  where, m_1 = mass of hot body,
  m_2 = mass of cold body,
  s_1 = specific heat of hot body
  and s_2 = specific heat of cold body.
- Matter normally exists in three states : solid, liquid and gas.
- A transition from one of these states to another is called a **change of state**.
- The change of state from solid to liquid is called **melting** and from liquid to solid is called **fusion**.
- Both the solid and the liquid states of the substance co-exist in thermal equilibrium, during the change of states from solid to liquid.
- The temperature at which the solid and the liquid states of the substance is in thermal equilibrium with each other is called its **melting point**.
- The melting point of a substance at standard atmospheric pressure is called its **normal melting point**.

KEY NOTES

- The phenomenon in which ice melts when pressure is increased and freezes again when pressure is removed is called **regelation**.
- The change of state from liquid to vapour (or gas) is called **vaporisation**.
- The temperature at which the liquid and the vapour states of the substance co-exist is called its **boiling point**.
- The boiling point of a substance at standard atmospheric pressure is called its **normal boiling point**.
- The change from solid state to vapour state without passing through the liquid state is called **sublimation** and the substance is said to **sublime**.

Latent Heat

- The amount of heat transferred per unit mass during the change of state of a substance without any change in its temperature is called latent heat of the substance for particular change.

$$Q \propto m \Rightarrow Q = mL$$

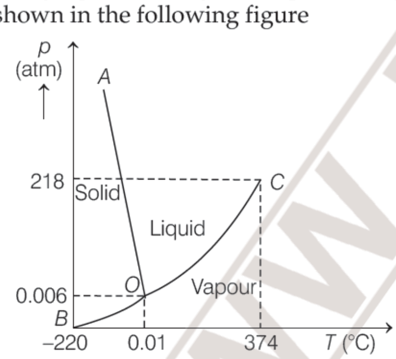
where, L = latent heat of the material.

There are two types of latent heat of materials

(i) The latent heat for a solid-liquid state change is called the **latent heat of fusion** L_F. For water, its value is 3.33×10^5 J kg^{-1}.

(ii) The latent heat for a liquid-gas state change is called the **latent heat of vaporisation** L_V. For water, its value is 22.6×10^5 J kg^{-1}.

- The temperature of a substance remains constant during its state change (phase change). The phase diagram of water is shown in the following figure



(i) The phase diagram divides the p-T plane into a **solid region**, the **vapour region** and the **liquid region**.

(ii) The regions are seperated by the curve such as **sublimation curve** (BO), **fusion curve** (AO) and **vaporisation curve** [CO].

(iii) The points on sublimation curve BO represents states in which solid and vapour phases co-exist. Points on the fusion curve AO represents states in which solid and liquid phases co-exist. Points on vaporisation curve CO represents states in which the liquid and vapour phases co-exist.

(iv) The temperature and pressure at which the fusion curve, the vaporisation curve and the sublimation curve meet and all the three phases of a substance co-exist is called the **triple point of the substances**.

(v) The triple point of water is represented by the temperature 273.16K and pressure 6.11×10^{-3} Pa.

Heat Transfer

- Heat is energy transfer from one system to another or from one part of a system to another part, arising due to temperature difference.
- Heat transfer takes place by three distinct modes, namely conduction, convection and radiation.

Conduction

- It is the mechanism of transfer of heat between two adjacent parts of a body because of their temperature difference.
- The rate of flow of heat (or heat current) H is proportional to the temperature difference ΔT and the area of cross-section A and is inversely proportional to the length L, i.e. $H = K \cdot A \dfrac{\Delta T}{L}$

  where, K is called the **thermal conductivity** of the material.

  The SI unit of K is Js^{-1}mK^{-1}.

Convection

- The process of heat transmission in which the particles of the fluid (liquid or gas) move is called convection.
- If the heated material is forced to move by an agency like blower or pump, then the process of heat transfer is called **forced convection.**
- On earth, a convection current sets up, with the air at the equatorial surface rising and moving out towards the poles, descending and streaming in towards the equator. This is called **trade wind**.
- Conduction and convection require some material as a transport medium..

Radiation

- The mechanism in which heat is transferred from one place to another without any medium is called **radiation**.
- The energy so transferred by electromagnetic waves is called **radiant energy**. It is the fastest mode of transfer of heat.
- The electromagnetic radiation emitted by a body by virtue of its temperature, like radiation by a red hot iron or light from a filament lamp is called **thermal radiation**.
- When thermal radiation falls on other bodies, it is partly reflected and partly absorbed. The amount of heat that a body can absorb by radiation depends on the colour of the body.

- **Black Body Radiation** A black body is an object which absorbs all the radiation falling on it.
- **Wien's displacement law** states that "as temperature of black body T increases, the wavelength λ_m corresponding to maximum emission decreases" such that

$$\lambda_m T = b \text{ (constant)}$$

where, b is known as **Wien's constant** and its value is 2.89×10^{-3} mK.

Stefan-Boltzmann Law

- For a body, which is a perfect radiator, the energy emitted per unit time is given by $H = A\sigma T^4$

  where, σ = Stefan-Boltzmann constant and its value in SI units is 5.67×10^{-8} Wm^{-2} K^{-4}, A is the surface area of body and T is the absolute temperature of the body.
- For a body whose emissivity is e, then energy emitted per unit time is given by $H = Ae\sigma T^4$.

  Here, $e = 1$ for perfect radiator.
- A body at temperature T, with surroundings at temperature T_s emits as well as receives energy. For a perfect radiator, the net rate of loss of radiant energy is

$$H = \sigma A(T^4 - T_s^4)$$

For a body with emissity e, the relation modifies to

$$H = e\,\sigma\,A(T^4 - T_s^4)$$

- A large portion of the thermal radiations of earth is absorbed by greenhouse gases (CO_2, CH_4, N_2O, CF_xCl_x and O_3). This heats up the atmosphere and gives more energy to earth, resulting in warmer surface.
- This increases the intensity of radiation from the surface. This cycle is repeated until no radiation is available for absorption. The net result is heating up of earth's surface and atmosphere. This is known as **greenhouse effect**.

Newton's Law of Cooling

- According to this law, "rate of cooling of a body is directly proportional to the temperature difference between the body and the surroundings provided that the temperature difference is small."

  Mathematically, $-\dfrac{dQ}{dt} = k(T_2 - T_1)$

  where, k is a positive constant depending upon the area and nature of the surface of the body.
- If a body cools by radiation through a small temperature difference from T_1 to T_2 in a short time t when the surrounding temperature is T_0, then

$$\frac{dQ}{dt} = ms\frac{dT_2}{dt} = k\,\frac{T_1 - T_2}{t}$$

$$= k\left[\frac{T_1 + T_2}{2} - T_0\right]$$

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ Temperature and Heat

1 A glass of ice-cold water left on a table on a hot summer day eventually warms up, whereas a cup of hot tea on the same table cools down because
(a) its surrounding media are at different temperature
(b) the direction of heat flow depends on the surrounding temperature with respect to the body
(c) heating or cooling does not depend on surrounding temperature
(d) Both (a) and (b)

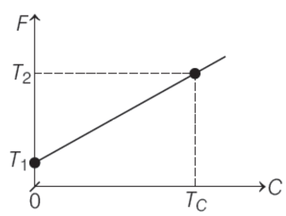
2 The common physical property which is to be used as the basis for constructing thermometer is
(a) the variation of the volume of a liquid with temperature
(b) the variation of the pressure of a gas with temperature
(c) the variation of the resistance of a wire with temperature
(d) All of the above

3 The ice point and the steam point of water are two convenient fixed points and are known as the
(a) cooling point and heating point, respectively
(b) heating point and cooling point, respectively
(c) freezing point and boiling point, respectively
(d) boiling point and freezing point,respectively

4 On a hilly region, water boils at 95°C. The temperature expressed in Fahrenheit is
(a) 100°F
(b) 20.3°F
(c) 150°F
(d) 203°F

5 The temperature at which centigrade and Fahrenheit scales give the same reading, is
(a) – 40° (b) 40°
(c) – 30° (d) 30°

6 The graph of Fahrenheit temperature (F) *versus* Celsius temperature (C) is shown below. The correct relation between F and C which can be deduced from graph, is



(a) $\frac{F-32}{T_2-T_1}=\frac{T_C}{C}$ (b) $\frac{F-T_1}{T_2-T_1}=\frac{C}{T_C}$
(c) $\frac{F-32}{T_2-T_1}=\frac{C}{T_C}$ (d) $\frac{C}{T_1-T_2}=\frac{F-32}{T_C}$

7 On centigrade or Celsius scale (°C), the temperature of a body increases by 30° C. The increase in temperature on Fahrenheit scale (° F) is
(a) 50° (b) 40°
(c) 30° (d) 54°

8 A thermometer graduated according to a linear scale reads a value x_0, when in contact with boiling water and $x_0/3$, when in contact with ice. What is the temperature of an object in °C, if this thermometer in the contact with the object reads $x_0/2$? ***JEE Main 2019***
(a) 35 (b) 60 (c) 40 (d) 25

9 Two absolute scales A and B have triple points of water defined to be 400 A and 300 B. The relation between T_A and T_B is (triple point of water is 273.16 K temperature and 6.11×10^{-3} atm pressure at which water co-exists in gas, liquid and solid states)
(a) $T_A=\frac{4}{3}T_B$ (b) $T_B=\frac{4}{7}T_A$
(c) $T_A=\frac{4}{7}T_B$ (d) $T_B=T_A$

TOPIC 2~ *Ideal Gas Equation and Absolute Temperature*

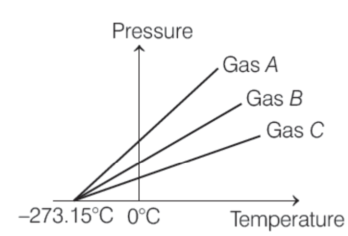
10 When the pressure is held constant, the volume of a quantity of the gas is related to the temperature as $V/T=$ constant. This relationship is known as
(a) Boyle's law (b) Dalton partial pressure law
(c) Charles' law (d) ideal gas equation

11 Measurements on real gases deviate from the values predicted by the ideal gas law at
(a) high temperature (b) low temperature
(c) room temperature (d) All of these

12 With a constant-volume gas thermometer, temperature is read in terms of
(a) volume (b) pressure (c) heat (d) density

13 An ideal gas is contained in a cylinder at pressure p_1 and temperature T_1. The initial moles of the gas is n_1. The gas leaks from the cylinder and attains a final pressure p_2 and temperature T_2. The new moles of the gas present in the cylinder is
(a) $\frac{p_2T_1}{p_1n_1T_2}$ (b) $\frac{n_1T_2\,p_2}{T_1\,p_1}$
(c) $\frac{n_1T_1\,p_2}{T_2\,p_1}$ (d) Data insufficient

14 The absolute minimum temperature for an ideal gas, inferred by extrapolating the straight line to the temperature axis as shown in the given graph, is called as



(a) Kelvin temperature
(b) Celsius temperature
(c) low temperature
(d) absolute zero

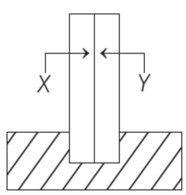
15 The absolute zero temperature in Fahrenheit scale is
(a) – 273° F (b) – 32° F (c) – 460° F (d) – 132° F

16 The correct value of 0°C on Kelvin scale will be
(a) 273.15 K (b) 273.00 K
(c) 273.05 K (d) 273.63 K

TOPIC 3~ *Thermal Expansion*

17 A fully inflated balloon shrinks when it is put into cold water, because
(a) water causes lesser pressure from outside on the balloon
(b) water causes a pull on balloon which presses it
(c) air inside the balloon contracts due to cooling
(d) rubber of balloon expands on cooling and compresses air inside

18 A bimetallic strip consists of metals X and Y. It is mounted rigidly at the base as shown in figure. The metal X has a higher coefficient of expansion compared to that of metal Y. When bimetallic strip is placed in a cold bath, then



(a) it will bend towards the right
(b) it will bend towards the left
(c) it will not bend but shrink
(d) it will neither bend nor shrink

19 A bar of iron is 10 cm at 20°C. At 19°C, it will be
(α of iron $= 11 \times 10^{-6}\,°\mathrm{C}^{-1}$)
(a) 11×10^{-6} cm, longer (b) 11×10^{-5} cm, shorter
(c) 11×10^{-6} cm, shorter (d) 11×10^{-5} cm, longer

20 A surveyor's 30 m steel tape is correct at a temperature of $20°\mathrm{C}$. The distance between the two points, as measured by this tape on a day when the temperature is $35°\mathrm{C}$, is 26 m . The true distance between the points is [α_l (steel) $= 1.2 \times 10^{-5}/°\mathrm{C}$]
(a) 25.9952 m (b) 26.0046 m (c) 27.995 m (d) 24.0046 m

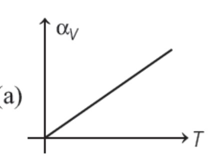
21 Two rods A and B of identical dimensions are at temperature 30ºC. If A is heated upto 180ºC and B upto Tº C, then new lengths are the same. If the ratio of the coefficients of linear expansion of A and B is 4 : 3, then the value of T is ***JEE Main 2019***
(a) 230ºC (b) 270ºC (c) 200ºC (d) 250ºC

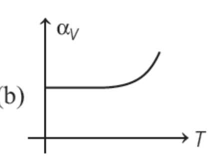
22 A copper rod of 88 cm and an aluminium rod of unknown length have their increase in length, independent of increase in temperature. The length of aluminium rod is ***NEET (National) 2019***
(a) 113.9 cm (b) 88 cm
(c) 68 cm (d) 6.8 cm

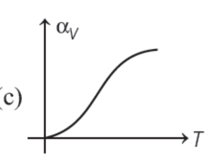
23 How much should the temperature of a brass rod be increased so as to increase its length by 1%? (Given, α for brass is $0.00002°\mathrm{C}^{-1}$). ***JIPMER 2018***
(a) 300°C (b) 400°C
(c) 500° C (d) 550° C

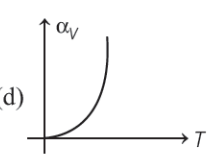
24 Two rods, one of aluminium and the other made of steel, having initial length l_1 and l_2 are connected together to form a single rod of length $l_1 + l_2$. The coefficients of linear expansion for aluminium and steel are α_a and α_s, respectively. If the length of each rod increases by the same amount when their temperatures are raised by $t°\mathrm{C}$, then find the ratio of l_1 with $l_1 + l_2$.
(a) $\dfrac{\alpha_s}{\alpha_a}$ (b) $\dfrac{\alpha_a}{\alpha_s}$
(c) $\dfrac{\alpha_s}{\alpha_a + \alpha_s}$ (d) $\dfrac{\alpha_a}{\alpha_a + \alpha_s}$

25 Coefficient of volumetric expansion α_V is not a constant. It depends on temperature. Variation of α_V with temperature T for metals is ***JEE Main 2016***

(a)


(b)


(c)


(d)


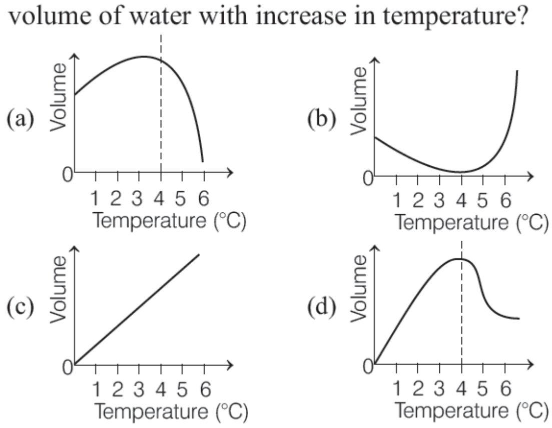
26 The coefficient of volume expansion of glycerine is $49 \times 10^{-5}\,°\mathrm{C}^{-1}$. What is the fractional change in density for a $30°\mathrm{C}$ rise in temperature? ***JIPMER 2018***
(a) 0.0155 (b) 0.0145
(c) 0.0255 (d) 0.0355

27 The value of coefficient of volume expansion of glycerin is $5 \times 10^{-4}\,\mathrm{K}^{-1}$. The fractional change in the density of glycerin for a rise of $40°\mathrm{C}$ in its temperature is ***CBSE AIPMT 2015***
(a) 0.015 (b) 0.020
(c) 0.025 (d) 0.010

28 For an ideal gas, coefficient of volume expansion is given by
(a) $\dfrac{nR\Delta T}{p}$ (b) $\dfrac{\Delta T}{T}$ (c) $\dfrac{R\Delta T}{T}$ (d) $\dfrac{1}{T}$

29 When temperature of water is raised from 0°C to 4°C, it
(a) expands
(b) contracts
(c) expands upto 2° C and then contracts upto 4° C
(d) contracts upto 2° C and then expands upto 4° C

30 Which of the following graph shows the variation of volume of water with increase in temperature?



31 Temperature of atmosphere in Kashmir falls below -10°C in winter. Due to this water, animal and plant life of Dal-lake
(a) is destroyed in winters
(b) frozen in winter and regenerated in summers
(c) survives as only top layer of lake in frozen
(d) None of the above

32 A brass wire 1.8 m long at 27°C is held taut with little tension between two rigid supports. If the wire is cooled to a temperature of -39°C, what is the tension developed in the wire, if its diameter is 2.0 mm? Coefficient of linear expansion of brass $= 2.0 \times 10^{-5}\,^\circ C^{-1}$ and Young's modulus of brass $= 0.91 \times 10^{11}$ Nm^{-2}.
(a) 3.77×10^2 N (b) 5.3×10^2 N
(c) 2.5×10^2 N (d) 4.3×10^2 N

33 Two rods of different materials having coefficients of thermal expansion α_1 and α_2 and Young's modulii Y_1 and Y_2, respectively are fixed between two rigid walls. The rods are heated, such that they undergo the same increase in temperature. There is no bending of rods. If $\alpha_1/\alpha_2 = 2/3$ and stresses developed in the two rods are equal, then Y_1/Y_2 is
(a) 3/2 (b) 1
(c) 2/3 (d) 1/2

34 A wire 3 m in length and 1 mm in diameter at 30°C is kept in a low temperature -170°C and is stretched by hanging a weight of 10 kg at one end, so the change in length of the wire is ($Y = 2 \times 10^{11}$ Nm^{-2}, $g = 10$ ms^{-2} and $\alpha = 1.2 \times 10^{-5}\,^\circ C^{-1}$)
(a) -5.2 mm (b) -2.5 mm
(c) -52 mm (d) -25 mm

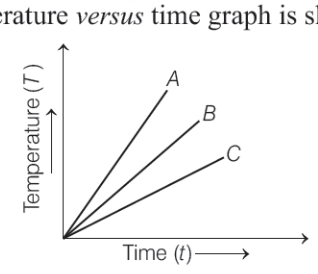
TOPIC 4 ~ Specific Heat Capacity, Calorimetry and Change of State

35 Amount of heat required to warm an object depends on
(a) mass of object
(b) temperature change
(c) nature of substance
(d) All of the above

36 Water is used as a coolant because of
(a) low specific heat capacity
(b) high specific heat capacity
(c) warms up quickly
(d) None of the above

37 Time taken to heat water upto a temperature of 40°C (from room temperature) is t_1 and time taken to heat mustard oil (of same mass and at room temperature) upto a temperature of 40°C is t_2, then (given mustard oil has smaller heat capacity)
(a) $t_1 = t_2$
(b) $t_1 > t_2$
(c) $t_2 > t_1$
(d) t_1 and t_2 both are less than 10 min

38 Which of the substances A, B and C has the lowest heat capacity? If heat is supplied to all of them at equal rates, the temperature *versus* time graph is shown below.



(a) A
(b) B
(c) C
(d) All have equal specific heat

39 A normal diet furnishes 200 kcal to a 60 kg person in a day. If this energy was used to heat the person with no losses to the surroundings, how much would the person's temperature increases? The specific heat of the human body is 0.83 cal g^{-1} °C^{-1}.
(a) 8.2°C (b) 4.01°C (c) 6.0°C (d) 5.03°C

40 Certain amount of heat is given to 100 g of copper to increase its temperature by 21° K. If the same amount of heat is given to 50 g water, then the rise in its temperature is (specific heat capacity of copper $= 400\ \text{Jkg}^{-1}\text{K}^{-1}$ and that of water $= 4200\ \text{Jkg}^{-1}\text{K}^{-1}$)

(a) 4°C (b) 5.25°C (c) 8°C (d) 6°C

41 A certain substance has a mass of 50 g for 1 mole. When 300 J of heat is added to 25 g of sample of this material, its temperature rises from 25°C to 45°C. Calculate specific heat capacity and molar heat capacity of the sample.

(a) $600\ \text{Jkg}^{-1}\,°\text{C}^{-1}$, $45\ \text{Jmol}^{-1}\,°\text{C}^{-1}$

(b) $450\ \text{Jkg}^{-1}\,°\text{C}^{-1}$, $30\ \text{Jmol}^{-1}\,°\text{C}^{-1}$

(c) $600\ \text{Jkg}^{-1}\,°\text{C}^{-1}$, $30\ \text{Jmol}^{-1}\,°\text{C}^{-1}$

(d) $700\ \text{Jkg}^{-1}\,°\text{C}^{-1}$, $80\ \text{Jmol}^{-1}\,°\text{C}^{-1}$

42 Two similar bodies of equal masses are heated to temperatures θ_1 and θ_2 $(\theta_1 > \theta_2)$ and are mixed together. If temperature of mixture is θ, then

(a) $\theta = \dfrac{\theta_1 + \theta_2}{2}$

(b) θ is never equal to $\dfrac{\theta_1 + \theta_2}{2}$

(c) θ is conditionally equal to $\dfrac{\theta_1 + \theta_2}{2}$

(d) $\theta > \dfrac{\theta_1 + \theta_2}{2}$

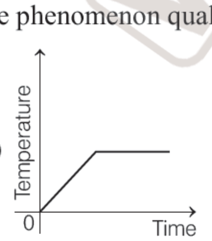
43 A metal block is made from a mixture of 2.4 kg of aluminium, 1.6 kg of brass and 0.8 kg of copper. The amount of heat required to raise the temperature of this block from 20°C to 80°C is (specific heats of aluminium, brass and copper are 0.216, 0.0917 and 0.0931 $\text{calkg}^{-1}°\text{C}^{-1}$, respectively)

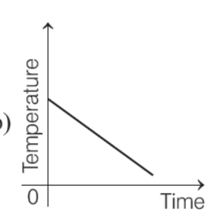
(a) 96.2 cal (b) 44.4 cal (c) 86.2 cal (d) 62.8 cal

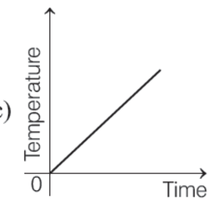
44 The temperature of equal masses of three different liquids A, B and C are 12°C, 19°C and 28°C, respectively. The temperature when A and B are mixed is 16°C and when B and C are mixed is 23°C. The temperature when A and C are mixed, is

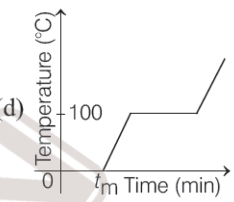
(a) 18.2°C (b) 22°C
(c) 20.2°C (d) 25.2°C

45 A block of ice at 0°C is slowly heated and converted into steam at 100°C. Which of these curves represent the phenomenon qualitatively?

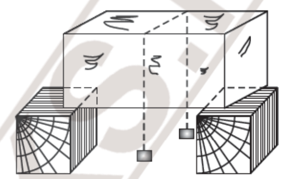
(a)


(b)


(c)


(d)


46 If a wire is pressed over a slab of ice as shown, then



(a) it cuts the slab into 2 parts and pass to other side after some time

(b) it passes through the ice slab and the slab does not split

(c) it remains over the slab (as initially placed)

(d) ice slab melts completely

47 At atmospheric pressure, water boils at 100°C. If pressure is reduced, then

(a) it still boils at same temperature

(b) it now boils at a lower temperature

(c) it now boils at a higher temperature

(d) it does not boil at all

48 A liquid boils when its vapour pressure is equal to

(a) 6.0 cm of Hg column

(b) atmospheric pressure

(c) double of atmospheric pressure

(d) 1000 Pa or more

49 Cooking is difficult on hills because

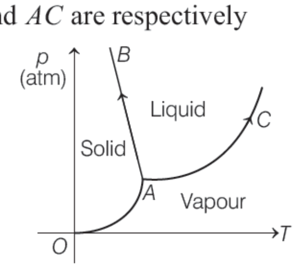
(a) atmospheric pressure is higher

(b) atmospheric pressure is lower

(c) boiling point of water is reduced

(d) Both (b) and (c)

50 For the phase diagram of water given in figure, curves OA, AB and AC are respectively ***JEE Main 2018***



(a) sublimation curve, vaporisation curve and fusion curve

(b) sublimation curve, fusion curve and vaporisation curve

(c) fusion curve, vaporisation curve and sublimation curve

(d) fusion curve, sublimation curve and vaporisation curve

51 When water boils or freezes, its state changes but its temperature
(a) increases
(b) decreases
(c) does not change
(d) sometimes increase and sometimes deceases

52 The latent heat of vaporisation of a substance is always
(a) greater than its latent heat of fusion
(b) greater than its latent heat of sublimation
(c) equals to its latent heat of sublimation
(d) less than its latent heat of fusion

53 Steam burns are more serious in comparison to those caused from boiling water because
(a) steam at 100°C carries same heat as that of water at 100°C
(b) steam is more reactive
(c) steam has less surface tension, so it burns surface more rapidly
(d) steam at 100°C carries more heat than water at 100°C

54 A piece of ice (heat capacity = $2100\,\text{Jkg}^{-1}\,°\text{C}^{-1}$ and latent heat = $3.36 \times 10^5\ \text{Jkg}^{-1}$) of mass m grams is at $-5°$C at atmospheric pressure. It is given 420 J of heat, so that the ice starts melting. Finally, when the ice-water mixture is in equilibrium, it is found that 1 g of ice has melted. Assuming there is no other heat exchange in the process, then find the value of m.
(a) 8 g (b) 2 g (c) 4 g (d) 6 g

55 0.15 kg of ice at 0°C is mixed with 0.30 kg of water at 50°C in a container. The resulting temperature is 6.7°C. Heat of fusion of ice is (given, specific heat of water is $4186\ \text{Jkg}^{-1}\text{K}^{-1}$)
(a) $3.34\times 10^5\ \text{Jkg}^{-1}$ (b) $3.34\times 10^4\ \text{Jkg}^{-1}$
(c) $3.34\times 10^2\ \text{Jkg}^{-1}$ (d) $3.34\times 10^6\ \text{Jkg}^{-1}$

56 Calculate the heat required to convert 3 kg of ice at –12°C kept in a calorimeter to steam at 100°C at atmospheric pressure. Given specific heat capacity of ice is $2100\ \text{Jkg}^{-1}\ \text{K}^{-1}$, specific heat capacity of water is $4186\ \text{Jkg}^{-1}\ \text{K}^{-1}$, latent heat of fusion of ice is $3.35\times10^5\ \text{Jkg}^{-1}$ and latent heat of steam is $2.256\times10^6\ \text{Jkg}^{-1}$.
(a) 8×10^4 J (b) 9.1×10^6 J
(c) 4×10^3 J (d) 7×10^6 J

TOPIC 5 ~ *Heat Transfer*

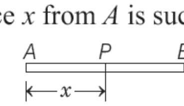
57 The rate of heat flow (or heat current) in a bar is proportional to
(a) temperature difference
(b) area of cross-section
(c) inversely to length of bar
(d) All of the above

58 Cooking pots have copper coating at the bottom. This is because
(a) copper is a good conductor of heat
(b) copper is a good conductor of electricity
(c) copper promotes the distribution of heat over the bottom of a pot
(d) Both (a) and (c)

59 Calculate the rate of loss of heat through a glass window of area 1000 cm^2 and thickness 0.4 cm, when temperature inside is 37°C and outside is −5°C. Coefficient of thermal conductivity of glass is $2.2\times 10^{-3}\ \text{cal s}^{-1}\text{cm}^{-1}\text{K}^{-1}$.
(a) 450 cal s^{-1} (b) 231 cal s^{-1}
(c) 439 cal s^{-1} (d) 650 cal s^{-1}

60 The two ends of a metal rod are maintained at temperatures 100°C and 110°C. The rate of heat flow in the rod is found to be 4 Js^{-1}. If the ends are maintained at temperatures 200°C and 210°C, the rate of heat flow will be ***CBSE AIPMT 2015***
(a) 44.0 Js^{-1} (b) 16.8 Js^{-1}
(c) 8.0 Js^{-1} (d) 4.0 Js^{-1}

61 Heat is flowing steadily from A to B. Temperature T at P, at distance x from A is such that



(a) T decreases linearly with x
(b) T increases linearly with x
(c) T decreases exponentially with x
(d) T increases with x as $T \propto x^2$

62 Water is boiled in a rectangular steel tank of thickness 2 cm by a constant temperature furnace. Due to vaporisation, water level falls at a steady rate of 1 cm in 9 min. Calculate the temperature of the furnace. Given, K for steel = $0.2\ \text{cals}^{-1}\text{m}^{-1}\,°\text{C}^{-1}$.
(a) 150°C (b) 110°C (c) 130°C (d) 200°C

63 A deep rectangular pond of surface area A, containing water (density $= \rho$, specific heat capacity $= s$), is located in a region where the outside air temperature is a steady at $-26°C$. The thickness of the frozen ice layer in this pond, at a certain instant is x.

Taking the thermal conductivity of ice as K and its specific latent heat of fusion as L, the rate of increase of the thickness of ice layer, at this instant would be given by **NEET (Odisha) 2019**

(a) $26K/\rho r(L-4s)$ (b) $26K/\rho x^2 - L$

(c) $26K/\rho xL$ (d) $26K/\rho r(L+4s)$

64 One rod of length 2 m and thermal conductivity 50 units is attached to another rod of length 1 m and thermal conductivity 100 units. Temperature of free ends are 70° C and 50°C respectively, then temperature of junction point will be **JIPMER 2019**

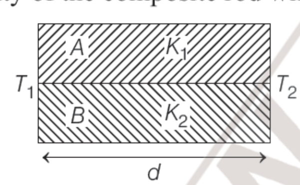
(a) 60°C (b) 54°C (c) 64°C (d) 68°C

65 Three bars of equal lengths and equal area of cross-sections are connected in series. Their thermal conductivities are in the ratio of 2 : 4 : 3. If the open ends of the first and the last bars are at temperature 200°C and 18°C, respectively in the steady state, then calculate the temperatures of both the junctions.

(a) 116°C, 74°C (b) 120°C, 180°C

(c) 125°C, 50°C (d) 130°C, 40°C

66 Two rods A and B of different materials are welded together as shown in figure and their thermal conductivities are K_1 and K_2. The thermal conductivity of the composite rod will be **NEET 2017**



(a) $\frac{K_1 + K_2}{2}$ (b) $\frac{3(K_1 + K_2)}{2}$

(c) $K_1 + K_2$ (d) $2(K_1 + K_2)$

67 Two rods of same length and material transfer a given amount of heat in 12 s, when they are joined end to end (i.e. in series). But when they are joined in parallel, they will transfer same heat under same temperature difference across their ends in

(a) 24 s (b) 3 s (c) 38 s (d) 1.5 s

68 A solid cylinder of radius R, made of a material of thermal conductivity K_1 is surrounded by a hollow cylinder of inner radius R and outer radius $2R$ made of material of thermal conductivity K_2. The two ends of the combined system are maintained at two different temperatures. There is no loss of heat across the cylindrical surface and the system is in steady state.

The effective thermal conductivity of the system is **JEE Main 2017**

(a) $K_1 + K_2$ (b) $\frac{K_1 + 3K_2}{4}$ (c) $\frac{K_1K_2}{K_1 + K_2}$ (d) $\frac{3K_1 + K_2}{4}$

69 Three rods made of the same material and having the same cross-section have been joined as shown in the figure. Each rod is of the same length. The left and right ends are kept at 0°C and 90°C, respectively. The temperature of the junction of the three rods will be

(a) 45° C (b) 90° C (c) 30° C (d) 60° C

70 The equatorial and polar regions of the earth receive unequal solar heat. The convection current arising is called

(a) land breeze (b) sea breeze

(c) trade wind (d) tornado

71 The amount of heat that a body can absorb by radiation

(a) depend on both colour and temperature of body

(b) depends on colour of body only

(c) depends on temperature of body only

(d) depends on density of body

72 The bottom of utensils for cooking food are blackened to

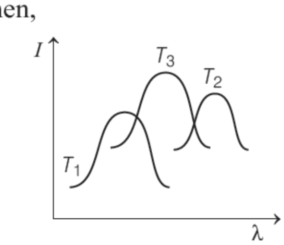
(a) absorb minimum heat from fire

(b) absorb maximum heat from fire

(c) emit radiations

(d) reflect heat to surroundings

73 The plots of intensity of radiation *versus* wavelength of three black bodies at temperature T_1, T_2 and T_3 are shown. Then,



(a) $T_3 > T_2 > T_1$ (b) $T_1 > T_2 > T_3$

(c) $T_2 > T_3 > T_1$ (d) $T_1 > T_3 > T_2$

74 A black body is at a temperature of 5760 K. The energy of radiation emitted by the body at wavelength 250 nm is U_1, at wavelength 500 nm is U_2 and that at 1000 nm is U_3 and Wien's constant, $b = 2.88 \times 10^6$ nm-K. Which of the following is correct? **NEET 2016**

(a) $U_3 = 0$ (b) $U_1 > U_2$ (c) $U_2 > U_1$ (d) $U_1 = 0$

75 The wavelength $\lambda_m = 5.5 \times 10^{-7}$ m corresponds to a temperature of the sun of 5500 K. If the furnace has wavelength λ_m equal to 11×10^{-7} m, then temperature of furnace is
(a) 5000 K (b) 1750 K (c) 3750 K (d) 2750 K

76 The intensity of radiation emitted by the sun has its maximum value at a wavelength of 510 nm and that emitted by the north star has the maximum value at wavelength of 350 nm. If these stars behave like black bodies, then the ratio of surface temperature of the sun and north star is
(a) 1.46 (b) 0.69 (c) 1.21 (d) 0.83

77 On observing light from three different stars P, Q and R, it was found that intensity of violet colour is maximum in the spectrum of P, the intensity of green colour is maximum in the spectrum of R and the intensity of red colour is maximum in the spectrum of Q. If T_P, T_Q and T_R are the respective absolute temperature of P, Q and R, then it can be concluded from the above observations that **CBSE AIPMT 2015**
(a) $T_P > T_Q > T_R$
(b) $T_P > T_R > T_Q$
(c) $T_P < T_R < T_Q$
(d) $T_P < T_Q < T_R$

TOPIC 6 ~ Stefan-Boltzmann Law and Newton's Law of Cooling

78 If the radius of a star is R and it acts as a black body, what would be the temperature of the star, in which rate of energy production is Q? (σ is Stefan's constant)
(a) $\dfrac{Q}{4\pi R^2\sigma}$ (b) $\left[\dfrac{Q}{4\pi R^2\sigma}\right]^{1/2}$
(c) $\left[\dfrac{Q}{4\pi R^2\sigma}\right]^{1/4}$ (d) $\left[\dfrac{4\pi R^2 Q}{\sigma}\right]^{1/4}$

79 The temperature of two bodies A and B are $727°$C and $327°$C respectively, the ratio $H_A : H_B$ of the rates of heat radiated by them is
(a) 727 : 327 (b) 5 : 3 (c) 25 : 9 (d) 625 : 81

80 Calculate radiation power for sphere whose temperature is 227°C, radius is 2 m and emissivity is 0.8. **AIIMS 2019**
(a) 142.5 kW (b) 1500 W
(c) 1255 W (d) 1575 W

81 At what temperature will the filament of 100 W lamp operate, if it is supposed to be perfectly black body of area $1.0\,\text{cm}^2$?
(a) 3449 K (b) 2049 K (c) 3000 K (d) 3010 K

82 A spherical black body with a radius of 12 cm radiates 450 W power at 500 K. If the radius were halved and the temperature doubled, the power radiated in watt would be **NEET 2017**
(a) 225 (b) 450 (c) 1000 (d) 1800

83 Due to the change in main voltage, the temperature of an electric bulb rises from 3000 K to 4000 K. What is the percentage rise in electric power consumed?
(a) 216 (b) 100 (c) 150 (d) 178

84 Three very large plates of same area are kept parallel and close to each other. They are considered as ideal black surfaces and have very high thermal conductivity. The first and third plate is maintained at temperature $2T$ and $3T$, respectively. The temperature of the middle (second) plate under steady state condition is
(a) $\left(\dfrac{65}{2}\right)^{1/4} T$ (b) $\left(\dfrac{97}{4}\right)^{1/4} T$
(c) $\left(\dfrac{97}{2}\right)^{1/4} T$ (d) $(97)^{1/4} T$

85 The power radiated by a black body is P and it radiates maximum energy at wavelength λ_0. If the temperature of the black body is now changed, so that it radiates maximum energy at wavelength $\dfrac{3}{4}\lambda_0$, the power radiated by it becomes nP. The value of n is **NEET 2018**
(a) $\dfrac{256}{81}$ (b) $\dfrac{4}{3}$ (c) $\dfrac{3}{4}$ (d) $\dfrac{81}{256}$

86 If temperature of sun = 6000 K, radius of sun $= 7.2 \times 10^5$ km, radius of earth = 6000 km and distance between earth and sun $= 15 \times 10^7$ km. Find intensity of light on earth. **AIIMS 2019**
(a) 19.2×10^{16} (b) 12.2×10^{16}
(c) 18.3×10^{16} (d) 9.2×10^{16}

87 Which of the following is not a greenhouse gas?
(a) CO_2 (b) CH_4
(c) O_3 (d) H_2O

88 Hot water or milk, when left on a table begins to cool gradually, because
(a) temperature of surroundings is higher
(b) everything cools down with time irrespective of the temperature of the surroundings
(c) temperature of surroundings is lesser
(d) None of the above

89 The rate of loss of heat depends on
(a) the sum of temperature of the body and its surroundings
(b) the difference in temperature of the body and its surroundings
(c) the product of temperature of the body and its surroundings
(d) the ratio of temperature of the body and its surroundings

90 In equation $-\frac{dQ}{dt} = k\,(T_2 - T_1)$, where k is a positive constant which depends upon
(a) the area of exposed surface
(b) the nature of the surface of the body
(c) Both (a) and (b)
(d) Neither (a) nor (b)

91 Suppose a body of mass m and specific heat capacity s is at temperature T_2. Let T_1 be the temperature of the surroundings. If the temperature falls by a small amount dT_2 in time dt, then the amount of heat lost is
(a) $dQ = -4\,ms\,dT_2$ (b) $dQ = 2\,ms\,dT_2$
(c) $dQ = ms\,dT_2$ (d) $dQ = -2\,ms\,dT_2$

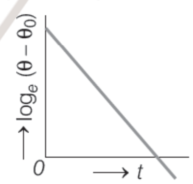
92 Certain quantity of water cools from 70°C to 60°C in the first 5 min and to 54°C in the next 5 min. The temperature of the surroundings is ***CBSE AIPMT 2014***
(a) 45°C (b) 20°C
(c) 42°C (d) 10°C

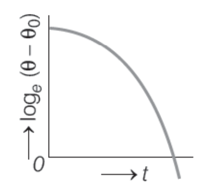
93 A body cools in 7 min from 60°C to 40°C, then what will be its temperature after the next 7 min? The temperature of the surroundings is 10°C.
(a) 40°C (b) 30°C
(c) 15°C (d) 28°C

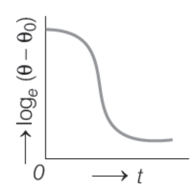
94 A cup of tea cools from 81°C to 79°C in 1 min. The ambient temperature is 30°C. What time is needed for cooling of same cup of tea in same ambience from 61°C to 59°C ?
(a) 1 min 40 s (b) 1 min 6 s
(c) 1 min 22 s (d) 4 min 3 s

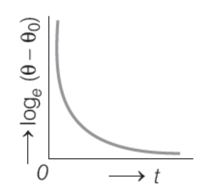
95 An object kept in a large room having air temperature of 25°C takes 12 min to cool from 80°C to 70°C.
The time taken to cool for the same object from 70°C to 60°C would be nearly ***NEET (Odisha) 2019***
(a) 10 min (b) 12 min
(c) 20 min (d) 15 min

96 A liquid in a beaker has temperature $\theta(t)$ at time t and θ_0 is temperature of surroundings, then according to Newton's law of cooling, the correct graph between $\log_e(\theta - \theta_0)$ and t is ***JEE Main 2018***

(a)


(b)


(c)


(d)


SPECIAL TYPES QUESTIONS

I. Assertion and Reason

■ **Direction** (Q. Nos. 97-111) *In the following questions, a statement of Assertion is followed by a corresponding statement of Reason. Of the following statements, choose the correct one.*
(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

97 **Assertion** A hotter body has more heat content than a colder body.
Reason Temperature is the measure of degree of hotness of a body.

98 **Assertion** When heat transfer takes place between a system and surroundings, the total heat content of system or surroundings separately remains same.
Reason Heat is a form of energy which follows the principle of conservation of energy.

99 **Assertion** Houses made of concrete roofs get very hot during summer days.

Reason Thermal conductivity of concrete is much smaller than that of metal.

100 **Assertion** When temperature difference across the two sides of a wall is increased, its thermal conductivity increases.

Reason Thermal conductivity depends on the nature of material of the wall.

101 **Assertion** If equal amount of heat is added to equal masses of different substances, the resulting change in temperature is also equal.

Reason Every substance requires a unique value of heat to change its temperature per unit mass, per degree centigrade (or per kelvin).

102 **Assertion** Water kept in an open vessel will quickly evaporate on the surface of the moon.

Reason The temperature at the surface of the moon is much higher than boiling point of water.

103 **Assertion** When a rod is heated freely, it expands and thermal strain set up in rod due to heating.

Reason Strain is a change in length per unit original length.

104 **Assertion** Desert regions are hotter in day and colder at night.

Reason Desert sand is dry.

105 **Assertion** NH_3 is liquified more easily than CO_2.

Reason Critical temperature of NH_3 is more than CO_2. *AIIMS 2019*

106 **Assertion** The triple point of water is a standard fixed point in modern thermometry.

Reason Melting point of ice and the boiling point of water changes due to change in atmospheric pressure.

107 **Assertion** A black body at higher temperature T radiates energy U. When temperature falls to one-third, the radiated energy will be $U/81$.

Reason $U^2 \propto T^4$.

108 **Assertion** The SI unit of Stefan's constant is $Wm^{-2}\ K^{-4}$.

Reason This follows from Stefan's law, $E = \sigma T^4$

$$\therefore \quad \sigma = \frac{E}{T^4}$$

109 **Assertion** The radiation from the sun's surface varies as the fourth power of its absolute temperature.

Reason Sun is not a black body.

110 **Assertion** For higher temperatures, the peak emission wavelength of a black body shifts to lower wavelengths.

Reason Peak emission wavelength of a black body is proportional to the four power of temperature.

111 **Assertion** The rate of loss of heat of a body at 300 K is R. At 900 K, the rate of loss becomes 81 R.

Reason This is as per Newton's law of cooling.

II. Statement Based Questions

112 A body A is at a temperature T_A and a body B is at a temperature T_B such that $T_A > T_B$. Bodies A and B are connected. Which of the following statements is correct related to two bodies?

I. Body A is hotter than body B.
II. Heat flows from A to B.
III. Heat flows from B to A.

(a) Both I and II (b) Only I
(c) Both II and III (d) Both I and III

113 During vaporisation,

I. the change of state from liquid to vapour state occurs.
II. the temperature remains constant.
III. both liquid and vapour states co-exist in equilibrium.
IV. specific heat of substance increases.

Which of the following statement(s) is/are correct?

(a) I, II and IV (b) II, III and IV
(c) I, III and IV (d) I, II, III and IV

114 I. Gases are poor thermal conductors.
II. Liquids have conductivities intermediate between solids and gases.
III. Heat conduction can take place from cold body to hotter body.

Which of the following statement (s) is/are correct?

(a) Only I (b) Only II
(c) Only III (d) Both I and II

115 I. Convection is a mode of heat transfer by actual motion of matter.
II. Convection is possible only in gases.
III. Convection can be natural or forced.

Which of the following statement(s) is/are correct?

(a) Only I (b) Both I and III
(c) Only II (d) I, II and III

116 I. Thermos bottle consists of a double-walled glass vessel with inner and outer walls coated with silver.
II. In flask, space between the walls is evacuated to reduce conduction and convection losses.
III. Thermos bottle is useful for preventing hot contents (like milk) from getting cold or to store cold content (like ice).

Which of the following statement(s) is/are correct?
(a) Only I (b) Only II
(c) Both I and II (d) I, II and III

117 I. Conduction of heat takes places in solids and liquids like mercury and molten metals.
II. In radiation, energy directly flows from heat source to the given body at a speed of 3×10^8 ms^{-1}.
III. Convection of heat takes place in liquids only.

Which of the following statement(s) is/are correct?
(a) Only I (b) Both II and III
(c) Only III (d) Both I and II

118 I. It is the phenomenon which keeps the earth's surface cool at night.
II. The wavelength of thermal radiation lies in infrared region.
III. A large portion of thermal radiation is absorbed by greenhouse gases like CO_2, CH_4, N_2O, CFCs and O_3, which heats up the atmosphere and give more energy to earth, resulting in warmer surface.

Which of the following statement(s) is/are correct regarding with greenhouse effect?
(a) Both I and II (b) Both II and III
(c) Both III and I (d) I, II and III

119 Gulab jamuns (assumed to be spherical) are to be heated in an oven. They are available in two sizes, one twice bigger (in radius) than the other. Pizzas (assumed to be discs) are also to be heated in oven. They are also in two sizes, one twice bigger (in radius) than the other. All four are put together to be heated to oven temperature. Choose the correct statement from the following.
(a) Both size gulab jamuns will get heated in the same time.
(b) Smaller gulab jamuns are heated before bigger ones.
(c) Bigger pizzas are heated before smaller ones.
(d) Bigger pizzas are heated before smaller gulab jamuns .

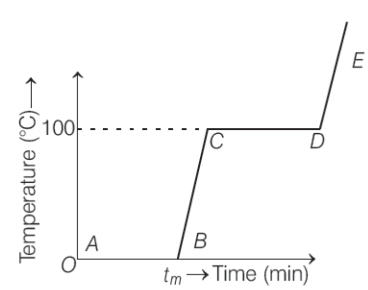
120 Which one of the following statement is correct for dependance of the coefficient of linear expansion of a metal rod?
(a) The original length of the rod.
(b) The change in temperature of the rod.
(c) The specific heat of the metal.
(d) The nature of the metal.

121 A bimetallic strip is formed out of two identical strips, one of copper and other of brass. The coefficients of linear expansion of the two metals are α_c and α_b. On heating, the temperature of the strip goes up by ΔT and the strip bends to form an arc of radius of curvature R. Then, which of the following statement is correct about the radius of curvature?
(a) It is proportional to ΔT.
(b) It is inversely proportional to ΔT.
(c) It is proportional to $|\alpha_b - \alpha_c|$.
(d) It is inversely proportional to $|\alpha_b + \alpha_c|$.

122 A uniform metallic circular disc of mass M and radius R, mounted on frictionless bearings, is rotating (with angular frequency ω) about an axis passing through its centre and perpendicular to its plane. The temperature of the disc is then increased by Δt. If α is the coefficient of linear expansion of the metal, then which of the following statement is correct?
(a) The moment of inertia increases by $MR^2\alpha\Delta t$.
(b) The moment of inertia remains unchanged.
(c) The angular frequency increases by $2\alpha\omega\,\Delta t$.
(d) The angular frequency decreases by $\alpha\omega\,\Delta t$.

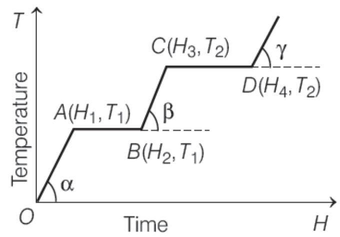
123 The coefficient of volume expansion of a liquid is 49×10^{-5} K^{-1}. When temperature is raised by $30°$C, then which of the following statement is correct?
(a) Its density decreases.
(b) Its density increases.
(c) Its fractional decrease in density is 2.5×10^{-2}.
(d) Its fractional increase in density is 2.5×10^{-2}.

124 Refer to the plot of temperature *versus* time (figure) showing the changes in the state, if ice on heating (not to scale). Which of the following statement is correct?



(a) The region AB represents ice and water in thermal equilibrium.
(b) At B water starts boiling.
(c) At C all the water gets converted into steam.
(d) C to D represents water and steam in equilibrium below boiling point.

125 The graph shows the variation of temperature T of one kilogram of a material with the heat H supplied to it. At point O, the substance is in the solid state. From the graph, which of the following statement is correct?



(a) T_2 is the melting point of the solid.
(b) AB represents the change of state from solid to liquid.
(c) $(H_2 + H_1)$ represents the latent heat of fusion of the substance.
(d) $(H_3 - H_1)$ represents the total latent heat of vaporisation of the liquid.

III. Matching Type

126 If 10g of oxygen are subjected to a pressure of 3 atm at a temperature of 10°C. Heating at a constant pressure, the gas is expanded to 10L.

With reference to the given situation, match the Column I (physical quantity) with Column II (value) and select the correct answer from the codes given below.
($R = 0.0821$ atm-litre K^{-1} mol^{-1})

Column I		Column II	
A.	The volume of the gas before expansion (in litres)	1.	4.13
B.	The temperature of the gas after expansion (in kelvin)	2.	1.0
C.	The density of gas before expansion (in gL^{-1})	3.	2.42
D.	The density of gas after expansion (in gL^{-1})	4.	1169.4

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	1	2
(c)	3	4	1	2
(d)	4	2	3	1

127 Match the Column I (physical quantity) with Column II (temperature) as per the anomalous behaviour of water and select the correct answer from the codes given below.

Column I		Column II	
A.	Density maximum	1.	4°C
B.	Volume increases	2.	27°C to 10°C
C.	Volume decreases	3.	4°C to 0°C

	A	B	C		A	B	C
(a)	1	3	2	(b)	1	2	3
(c)	1	4	3	(d)	1	4	2

128 Match the Column I (mixture) with Column II (temperature) and select the correct answer from the codes given below.

Three liquids A, B and C having same specific heat and masses m, $2m$ and $3m$ at temperatures 20°C, 40°C and 60°C, respectively. Temperature of the mixture when

Column I		Column II	
A.	A and B are mixed	1.	33.3°C
B.	A and C are mixed	2.	52°C
C.	B and C are mixed	3.	50°C
D.	A, B and C all three are mixed	4.	None

	A	B	C	D		A	B	C	D
(a)	1	3	2	4	(b)	1	2	3	4
(c)	1	4	2	3	(d)	1	3	4	2

129 Match the Column I (quantity) with Column II (dimension) and select the correct answer from the codes given below.

Column I		Column II	
A.	Thermal resistance	1.	$[MT^{-3}K^{-4}]$
B.	Stefan's constant	2.	$[M^{-1}L^{-2}T^{3}K]$
C.	Wien's constant	3.	$[ML^{2}T^{-3}]$
D.	Heat current	4.	$[LK]$

	A	B	C	D
(a)	1	2	3	4
(b)	1	4	3	2
(c)	2	1	4	3
(d)	2	1	3	4

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

130 Two ideal gas thermometers A and B use oxygen and hydrogen, respectively. The following observations are made

Temperature	Pressure thermometer A	Pressure thermometer B
Triple point of water	1.25×10^5 Pa	0.2×10^5 Pa
Normal melting point of sulphur	1.797×10^5 Pa	0.287×10^5 Pa

The absolute temperature of normal melting point of sulphur as read by thermometer A is
(a) 292.60 K (b) 392.69 K (c) 362.00 K (d) 491.98 K

131 A steel tape 1 m long is correctly calibrated for a temperature of 27.0°C. The length of steel rod measured by this tape is found to be 63.0 cm on a hot day, when the temperature is 45.0°C. What is the actual length of the steel rod on that day? Coefficient of linear expansion of steel is $1.20 \times 10^{-5} \text{K}^{-1}$.
(a) 63 cm
(b) more than 63 cm but less than 64 cm
(c) less than 63 cm
(d) 62 cm

132 A large steel wheel is to be fitted on a shaft of the same material. At 27°C, the outer diameter of the shaft is 8.70 cm and the diameter of the central hole in the wheel is 8.69 cm.

The shaft is cooled using dry ice. At what temperature of the shaft does the wheel slip on the shaft? Assume the coefficient of linear expansion of the steel to be constant over the required temperature range.
$\alpha_{\text{steel}} = 1.20 \times 10^{-5} \text{K}^{-1}$
(a) 0°C (b) – 50°C (c) – 70°C (d) – 20°C

133 A brass wire 1.8 m long at 27°C is held taut with negligible tension between two rigid supports. Diameter of the wire is 2 mm, its coefficient of linear expansion, $\alpha_{\text{brass}} = 2 \times 10^{-5}\ °\text{C}^{-1}$ and its Young's modulus, $Y_{\text{brass}} = 0.91 \times 10^{11}\ \text{Nm}^{-2}$. If the wire is cooled to a temperature $-39°$C, then tension developed in the wire is
(a) 2.7×10^2 N (b) 3.7×10^2 N
(c) 4.7×10^2 N (d) 5.7×10^2 N

134 A cubical thermocole ice box of side 30 cm has a thickness 5 cm. If 4 kg of ice is put in the box, the amount of ice remaining after 6 h is (the outside temperature is 45° C, the coefficient of thermal conductivity of thermocole is $0.01\ \text{Js}^{-1}\text{m}^{-1}\text{K}^{-1}$ and latent heat of fusion of ice is $335 \times 10^3\ \text{Jkg}^{-1}$)
(a) 3.7 kg (b) 3.9 kg (c) 4.7 kg (d) 4.9 kg

135 Two absolute scales A and B have freezing points of water defined to be $200A$ and $350B$. What is the relation between T_A and T_B?
(a) $T_A = \frac{2}{7} T_B$
(b) $T_A = \frac{4}{7} T_B$
(c) $T_A = \frac{5}{7} T_B$
(d) $T_A = \frac{6}{7} T_B$

136 The electrical resistance (in ohms) of a certain thermometer varies with temperature according to the approximate law is $R = R_0\,[1 + \alpha\,(T - T_0)]$, where α = constant.

The resistance is $101.6\ \Omega$ at the triple point of water 273.16 K and $165.5\ \Omega$ at the normal melting point of lead (600.5 K). The temperature when the resistance is $123.4\ \Omega$,is
(a) 358.4 K (b) 384.8 K
(c) 278.8 K (d) 111.67 K

137 A 10 kW drilling machine is used to drill a bore in an aluminium block of mass 8.0 kg. Block is worked on by machine for 2.5 min to drill a hole and 50% of power is used up in heating the aluminium block. Specific heat of aluminium is $0.91\ \text{Jg}^{-1}\text{K}^{-1}$. Rise in temperature of block due to drilling will be
(a) 100°C (b) 103°K (c) 103°C (d) 50°C

138 A copper block of mass 2.5 kg is heated in a furnace to a temperature of 500°C and then placed on a large ice block. Specific heat of copper is $0.39\ \text{Jg}^{-1}\text{K}^{-1}$ and heat of fusion of water is $335\ \text{Jg}^{-1}$. Maximum amount of ice that can be melted is
(a) 1 kg (b) 1.5 kg
(c) 2 kg (d) 2.5 kg

139 In an experiment on the specific heat of a metal, a 0.20 kg block of the metal at 150°C is dropped in a copper calorimeter (of water equivalent 0.025 kg) containing 150 cm^3 of water at 27°C. The final temperature is 40°C. The specific heat of the metal is

(a) $1 \text{ Jg}^{-1}\text{K}^{-1}$ (b) $1.5 \text{ Jg}^{-1}\text{K}^{-1}$
(c) $0.43 \text{ Jg}^{-1}\text{K}^{-1}$ (d) $0.8 \text{ Jg}^{-1}\text{K}^{-1}$

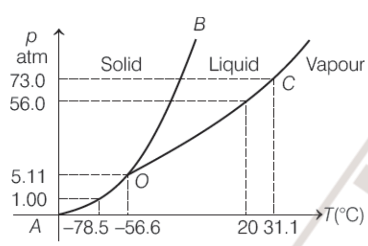
140 A brass boiler has a base area 0.15 m^2 and thickness 1.0 cm. It boils water at the rate of 6.0 kg min^{-1} when placed on a gas stove. Estimate the temperature of the part of the flame in contact with the boiler. Thermal conductivity of brass is 109 J/s-m-K and heat of vaporisation of water is $2256 \times 10^3 \text{ J kg}^{-1}$.

(a) 205°C (b) 268°C
(c) 238°C (d) 280°C

141 A body cools from 80°C to 50°C in 5 min. Calculate the time it takes to cool from 60°C to 30°C, if the temperature of the surroundings is 20°C.

(a) 7 min (b) 9 min
(c) 16 min (d) 20 min

142 p-T phase diagram for CO_2 gas is given. Which of these are correct according to p-T graph?



I. CO_2 at 1 atm and – 60° C is compressed isothermally, it is eventually converted to liquid form.
II. When CO_2 at 4 atm is cooled from room temperature at constant pressure, it is condensed to solid without passing through liquid phase.
III. CO_2 at 10 atm and – 65° C is heated, it turns to liquid then into vapour.
IV. CO_2 is compressed at 70°C isothermally, it becomes liquid and then solid.

(a) Both I and II (b) Both II and III
(c) Both III and IV (d) I, II, III and IV

NCERT Exemplar

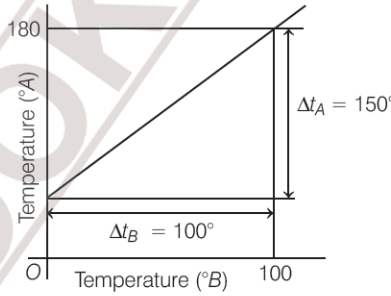
143 A bimetallic strip is made of aluminium and steel ($\alpha_{Al} > \alpha_{steel}$). On heating, the strip will

(a) remain straight
(b) get twisted
(c) bend with aluminium on concave side
(d) bend with steel on concave side

144 A uniform metallic rod rotates about its perpendicular bisector with constant angular speed. If it is heated uniformly to raise its temperature slightly, then

(a) its speed of rotation increases
(b) its speed of rotation decreases
(c) its speed of rotation remains same
(d) its speed increases because its moment of inertia increases

145 The graph between two temperature scales A and B is shown in figure between upper fixed point and lower fixed point. There are 150 equal division on scale A and 100 on scale B. The relationship for conversion between the two scales is given by



(a) $\frac{t_A - 180}{100} = \frac{t_B}{150}$ (b) $\frac{t_A - 30}{150} = \frac{t_B}{100}$
(c) $\frac{t_B - 180}{150} = \frac{t_A}{100}$ (d) $\frac{t_B - 40}{100} = \frac{t_A}{180}$

146 An aluminium sphere is dipped into water. Which of the following is true?

(a) Buoyancy will be less in water at 0°C than that in water at 4°C.
(b) Buoyancy will be more in water at 0°C than that in water at 4°C.
(c) Buoyancy in water at 0°C will be same as that in water at 4°C.
(d) Buoyancy may be more or less in water at 4°C depending on the radius of the sphere.

147 As the temperature is increased, the period of a pendulum

(a) increases as its effective length increases even though its centre of mass still remains at the centre of the bob
(b) decreases as its effective length increases even though its centre of mass still remains at the centre of the bob
(c) increases as its effective length increases due to shifting to centre of mass below the centre of the bob
(d) decreases as its effective length remains same but the centre of mass shifts above the centre of the bob

148 Heat is associated with

(a) kinetic energy of random motion of molecules
(b) kinetic energy of orderly motion of molecules
(c) total kinetic energy of random and orderly motion of molecules
(d) kinetic energy of random motion in some cases and kinetic energy of orderly motion in other

149 The radius of a metal sphere at room temperature T is R and the coefficient of linear expansion of the metal is α. The sphere heated a little by a temperature ΔT, so that its new temperature is $T + \Delta T$. The increase in the volume of the sphere is approximately

(a) $2\pi R\alpha\Delta T$ (b) $\pi R^2\alpha\Delta T$

(c) $4\pi R^3\alpha\Delta T / 3$ (d) $4\pi R^3\alpha\Delta T$

150 100 g of water is supercooled to $-10°$C. At this point, due to some disturbance mechanised or otherwise some of it suddenly freezes to ice. What will be the temperature of the resultant mixture and how much mass would freeze?

($s_w = 1\,\text{cal/g°C}$ and $L_{w(\text{Fusion})} = 80\,\text{cal/g}$)

(a) 0°C, 12.5 g (b) 20°C, 50 g

(c) 30°C, 30 g (d) 50°C, 10 g

151 Find out the increase in moment of inertia I of a uniform rod (coefficient of linear expansion α) about its perpendicular bisector when its temperature is slightly increased by ΔT.

(a) $2I\alpha\Delta T$ (b) $4I\alpha\Delta T$

(c) $6I\alpha\Delta T$ (d) $3I\alpha T$

152 Calculate the stress developed inside a tooth cavity filled with copper when hot tea at temperature of 57°C is drunk. You can take body (tooth) temperature to be 37°C, $\alpha = 1.7 \times 10^{-5}$/°C and bulk modulus for copper is $140 \times 10^9\ \text{Nm}^{-2}$.

(a) $5 \times 10^4\ \text{Nm}^{-2}$

(b) $3 \times 10^2\ \text{Nm}^{-2}$

(c) $1.428 \times 10^8\ \text{Nm}^{-2}$

(d) $3.46 \times 10^5\ \text{Nm}^{-2}$

Answers

> Mastering NCERT with MCQs

1 (d)	2 (a)	3 (c)	4 (d)	5 (a)	6 (b)	7 (d)	8 (d)	9 (a)	10 (c)
11 (b)	12 (b)	13 (c)	14 (d)	15 (c)	16 (a)	17 (c)	18 (b)	19 (b)	20 (a)
21 (a)	22 (c)	23 (c)	24 (c)	25 (c)	26 (b)	27 (b)	28 (d)	29 (b)	30 (b)
31 (c)	32 (a)	33 (a)	34 (a)	35 (d)	36 (b)	37 (b)	38 (c)	39 (b)	40 (a)
41 (c)	42 (c)	43 (b)	44 (c)	45 (d)	46 (b)	47 (b)	48 (b)	49 (d)	50 (b)
51 (c)	52 (a)	53 (d)	54 (a)	55 (a)	56 (b)	57 (d)	58 (d)	59 (b)	60 (d)
61 (a)	62 (b)	63 (c)	64 (b)	65 (a)	66 (a)	67 (b)	68 (b)	69 (d)	70 (c)
71 (a)	72 (b)	73 (d)	74 (c)	75 (d)	76 (b)	77 (b)	78 (c)	79 (d)	80 (a)
81 (b)	82 (d)	83 (a)	84 (c)	85 (a)	86 (a)	87 (d)	88 (c)	89 (b)	90 (c)
91 (c)	92 (a)	93 (d)	94 (a)	95 (d)	96 (a)				

> Special Types Questions

97 (d)	98 (d)	99 (b)	100 (d)	101 (d)	102 (c)	103 (d)	104 (a)	105 (a)	106 (a)
107 (c)	108 (c)	109 (c)	110 (c)	111 (c)	112 (a)	113 (d)	114 (d)	115 (b)	116 (d)
117 (d)	118 (b)	119 (b)	120 (d)	121 (b)	122 (a)	123 (a)	124 (a)	125 (b)	126 (c)
127 (a)	128 (a)	129 (c)							

> NCERT & NCERT Exemplar MCQs

130 (b)	131 (b)	132 (c)	133 (b)	134 (a)	135 (b)	136 (b)	137 (b)	138 (b)	139 (c)
140 (c)	141 (b)	142 (b)	143 (d)	144 (b)	145 (b)	146 (a)	147 (a)	148 (a)	149 (d)
150 (a)	151 (a)	152 (c)							

Hints & Explanations

1 (*d*) When the temperature of a body and its surrounding medium are different, then heat transfer takes place between them.

The direction of heat flow depends on the surrounding temperature with respect to that of body.

In given case, the ice-cold water having lower temperature than the surrounding, when left on a table on a hot summer day takes heat from surrounding and warms up, whereas a cup of tea having higher temperature than surrounding cools down by releasing heat to surrounding.

Thus, both the statements given in options (a) and (b) are correct.

4 (*d*) It is given that on a hilly region, water boils at 95° C.

$\therefore$ Temperature in centigrade, $C = 95°$ C.

So, the temperature in Fahrenheit can be calculated,

By using relation $\frac{F-32}{180} = \frac{C}{100}$, we get

$$\frac{F-32}{9} = \frac{95}{5} \qquad (\because C = 95°\text{C})$$

$$\Rightarrow \quad F - 32 = 9 \times 19$$

$$\Rightarrow \quad F - 32 = 171$$

$$\Rightarrow \quad F = 171 + 32 = 203°\text{F}$$

5 (*a*) Using relation,

$$\frac{F-32}{180} = \frac{C}{100} \qquad \text{...(i)}$$

If $F = C = x$, then substituting value in Eq. (i), we get

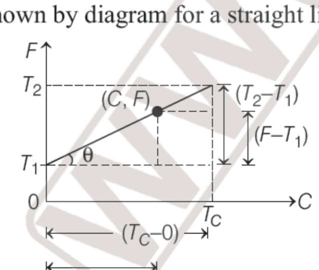
$$\Rightarrow \quad \frac{x-32}{180} = \frac{x}{100} \Rightarrow \frac{x}{5} = \frac{x-32}{9}$$

$$\Rightarrow \quad 9x = 5x - 160 \Rightarrow 160 = -4x$$

$$\therefore \quad x = -40°$$

This is the required temperature at which centigrade and Fahrenheit scale give same reading.

6 (*b*) The relationship for conversion between two scales, can be shown by diagram for a straight line as



The slope of graph is given by

$$\tan\theta = \frac{T_2 - T_1}{T_C - 0} = \frac{T_2 - T_1}{T_C} \qquad \text{...(i)}$$

Similarly, for any arbitrary point (C, F), it is given by

$$\tan\theta = \frac{F - T_1}{C - 0} = \frac{F - T_1}{C} \qquad \text{...(ii)}$$

From Eqs. (i) and (ii), we get

$$\frac{T_2 - T_1}{T_C} = \frac{F - T_1}{C} \Rightarrow \frac{F - T_1}{T_2 - T_1} = \frac{C}{T_C}$$

This is the required relation between F and C. Hence, option (b) is correct.

7 (*d*) Let initial temperature in Fahrenheit and Celsius scales be F_1 and C_1, respectively and the final temperature be F_2 and C_2, respectively.

From relation, $\frac{F-32}{180} = \frac{C}{100}$ or $\frac{F_1 - 32}{180} = \frac{C_1}{100}$ ...(i)

or $$\frac{F_2 - 32}{180} = \frac{C_2}{100} \qquad \text{...(ii)}$$

Subtracting Eq. (i) from Eq. (ii), we get

$$\frac{F_2 - 32 - F_1 - 32}{180} = \frac{C_2 - C_1}{100}$$

$$\frac{F_2 - F_1}{180} = \frac{C_2 - C_1}{100}$$

Given, $\quad C_2 - C_1 = 30°$ C

$$\Rightarrow \quad F_2 - F_1 = \frac{180}{100} \times 30° \text{ C} = 54° \text{F}$$

$\therefore$ The increase in temperature on Fahrenheit scale is 54°.

8 (*d*) By principle of thermometry for any liner temperature scale,

$$\frac{T - T_{\text{LFP}}}{T_{\text{UFP}} - T_{\text{LFP}}} = \text{a (constant)}$$

where,

T = temperature measured

T_{LFP} = temperature of melting ice or lower fixed point.

T_{UFP} = temperature of boling water or upper fixed point.

If, T = temperature of given object.

Then we have,

$$\frac{T - 0°\text{C}}{100°\text{C} - 0°\text{C}} = \frac{\frac{x_0}{2} - \frac{x_o}{3}}{x_0 - \frac{x_0}{3}}$$

or $$\frac{T}{100} = \frac{1}{4} \text{ or } T = 25°\text{ C}$$

9 (*a*) As per the question, the triple point of water is 273.16 K on Kelvin scale, 400 *A* on scale *A* and 300 *B* on scale *B*, so

$$273.16 \text{ K} = 400\,A = 300\,B$$

$$\Rightarrow \quad A = \frac{273.16}{400}\text{K and } B = \frac{273.16}{300}\text{K}$$

If T_A and T_B be the triple points of water, then

$$\frac{273.16}{400}T_A = \frac{273.16}{300}T_B$$

$$\Rightarrow \quad \frac{T_A}{T_B} = \frac{400}{300} \Rightarrow T_A = \frac{4}{3}T_B$$

12 (b) Using ideal gas equation, holding the volume of a gas constant, it gives $p \propto T$. Thus, with a constant volume gas thermometer, temperature is read in terms of pressure.

13 (c) According to ideal gas equation,

$$pV = nRT \quad \ldots(i)$$

where, R = gas constant.

Since, moles are changing but volume is constant.

Eq. (i) can be written as

$$\frac{p}{nT} = \frac{R}{V} = \text{constant}$$

$$\Rightarrow \quad \frac{p_1}{n_1 T_1} = \frac{p_2}{n_2 T_2} \Rightarrow n_2 = \frac{n_1 T_1 p_2}{T_2 p_1}$$

where, p_1, p_2 are the initial and final pressure of gas and T_1 and T_2 are initial and final temperature of gas.

15 (c) Absolute temperature is the zero point on Kelvin scale, i.e. 0 K which corresponds to $-273.15°$ C, i.e. $t_c = 273.15°$ C or $-273°$ C.

The relation between Celsius and Fahrenheit scale is

$$\frac{t_F - 32}{180} = \frac{t_C}{100}$$

$$\Rightarrow \quad t_F = \frac{9}{5} t_C + 32 = \frac{9}{5}(-273) + 32$$

$$\simeq -460° \text{ F}$$

17 (c) A change in temperature of a body causes a change in dimensions. So, due to this reason, air inside the balloon contracts due to cooling and therefore, a fully inflated balloon walls shrink, when it is put into cold water.

18 (b) The metal X has a higher coefficient of expansion compared to that of metal Y, so on placing bimetallic strip in a cold bath, X will shrink more than Y. Hence, the strip will bend towards the left.

19 (b) Given, $L_1 = 10$ cm, $L_2 = ?$

$$\theta_1 = 20° \text{C}, \theta_2 = 19° \text{C}$$

and $\alpha = 11 \times 10^{-6} \, °\text{C}^{-1}$.

According to linear expansion, we get

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

$$\frac{L_1}{L_2} = \frac{1 + \alpha (\Delta\theta_1)}{1 + \alpha (\Delta\theta_2)}$$

$$\frac{10}{L_2} = \frac{1 + 11 \times 10^{-6} \times 20}{1 + 11 \times 10^{-6} \times 19}$$

$$\Rightarrow \quad L_2 = 9.99989 \text{ cm}$$

Shortness in length $= 10 - 9.99989 = 0.00011$

$$= 11 \times 10^{-5} \text{ cm}$$

20 (a) Initial temperature at which steel tape is corrected $= 20°$ C. Temperature when the distance between the two points is 26 m $= 35°$ C.

Let T be the rise in temperature from correct value, then

$$T = 35° \text{C} - 20° \text{C} = 15° \text{C}$$

Using the relation,

Measured length = Correct length $\times (1 + \alpha_l T)$

where, α_l = coefficient of linear expansion

$= 1.2 \times 10^{-5} / °\text{C}$ for steel (given)

$$\Rightarrow \quad 26 = l(1 + 1.2 \times 10^{-5} \times 15)$$

$$l = \frac{26}{1.00018} = 25.9952 \text{ m}$$

Thus, the true distance between the points is 25.9952 m.

21 (a) Let initial length of identical rods is l_0 Thermal expansion in length of rod due to heating is given by the relation

$$\Delta l = l_0 \, \alpha \, (\Delta T) = l_0 \, \alpha \, (T_2 - T_1)$$

Here, α is coefficient of linear expansion.

So, change in length of rods are

$$\Delta l_1 = l_0 \, \alpha_1 (180 - 30)$$

$$\Delta l_2 = l_0 \alpha_2 (T - 30)$$

Because new lengths are same, so change in lengths of both rods are equal.

i.e. $\Delta l_1 = \Delta l_2$

$\Rightarrow \quad l_0 \, \alpha_1 \, (180 - 30) = l_0 \, \alpha_2 \, (T - 30)$

or $\quad \dfrac{\alpha_1}{\alpha_2} = \dfrac{(T - 30)}{150}$

Given, $\alpha_1 : \alpha_2 = 4 : 3$

$\therefore \quad \dfrac{T - 30}{150} = \dfrac{4}{3} \Rightarrow T - 30 = \dfrac{4}{3} \times 150 = 200$

or $\quad T = 200 + 30 = 230°\text{C}$

22 (c) Due to change in temperature, the thermal strain produced in a rod of length L is given by

$$\frac{\Delta L}{L} = \alpha \, \Delta T \Rightarrow \Delta L = L \alpha \, \Delta T$$

where, L = original length of rod and α = coefficient of linear expansion of solid rod.

As the change in length (ΔL) of the given two rods of copper and aluminium are independent of temperature change, i.e. ΔT is same for both copper and aluminium.

$$\Rightarrow \quad L_{\text{Cu}} \alpha_{\text{Cu}} = L_{\text{Al}} \alpha_{\text{Al}} \quad \ldots (i)$$

Here, $\alpha_{\text{Cu}} = 1.7 \times 10^{-5} \text{ K}^{-1}$, $\alpha_{\text{Al}} = 2.2 \times 10^{-5} \text{ K}^{-1}$

and $L_{\text{Cu}} = 88$ cm

Substituting the given values in Eq. (i), we get

$$L_{\text{Al}} = \frac{L_{\text{Cu}} \alpha_{\text{Cu}}}{\alpha_{\text{Al}}} = \frac{88 \times 1.7 \times 10^{-5}}{2.2 \times 10^{-5}} \simeq 68 \text{ cm}$$

23 (c) Here, $\Delta T = ?$, $\dfrac{\Delta L}{L} = \dfrac{1}{100}$, $\alpha = 0.00002° \text{ C}^{-1}$

As, $\quad \Delta L = \alpha L \Delta T$

$\therefore \quad \alpha \Delta T = \dfrac{\Delta L}{L}$ or $\Delta T = \dfrac{\Delta L}{L\alpha} = \dfrac{1}{100 \times 0.00002}$

$$\Delta T = \frac{10^5}{2 \times 10^2} = 500°\text{C}$$

So, $500°$ C of temperature of a brass rod should be increased, so as to increase its length by 1%.

24 (*c*) Given, change in length of rod of aluminium = change in length of rod of steel, i.e. $\Delta l_1 = \Delta l_2$

or $l_1 \alpha_a t = l_2 \alpha_s t$

$\therefore \quad \dfrac{l_1}{l_2} = \dfrac{\alpha_s}{\alpha_a}$ or $\dfrac{l_1}{l_1 + l_2} = \dfrac{\alpha_s}{\alpha_a + \alpha_s}$ ...(i)

So, Eq. (i) shows, if the length of each rod increases, by same amount when their temperatures we raised by $t°$ C, then the ratio of their length $= \dfrac{\alpha_s}{\alpha_a + \alpha_s}$.

where, α_a and α_s are coefficients of linear expansion for aluminium and steel.

Thus, option (c) is correct.

25 (*c*) α_V is a characteristic of the substance but is not strictly a constant. It depends in general on temperature as shown in figure (c). It is seen that α_V becomes constant only at a higher temperature. Hence, option (c) is correct.

26 (*b*) Given, $\alpha_V = 49 \times 19^{-5}\,°\text{C}^{-1}$

$$\Delta T = 30°\text{ C}$$

$$V' = V + \Delta V = V(1 + \alpha_V \Delta T)$$

$\therefore \quad V' = V\,(1 + 49 \times 10^{-5} \times 30) = 1.0147\,V$

$\because \quad \rho = \dfrac{m}{V}$ and $\rho' = \dfrac{m}{V'} = \dfrac{m}{1.0147V} = 0.9855\,\rho$

Hence, fractional change in density

$$= \frac{\rho - \rho'}{\rho} = \frac{\rho - 0.9855\,\rho}{\rho} = 0.0145$$

27 (*b*) Given, the value of coefficient of volume expansion of glycerin is $5 \times 10^{-4}\ \text{K}^{-1}$.

As mass, $m = \rho V \Rightarrow \rho = \dfrac{m}{V}$

$\therefore \quad \dfrac{\Delta \rho}{\rho} = -\dfrac{\Delta V}{V} = -\alpha_V \Delta T \quad \left(\because \dfrac{\Delta V}{V} = \alpha_V \Delta T\right)$

$\Rightarrow \quad \dfrac{\Delta \rho}{\rho} = -5 \times 10^{-4} \times 40 = -0.020$

or $\quad \left|\dfrac{\Delta \rho}{\rho}\right| = 0.020$

Thus, the required fractional change in density of glycerin is 0.020.

28 (*d*) For an ideal gas, the coefficient of volume expansion at constant pressure can be found from the ideal gas equation, $\quad pV = \mu RT$ ...(i)

At constant pressure, $p\Delta V = \mu R\,\Delta T$ ...(ii)

Divide Eq. (ii) by Eq. (i), we get

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

Also, $\quad \dfrac{\Delta V}{V} = \alpha_V \Delta T$

i.e. $\quad \alpha_V = \dfrac{1}{T}$, for ideal gas

So, for an ideal gas, coefficient of volume expansion is given by $\dfrac{1}{T}$.

30 (*b*) Water contracts when it is heated from 0°C to 4°C. Thus, its density increases and volume decreases. Density of water is maximum at 4°C and hence, volume is minimum. When the water is further heated, it expands and volume thus increases.

So, the graph given in option (b) shows the correct variation of volume of water.

31 (*c*) Ice formed floats over surface, it exerts pressure over and below the water which causes lowering of freezing point and ice layer on top also acts like an insulator. So, bottom of lake remains in liquid state due to above reason. Hence, the animal and plant life of Dal-lake survives as only top layer of lake in frozen.

32 (*a*) Thermal strain in the wire, $\dfrac{\Delta l}{l} = \alpha\,\Delta T$

The corresponding stress is, $Y \times \text{strain} = Y\alpha\,\Delta T$

The tension F developed in the wire is

$$F = \text{Stress} \times \text{Cross-sectional area}$$
$$= Y\alpha\Delta T \times A = YA\alpha\Delta T$$

Here, $A = \pi r^2 = 3.14\,(1.0 \times 10^{-3}\ \text{m})^2 = 3.14 \times 10^{-6}\ \text{m}^2$

and $\quad \Delta T = 27° - (-39°) = 66°\text{ C}$

$\therefore \quad F = (0.91 \times 10^{11}\ \text{Nm}^{-2})\,(3.14 \times 10^{-6}\ \text{m}^2)\,(2.0 \times 10^{-5}\,°\text{C}^{-1})\,(66°\text{ C})$

$$= 377\ \text{N} = 3.77 \times 10^2\ \text{N}$$

33 (*a*) Given, $\dfrac{\alpha_2}{\alpha_1} = \dfrac{3}{2}$

Thermal stress $= Y\alpha\ \Delta T$

where, Y is Young's modulus, α is the coefficient of linear expansion and ΔT is the change in temperature.

Both the rods are heated, for equal stresses,

$\therefore \quad Y_1 \alpha_1 \Delta T_1 = Y_2 \alpha_2 \Delta T_2$

Since, $\quad \Delta T_1 = \Delta T_2 \Rightarrow \dfrac{Y_1}{Y_2} = \dfrac{\alpha_2}{\alpha_1} = \dfrac{3}{2}$

34 (*a*) Given, $L = 3$ m, $d = 1$ mm $\Rightarrow r = \dfrac{1}{2} \times 10^{-3}$ m

and $m = 10$ kg

The contraction in the length of the wire due to change in temperature is given as

$$\Delta L_1 = \alpha L \Delta T = 1.2 \times 10^{-5} \times 3 \times (-170 - 30)$$
$$= -\,7.2 \times 10^{-3}\ \text{m}$$

$$A = 3.14 \times \left(\frac{1}{2} \times 10^{-3}\right)^2 \approx 0.75 \times 10^{-6}\text{m}^2$$

The expansion in the length of wire due to stretching force is given as

$$\Delta L_2 = \frac{FL}{AY} = \frac{mgL}{AY}$$

$$= \frac{(10 \times 10) \times 3}{(0.75 \times 10^{-6})(2 \times 10^{11})}$$

$$= 2 \times 10^{-3} \text{ m}$$

Resultant change in length,

$$\Delta L_1 + \Delta L_2 = -7.2 \times 10^{-3} + 2 \times 10^{-3}$$

$$= -5.2 \times 10^{-3}$$

$$\Delta L = -5.2 \text{ mm}$$

Negative sign shows a contraction in the length of the wire.

36 (*b*) Water has the highest specific heat capacity as compared to the other substances. For this reason, water is used as a coolant in automobile radiators as well as a heater in hot water bags.

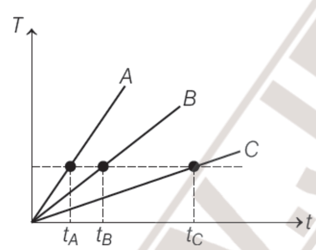
Owing to its high specific heat capacity, the water warms up much slowly than the other liquids.

37 (*b*) The heat capacity of a substance is $S = \frac{\Delta Q}{\Delta T}$.

The heat capacity of mustard oil is less than that of water for same mass. So, same temperature rise ($\Delta T = 40°$ C), the quantity of heat (ΔQ) would be less than that is required by the same amount of water.

Hence, the time taken by water (t_1) to heat upto 40°C will be higher than that of mustard oil (t_2), i.e. $t_1 > t_2$.

38 (*c*) Substances having more heat capacity take longer time to get heated to a higher temperature and longer time to get cooled.



If we draw a line parallel to the time axis, then it cuts the given graphs at three different points, i.e. A, B and C. Corresponding points on the time axis show that

$$t_C > t_B > t_A \quad \text{...(i)}$$

Heat capacity, $S = \frac{\Delta Q}{\Delta t}$

As ΔQ is same, so $S \propto \frac{1}{\Delta t}$ ...(ii)

So, from relation (i) and (ii), we can say that

$$\therefore \quad S_C < S_B < S_A$$

Hence, substance C has lowest heat capacity.

39 (*b*) Given, $m = 60$ kg $= 60 \times 10^3$ g, $s = 0.83$ cal g^{-1} °C^{-1}

$$Q = 200 \text{ kcal} = 2 \times 10^5 \text{ cal}$$

Amount of heat required for a person,

$$\because \quad Q = ms\Delta T$$

$$\Rightarrow \quad \Delta T = \frac{Q}{ms} = \frac{2 \times 10^5}{60 \times 10^3 \times 0.83}$$

$$= 4.01° \text{C}$$

So, the person's temperature increases by 4.01° C. So, option (b) is correct.

40 (*a*) The amount of heat supplied is given by the relation,

$$Q = ms\Delta T$$

Given, $m = 100$ g $= 0.1$ kg, $s = 400$ Jkg^{-1}K^{-1}

As the change in temperature on any scale is equal, so

$$\Delta T = 21° \text{C} = 21° \text{K}$$

Thus, $Q = 0.1 \times 400 \times 21 = 840$ J

Hence, $840 = 0.05 \times 4200 \times \Delta T$

$\Rightarrow \quad \Delta T = 4°$ K $= 4°$ C

Therefore, the rise in the temperature of water is 4° C.

41 (*c*) Total heat supplied to sample, $\Delta Q = 300$ J and rise in temperature, $\Delta T = T_2 - T_1$

$$= 45° \text{C} - 25° \text{C} = 20° \text{C}$$

Heat capacity of substance $= \frac{\Delta Q}{\Delta T} = \frac{300}{20} = 15$ J°C^{-1}

As mass of sample, $m = 25$ g $= 0.025$ kg

Specific heat capacity, $s = \frac{1}{m} \cdot \frac{\Delta Q}{\Delta T} = \frac{1}{0.025} \times 15$

$$= 600 \text{ Jkg}^{-1} \text{°C}^{-1}$$

As the substance has a mass of 50 g /mol, hence number of moles in 25 g sample,

i.e. $\mu = \frac{25}{50} = 0.5$ mol

Molar heat capacity, $C = \frac{1}{\mu} \cdot \frac{\Delta Q}{\Delta T} = \frac{1}{0.5} \times 15$

$$= 30 \text{ Jmol}^{-1} \text{C}^{-1}$$

Among the given options, option (c) is correct.

42 (*c*) By principle of calorimetry method, we know heat lost by hot body = heat gained by cold body

$$\therefore \quad m_1 s_1 (\theta_1 - \theta) = m_2 s_2 (\theta - \theta_2)$$

$$m_1 s_1 \theta_1 - m_1 s_1 \theta = m_2 s_2 \theta - m_2 s_2 \theta_2$$

$$\Rightarrow \quad m_1 s_1 \theta_1 + m_2 s_2 \theta_2 = (m_1 s_1 + m_2 s_2)\theta$$

$$\Rightarrow \quad \theta = \frac{m_1 s_1 \theta_1 + m_2 s_2 \theta_2}{m_1 s_1 + m_2 s_2}$$

As it is given that, masses and specific heat capacity of both bodies are equal.

So, when $m_1 = m_2$ and $s_1 = s_2$, then

$$\theta = \frac{\theta_1 + \theta_2}{2}$$

Hence, $\theta = \frac{\theta_1 + \theta_2}{2}$, under the condition $m_1 = m_2$ and $s_1 = s_2$.

43 (*b*) Given, $m_1 = 2.4$ kg, $m_2 = 1.6$ kg, $m_3 = 0.8$ kg

$s_1 = 0.216$ cal $kg^{-1}\,°C^{-1}$, $s_2 = 0.0917$ cal $kg^{-1}\,°C^{-1}$,

$s_3 = 0.0931$ cal $kg^{-1}\,°C^{-1}$

and $\Delta T = T_2 - T_1 = (80 - 20)°C = 60°C$

$$Q = m_1 s_1 \,\Delta\theta + m_2 s_2 \,\Delta\theta + m_3 s_3 \,\Delta T$$
$$= (2.4 \times 0.216 + 1.6 \times 0.0917 + 0.8 \times 0.0931)\,(60)$$
$$= 44.376 \text{ cal} \approx 44.4 \text{ cal}$$

44 (*c*) By applying calorimetry method, we get

Heat gain = Heat lost

When liquids A and B are mixed, then

$$s_A\,(16 - 12) = s_B\,(19 - 16) \Rightarrow \frac{s_A}{s_B} = \frac{3}{4}$$

and when liquids B and C are mixed, then

$$s_B\,(23 - 19) = s_C\,(28 - 23)$$
$$\Rightarrow \quad \frac{s_B}{s_C} = \frac{5}{4}$$
$$\Rightarrow \quad \frac{s_A}{s_C} = \frac{s_A}{s_B} \times \frac{s_B}{s_C} = \frac{3}{4} \times \frac{5}{4} = \frac{15}{16} \quad \ldots\text{(i)}$$

If θ is the temperature when A and C are mixed, then

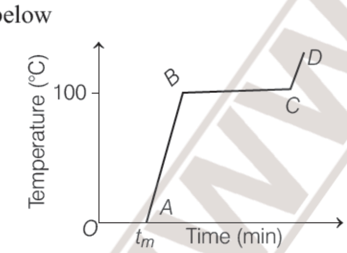
$$s_A\,(\theta - 12) = s_C\,(28 - \theta)$$
$$\Rightarrow \quad \frac{s_A}{s_C} = \frac{28 - \theta}{\theta - 12} \quad \ldots\text{(ii)}$$

On solving Eqs. (i) and (ii), we have

$$\frac{28 - \theta}{\theta - 12} = \frac{15}{16}$$
$$\Rightarrow \quad 448 - 16\theta = 15\theta - 180$$
$$\therefore \quad \theta = 20.2°C$$

So, when liquids A and B are mixed, then the temperature is 20.2° C.

45 (*d*) A plot of temperature *versus* time showing the changes in the state of ice on heating (not to scale), is given below



In graph, the transition from O to A represents the conversion of solid (or ice) at 0°C to liquid (or water) at 0°C. So, temperature remains constant with time for change of state.

In transition from A and B, the water at 0°C is heated to water at 100°C, so temperature increases with time as shown.

In transition from B to C, the water at 100°C is converted to steam at 100°C, so temperature remains constant with time for change of state.

In transistion from C to D, the temperature of steam at 100°C increases with time.

46 (*b*) The wire passes through the ice slab. This happens due to the fact that just below the wire, ice melts to water at lower temperature due to increase in pressure.

When the wire has passed the slab, water above the wire freezes again due to the low temperature of ice. Thus, the slab does not split. This phenomenon of freezing is called regelation.

47 (*b*) When pressure is increased, boiling point is elevated, i.e. at higher pressure, water boils at temperature greater than 100°C. Similarly, at reduced pressure, water boils at a lower temperature.

49 (*d*) The cooking is difficult on hills, because at high altitudes, atmospheric pressure is lower. This reduces the boiling point of water as compared to that at sea level.

When boiling point reduces, lesser heat is transmitted to the raw food, so it takes more time to cook it.

Hence, options (b) and (c) are correct.

50 (*b*) The point on the sublimation curve OA represents states in which the solid and vapour phases co-exist. Points on the fusion curve AB represents states in which solid and liquid phase co-exist.

Points on the vaporisation curve AC represents states in which the liquid and vapour phases co-exist.

Therefore, in the given graph, the curves OA, AB and AC are respectively sublimation curve, fusion curve and vaporisation curve.

52 (*a*) As more energy is required for enormous expansion, so latent heat of vaporisation of a substance is always greater than latent heat of fusion.

53 (*d*) For water, the latent heat of fusion and vaporisation are $L_F = 3.33 \times 10^5$ J kg^{-1} and $L_V = 22.6 \times 10^5$ J kg^{-1}, respectively, i.e. 3.33×10^5 J of heat is needed to melt 1 kg of ice at 0°C and 22.6×10^5 J of heat is needed to convert 1 kg of water to steam at 100°C.

So, steam at 100°C carries 22.6×10^5 Jkg^{-1} more heat than water at 100°C. This is why burns from steam are usually more serious than those from boiling water.

54 (*a*) Heat required for melting of 1g of ice,

$$Q = mL = \frac{1}{1000} \times 3.36 \times 10^5 = 336 \text{ J}$$

Heat used for raising temperature of m gram ice from $-5°C$ to 0°C,

$$\Delta Q = 420 - 336 = 84 \text{ J}$$

But $\quad \Delta Q = ms\Delta T$

$$\Rightarrow \quad 84 = m \times 2100 \times 5$$
$$m = 0.008 \text{ kg} = 8 \text{ g}$$

Since, there is no other exchange of heat in the process, therefore the required value of m is 8g.

55 (*a*) Given, mass of ice, $m_i = 0.15$ kg

Temperature of ice, $\theta_i = 0°C$

Mass of water, $m_w = 0.30$ kg

Temperature of water, $\theta_w = 50°C$

Final temperature of mixture, $\theta_f = 6.7° C$

Specific heat of water, $s_w = 4186 \, Jkg^{-1}K^{-1}$

Heat lost by water $= m_i s_w \, (\theta_i - \theta_F)_w$

$= (0.30 \text{ kg}) \, (4186 \text{ J kg}^{-1} \text{ K}^{-1}) \, (50.0°C - 6.7°C)$

$= 54376.14$ J

Heat required to melt ice $= m_i L_F = (0.15 \text{ kg}) \, L_F$

Heat required to raise temperature of ice water to final temperature $= m_i s_w \, (\theta_F - \theta_i)_F$

$= (0.15 \text{ kg}) \, (4186 \text{ J kg}^{-1}\text{K}^{-1}) \, (6.7°C - 0°C)$

$= 4206.93$ J

According to the principle of calorimetry,

Heat lost = Heat gained

$54376.14 \text{ J} = (0.15 \text{ kg}) \, L_F + 4206.93 \text{ J}$

$L_F = 3.34 \times 10^5 \text{ Jkg}^{-1}$

56 (*b*) Mass of the ice, $m = 3$ kg

Specific heat capacity of ice, $s_i = 2100 \, Jkg^{-1}K^{-1}$

Specific heat capacity of water, $s_w = 4186 \text{ J kg}^{-1}\text{K}^{-1}$

Latent heat of fusion of ice, $s_i = 3.35 \times 10^5 \, Jkg^{-1}$

Latent heat of steam, $L_s = 2.256 \times 10^6 \, Jkg^{-1}$

Now, Q = heat required to convert 3 kg of ice at –12°C to steam at 100°C.

Q_1 = Heat required to convert ice at –12°C to ice at 0° C

$= ms_i \, \Delta T_1 = 3 \times 2100 \times [0 - (-12)]° C = 75600 J$

Q_2 = Heat required to melt ice at 0°C to water at 0°C.

$= m L_i = 3 \times (3.35 \times 10^5 \, Jkg^{-1}K^{-1}) = 1005000 J$

Q_3 = Heat required to convert water at 0° C to water at 100°C.

$= ms_w \Delta T_2 = (3 \text{ kg})(4186 \text{ J kg}^{-1}\text{K}^{-1}) \times (100° C)$

$Q_3 = 1255800$ J

Q_4 = Heat required to convert water at 100°C to steam at 100°C

$= mL_s$

$= 3 \times (2.256 \times 10^6 \, Jkg^{-1}K^{-1}) = 6768000 J$

So, $Q = Q_1 + Q_2 + Q_3 + Q_4$

$= 75600J + 1005000J + 1255800J + 6768000J$

$= 9.1 \times 10^6$ J

59 (*b*) Given, $A = 1000 \text{ cm}^2, x = 0.4$ cm

$T_1 - T_2 = 37 - (-5) = 42° C$

$K = 2.2 \times 10^{-3} \text{ cal s}^{-1} \text{ cm}^{-1} \text{ K}^{-1}$

Rate of loss of heat $= H = \dfrac{Q}{t} = \dfrac{KA \, (T_1 - T_2)}{x}$

$$= \frac{2.2 \times 10^{-3} \text{cal s}^{-1}\text{cm}^{-1}\text{K}^{-1} \times 1000 \text{ cm}^2 \times 42° C}{0.4 \text{ cm}}$$

$= 231 \text{ cal s}^{-1}$

60 (*d*) The two ends of a rod are maintained at temperatures 100° C and 110° C.

Given, $\Delta T_1 = 110° C - 100° C = 10° C$

$$\frac{dQ_1}{dt} = 4 \text{ Js}^{-1}$$

$$\Delta T_2 = 210 - 200 = 10° C$$

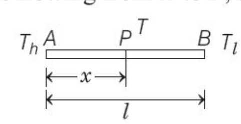
$$\frac{dQ_2}{dt} = ?$$

As the rate of heat flow is directly proportional to the temperature difference and the temperature difference in both cases is same, i.e. 10° C. So, the same rate of heat will flow in the second case.

Hence, $\dfrac{dQ_2}{dt} = 4 \text{ Js}^{-1}$

So, if the ends of the rod are maintained at temperatures 200°C and 210°C, then the rate of heat flow will remain same, i.e. $4 Js^{-1}$.

61 (*a*) As, heat is flowing from A to B, so



where, T_h = higher temperature

and T_l = lower temperature.

Heat current, $H = \dfrac{\Delta Q}{\Delta t} = \dfrac{KA(T_h - T_l)}{l} = \dfrac{KA(T_h - T)}{x}$

$$\Rightarrow \frac{x}{l}(T_h - T_l) = T_h - T \Rightarrow T = T_h - \left(\frac{T_h - T_l}{l}\right)x$$

Hence, T decreases linearly with x from T_h to T_l.

62 (*b*) Suppose area of the bottom of the tank $= A \text{ cm}^2$

Volume of water that vaporises in 9 min (or 540 s)

$= (A \times 1) \text{cm}^3$

Mass of water that vaporises in 540 s

$= A \text{ cm}^3 \times 1 \text{ g cm}^{-3} = A$ g

$\therefore \quad Q = mL = A \times 540$ cal

But $\quad Q = \dfrac{KA \, (T_1 - T_2)}{x} \times t$

or $\quad T_1 - T_2 = \dfrac{Qx}{KAt} = \dfrac{A \times 540 \times 2}{0.2 \times A \times 540} = 10$

Total temperature of the furnace, i.e.

$T_1 = T_2 + 10 = 100 + 10 = 110° C$

63 (*c*) If area of cross-section of a surface is not uniform or if the steady state condition is not reached, then the heat flow equation can be applied to a thin layer of material perpendicular to the direction of heat flow.

In this case, the thickness of a frozen layer in the pond at a certain instant is x.

So, the rate of heat flow by conduction for growth of ice is given by

$$\frac{dQ}{dt}=\frac{KA(\theta_0-\theta_1)}{x} \quad \ldots\text{(i)}$$

where, $dQ=\rho A dx L$, $\theta_0=0$ and $\theta_1=-\theta$

Given, $\theta_0=0°$ C and $\theta_1=-26°$ C

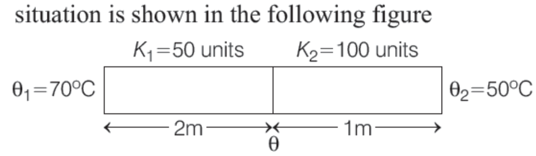
The rate of increase of thickness can be calculated from Eq. (i), we get

$$\frac{dQ}{dt}=\frac{KA(\theta_0-\theta_1)}{x}$$

$$\Rightarrow \quad \frac{\rho A dx L}{dt}=\frac{KA(\theta_0-\theta_1)}{x}$$

$$\Rightarrow \quad \frac{dx}{dt}=\frac{KA(\theta_0-\theta_1)}{\rho A x L}=\frac{K[0-(-26)]}{\rho x L}=\frac{26K}{\rho x L}$$

64 (*b*) Let θ be the junction temperature, then given situation is shown in the following figure



The rate of heat current due to conduction in both rod will be same, i.e. $H_1=H_2$

$$\Rightarrow \quad K_1\frac{A\Delta\theta_1}{l_1}=K_2\frac{A\Delta\theta_2}{l_2}$$

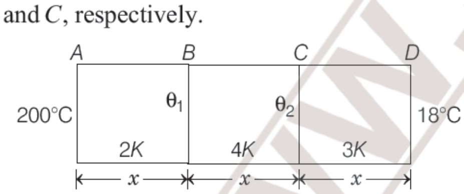
$$K_1\frac{\Delta\theta_1}{l_1}=K_2\frac{\Delta\theta_2}{l_2}$$

$$50\frac{(70-\theta)}{2}=100\frac{(\theta-50)}{1}$$

$$5\theta=270$$

$$\Rightarrow \quad \theta=54°\text{C}$$

65 (*a*) Suppose θ_1 and θ_2 be the temperatures of junctions B and C, respectively.



In the steady state, the rate of flow of heat through each bar will be same.

$$\frac{Q}{t}=\frac{2K\times A\,(200-\theta_1)}{x}=\frac{4K\times A\,(\theta_1-\theta_2)}{x}$$

$$=\frac{3K\times A\,(\theta_2-18)}{x}$$

$$2\,(200-\theta_1)=4\,(\theta_1-\theta_2)=3(\theta_2-18)$$

$$200-\theta_1=2\theta_1-2\theta_2$$

and $4\theta_1-4\theta_2=3\theta_2-54$

$\Rightarrow \quad 3\theta_1-2\theta_2=200$ and $4\theta_1-7\theta_2=-54$

Solving the given expressions for θ_1 and θ_2, we get

$$\Rightarrow \quad \theta_2=74°\text{C}$$

and $\quad \theta_1=116°\text{C}$

66 (*a*) In parallel arrangement of n rods,

Equivalent thermal conductivity is given by

$$K_{\text{eq}}=\frac{K_1A_1+K_2A_2+\ldots+K_nA_n}{A_1+A_2+\ldots+A_n}$$

If rods are of same area, then

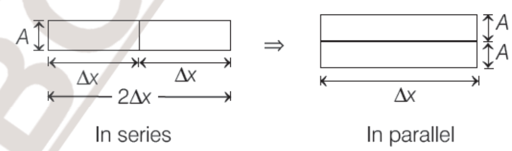
$$K_{\text{eq}}=\frac{K_1+K_2+\ldots+K_n}{n}$$

$\therefore$ Equivalent thermal conductivity of the system of two rods, $\quad K_{\text{eq}}=\dfrac{K_1+K_2}{2}$

67 (*b*) When two rods of same length are joined in parallel,

the time required for heat transfer is $\Delta t=\dfrac{\Delta Q\,(\Delta x)}{KA(\Delta T)}$

Two rods of same length, which are joined in series, when connect in parallel combination, the area of heat conduction becomes twice, i.e. $A\rightarrow 2$ times and length becomes half, i.e. $\Delta x\rightarrow\dfrac{1}{2}$ times as shown in figure.



$$\therefore \quad \frac{\Delta t_1}{\Delta t_2}=\frac{\Delta x_1}{A_1}\times\frac{A_2}{\Delta x_2}$$

$$=\frac{\Delta x_1}{\Delta x_2}\times\frac{A_2}{A_1}$$

$$=2\times2=4$$

$$\Rightarrow \quad \Delta t_2=\frac{1}{4}\Delta t_1=\frac{1}{4}\times12=3\text{ s}$$

68 (*b*) It is given that solid cylinder of radius R (made of a material of thermal conductivity K_1 is surrounded by a hollow cylinder of inner radius R and other radius $2R$ (made of material of thermal conductivity K_2).

Rate of flow of heat in the combined system = Rate of flow of heat through cross-section of inner cylinder +Rate of flow of heat through cross-section of outer cylinder

$$\Rightarrow \quad \frac{KA\,(\theta_1-\theta_2)}{l}=\frac{K_1A_1\,(\theta_1-\theta_2)}{l}+\frac{K_2A_2\,(\theta_1-\theta_2)}{l}$$

$$\Rightarrow \quad KA=K_1A_1+K_2A_2$$

$$\Rightarrow \quad K\pi\,(2R)^2=K_1\,(\pi R^2)+K_2\pi\,[(2R)^2-R^2]$$

$$\Rightarrow \quad \pi R^2\,(K\times4)=\pi R^2\,(K_1+3K_2)$$

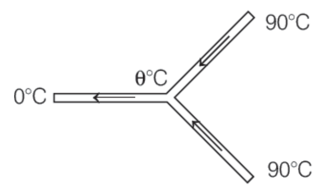
$$\therefore \quad K=\frac{K_1+3K_2}{4}$$

So, the effective thermal conductivity of the system is $\dfrac{K_1+3K_2}{4}$.

69 (*d*) Let the temperature of junction be θ, then

$$H = H_1 + H_2$$

$$\Rightarrow \quad \frac{KA(\theta - 0)}{L} = \frac{KA(90° - \theta)}{L} + \frac{KA(90° - \theta)}{L}$$



or $\theta = 90° - \theta + 90° - \theta$

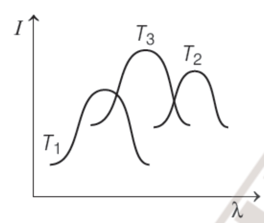
or $\theta = 180° - 2\theta$

or $3\theta = 180°$ or $\theta = 60°\,C$

72 (*b*) Black bodies absorb and emit radiant energy better than bodies of lighter colours. The bottoms of the utensils for cooking food are blackened, so that they absorb maximum heat from the fire and give it to the vegetables to be cooked.

73 (*d*) According to Wien's law, $\lambda_m \propto \frac{1}{T}$

and from the figure, $(\lambda_m)_1 < (\lambda_m)_3 < (\lambda_m)_2$



Therefore, $T_1 > T_3 > T_2$

74 (*c*) Given, temperature, $T_1 = 5760$ K

Since, it is given that energy of radiation emitted by the body at wavelength 250 nm is U_1, at wavelength 500 nm is U_2 and that at 1000 nm is U_3.

According to Wien's law, we get

$$\lambda_m T = b$$

where, b = Wien's constant $= 2.88 \times 10^6$ nm-K

$$\Rightarrow \quad \lambda_m = \frac{b}{T}$$

$$\text{or} \quad \lambda_m = \frac{2.88 \times 10^6 \text{ nm-K}}{5760 \text{ K}}$$

$$\Rightarrow \quad \lambda_m = 500 \text{ nm}$$

$\because \lambda_m$ = wavelength corresponding to maximum energy, so $U_2 > U_1$.

75 (*d*) According to Wien's displacement law,

$$\lambda_m T = b \text{ or } \lambda_m \propto \frac{1}{T} \quad \ldots\text{(i)}$$

where, b is Wien's constant, whose value is 2.9×10^{-3} mK.

Using the relation given by Eq. (i), we get

$$\frac{(\lambda_m)_s}{(\lambda_m)_f} = \frac{T_f}{T_s} \text{ or } T_f = T_s \times \frac{(\lambda_m)_s}{(\lambda_m)_f}$$

$$= 5500 \text{ K} \times \frac{(5.5 \times 10^{-7} \text{ m})}{(11 \times 10^{-7} \text{ m})} = 2750 \text{ K}$$

76 (*b*) It is given that, the intensity of radiation emitted by sun has its maximum value at $(\lambda_m)_s = 510$ nm and that emitted by north star has maximum value at $(\lambda_m)_F = 350$ nm

From Wien's displacement law,

$$\Rightarrow \quad \lambda_m T = \text{constant}$$

$$\Rightarrow \quad \lambda_{m_1} T_1 = \lambda_{m_2} T_2$$

$$\text{or} \quad \frac{T_1}{T_2} = \frac{\lambda_{m_2}}{\lambda_{m_1}} \quad \ldots\text{(i)}$$

Given, $\lambda_{m_1} = 510$ nm,

and $\lambda_{m_2} = 350$ nm

Putting these values in Eq. (i), we get

$$\frac{T_1}{T_2} = \frac{350}{510}$$

$$\Rightarrow \quad \frac{T_1}{T_2} = \frac{35}{51} = 0.69$$

So, this is the required ratio of surface temperature of the sun and north star.

77 (*b*) We know from Wien's displacement law,

$$\lambda_m T = \text{constant}$$

So, $T \propto \frac{1}{\lambda_m}$

As, $\lambda_r > \lambda_g > \lambda_v$

So, $T_r < T_g < T_v$

Given, $P \to v_{\max}, Q \to r_{\max}, R \to g_{\max}$

Hence, $T_Q < T_R < T_P$

i.e. $T_P > T_R > T_Q$

78 (*c*) According to Stefan's law, $Q = \sigma e A T^4$

For black body, $e = 1$

$$\Rightarrow \quad T = \left[\frac{Q}{\sigma(4\pi R^2)}\right]^{1/4}$$

79 (*d*) Given, $T_A = 727°$ C and $T_B = 327°$ C

As we know, $Q \propto T^4$

$$\Rightarrow \quad \frac{Q_A}{Q_B} = \frac{H_A}{H_B} = \left(\frac{273 + 727}{273 + 327}\right)^4 = \frac{625}{81}$$

80 (*a*) Given, temperature of sphere, $T = 227°$ C

$$= 273 + 227 = 500 \text{ K}$$

Radius, $r = 2$ m

Emissivity, $e = 0.8$

$\therefore$ Radiation power of sphere = Radiated energy per second

$= \sigma A e T^4$

$= 5.67 \times 10^{-8} \times 4\pi \times 2^2 \times 0.8 \times (500)^4$

$= 142430.4 \text{ W} = 142.4 \text{ kW} \approx 142.5 \text{ kW}$

81 (*b*) $\sigma = 5.67 \times 10^{-5}$ erg cm^{-2} s^{-1} K^{-4}

Power of lamp $= 100 \text{ W} = 100 \text{ Js}^{-1}$

$\therefore$ Rate of emission of energy,

$$E = 100 \times 10^7 \text{ erg s}^{-1} \qquad (\because 1\text{J} = 10^7 \text{erg})$$

Area, $A = 1 \text{ cm}^2$, temperature, $T = ?$

According to Stefan-Boltzmann law, we get

$$E = \sigma T^4 \times A$$

$$\therefore \quad T^4 = \frac{E}{\sigma A} = \frac{100 \times 10^7}{5.67 \times 10^{-5} \times 1} = \frac{100 \times 10^{12}}{5.67}$$

$$\Rightarrow \quad T = \left(\frac{100}{5.67}\right)^{1/4} \times 10^3 = 2.049 \times 10^3$$

$= 2049 \text{ K}$

82 (*d*) Radiated power of a black body, $P = \sigma A T^4$

where, A = surface area of the body,

T = temperature of the body

and σ = Stefan's constant.

When radius of the sphere is halved, new area,

$$A' = \frac{A}{4}$$

$\therefore$ Power radiated, $P' = \sigma\left(\frac{A}{4}\right)(2T)^4 = \frac{16}{4} \cdot (\sigma A T^4)$

$= 4P = 4 \times 450$

$= 1800 \text{ W}$

83 (*a*) Electric power consumed in first case,

$$P_1 = \sigma T_1^4 = \sigma\,(3000)^4 \quad \ldots\text{(i)}$$

Electric power consumed in second case,

$$P_2 = \sigma T_2^4 = \sigma\,(4000)^4 \quad \ldots\text{(ii)}$$

On dividing Eq. (ii) by Eq. (i), we get

$$\frac{P_2}{P_1} = \frac{(4000)^4}{(3000)^4} = \frac{256}{81}$$

As we know, percentage rise in power

$$= \frac{P_2 - P_1}{P_1} \times 100 = \left(\frac{256 - 81}{81}\right) \times 100$$

$$= \left(\frac{175}{81}\right) \times 100 = 216\%$$

84 (*c*) It is given that the first and third plate is maintained at temperature $2T$ and $3T$, respectively.

If T' be the temperature of second plate, then under steady state,

Rate of energy received = Rate of energy emitted

$$\sigma A (3T)^4 - \sigma A (T')^4 = \sigma A (T')^4 - \sigma A (2T)^4$$

$$\Rightarrow \quad (3T)^4 - (T')^4 = (T')^4 - (2T)^4$$

$$\Rightarrow \quad T'^4 = \left(\frac{97}{2}\right) T^4 \text{ or } T' = \left(\frac{97}{2}\right)^{1/4} T$$

85 (*a*) According to Wien's law, $\lambda_{\max} \propto \frac{1}{T}$

i.e. $\lambda_{\max} T =$ constant

where, $\lambda_{\max}$ is the maximum wavelength of the radiation emitted at temperature T.

$$\therefore \quad \lambda_{(\max_1)} T_1 = \lambda_{(\max_2)} T_2 \text{ or } \frac{T_1}{T_2} = \frac{\lambda_{(\max_2)}}{\lambda_{(\max_1)}} \quad \ldots\text{(i)}$$

Given, $\lambda_{(\max_1)} = \lambda_0$ and $\lambda_{(\max_2)} = \frac{3}{4}\lambda_0$

Substituting the above values in Eq. (i), we get

$$\frac{T_1}{T_2} = \frac{\frac{3}{4}\lambda_0}{\lambda_0} = \frac{3}{4} \text{ or } \frac{T_1}{T_2} = \frac{3}{4} \quad \ldots\text{(ii)}$$

As we know that, from Stefan's law, the power radiated by a body at temperature T is given as

$$P = \sigma A e T^4$$

i.e. $P \propto T^4$

($\because$ the quantity $\sigma A e$ is constant for a body)

$$\Rightarrow \quad \frac{P_1}{P_2} = \frac{T_1^4}{T_2^4} = \left(\frac{T_1}{T_2}\right)^4$$

From Eq. (ii), we get

$$\frac{P_1}{P_2} = \left(\frac{3}{4}\right)^4 = \frac{81}{256}$$

Given, $P_1 = P$ and $P_2 = nP$

$$\Rightarrow \quad \frac{P_1}{P_2} = \frac{P}{nP} = \frac{81}{256} \text{ or } n = \frac{256}{81}$$

86 (*a*) Given, temperature of sun, $T_s = 6000 \text{ K}$

Radius of sun, $R_s = 7.2 \times 10^5 \text{ km} = 7.2 \times 10^8 \text{ m}$

Radius of earth, $R_e = 6000 \text{ km} = 6000 \times 10^3 \text{ m}$

Distance between earth and sun, $d = 15 \times 10^7$ km

$= 15 \times 10^{10}$ m

Intensity of light on the earth,

$$I = \frac{\text{Total energy emitted by sun}}{4\pi d^2} \times (\pi R_e^2)$$

$$= \frac{\sigma (T_s^4 \cdot 4\pi R_s^2 \times \pi R_e^2)}{4\pi d^2} = \frac{\sigma T_s^4 R_s^2 \times \pi R_e^2}{d^2}$$

$$= \frac{\left[\begin{array}{r} 5.67 \times 10^{-8} \times (6000)^4 \times (7.2 \times 10^8)^2 \times 3.14 \\ \times (6000 \times 10^3)^2 \end{array}\right]}{(15 \times 10^{10})^2}$$

$= 19.2 \times 10^{16}$

This is the required intensity of light on earth.

Hints & Explanations

87 (*d*) Greenhouse gases are CO_2, CH_4, N_2O, CF_xCl_x and O_3. Thus, H_2O is not a greenhouse gas.

88 (*c*) Hot water or milk, when left on a table begins to cool gradually because temperature of surroundings is lesser and it loses the heat to the surroundings.

89 (*b*) According to Newton's law of cooling, the rate of loss of heat is directly proportional to the difference in temperature of the body and its surroundings.

92 (*a*) Let the temperature of the surroundings be $t°$ C.
According to Newton's law of cooling,

$$-\frac{dQ}{dt} = K(T_2 - T_1)$$

For first case $\frac{(70-60)}{5\text{ min}} = K\ (65°\text{C} - t°\text{C})$

(65° C is average of 70° C and 60° C)

$$\frac{10}{5\text{ min}} = K\ (65°\text{C} - t°\text{C}) \quad \ldots\text{(i)}$$

For second case $\frac{(60-54)}{5\text{ min}} = K\ (57°\text{C} - t°\text{C})$

(57° C is average of 60° C and 54° C)

$$\frac{6}{5\text{min}} = K\ (57°\text{C} - t°\text{C}) \quad \ldots\text{(ii)}$$

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{10}{6} = \frac{(65-t)}{(57-t)}$$

So, $t = 45°$ C

93 (*d*) **In first case** $T_1 = 60°$ C, $T_2 = 40°$ C
$T_0 = 10°$ C, $t = 7$ min $= 420$ s
According to Newton's law of cooling, we get

$$ms\,\frac{T_1 - T_2}{t} = k\left(\frac{T_1 + T_2}{2} - T_0\right)$$

$$ms\,\frac{(60-40)}{420} = k\left(\frac{60+40}{2} - 10\right)$$

$$ms \times \frac{20}{420} = k \times 40 \quad \ldots\text{(i)}$$

In second case $T_1 = 40°$ C, $T_2 = ?$, $T_0 = 10°$ C
and $t = 7$ min $= 420$ s

$$ms \times \frac{40 - T_2}{420} = k\left(\frac{40 + T_2}{2} - T_0\right) \quad \ldots\text{(ii)}$$

On dividing Eq. (ii) by Eq. (i), we get

$$\frac{20}{40 - T_2} = \frac{40}{\frac{40 + T_2}{2} - 10}$$

$$20 + \frac{T_2}{2} - 10 = 80 - 2T_2$$

On solving, we get $T_2 = 28°$ C

94 (*a*) Given, in first case, $T_1 = 81°$ C, $T_2 = 79°$ C, $T_0 = 30°$ C and $t = 1$ min.
As fall in temperature in accordance with Newton's law of cooling expression is

$$-\frac{dQ}{dt} = K(T - T_0),\text{ we can write}$$

$$\Rightarrow \left(\frac{T_1 - T_2}{t}\right) = -K\left(\frac{T_1 + T_2}{2} - T_0\right)$$

$$\Rightarrow \frac{81-79}{1\text{ min}} = -K\left(\frac{81+79}{2} - 30\right)$$

$$\Rightarrow \frac{2}{1\text{ min}} = -K \times 50 \quad \ldots\text{(i)}$$

and in second case, $T_1' = 61°$ C, $T_2' = 59°$ C. If time of cooling be t', then

$$\frac{61-59}{t'} = -K\left[\frac{61+59}{2} - 30\right]$$

or $$\frac{2}{t'} = -K \times 30 \quad \ldots\text{(ii)}$$

On dividing Eq. (i) by Eq. (ii), we get

$$t' = \frac{50}{30}\text{ min} = \frac{5}{3}\text{ min} = 1\text{ min } 40\text{ s}$$

95 (*d*) From Newton's law of cooling, the time taken t by a body to cool from T_1 to T_2 when placed in a medium of temperature T_0 can be calculated from relation

$$-\frac{T_1 - T_2}{t} = K\left(\frac{T_1 + T_2}{2} - T_0\right)$$

When the object cool from 80°C to 70°C in 12 min, then from Newton's law of cooling,

$$-\frac{80-70}{12} = K\left(\frac{80+70}{2} - 25\right) \quad [\because T_0 = 25°\text{ C}]$$

$$-\frac{5}{6} = K\,50 \quad \ldots\text{(i)}$$

Similarly, when object cool from 70°C to 60°C, we get

$$-\frac{70-60}{t} = K\left(\frac{70+60}{2} - 25\right)$$

$$-\frac{10}{t} = K\,40 \quad \ldots\text{(ii)}$$

Dividing Eq. (i) by Eq. (ii), we get

$$\frac{5}{6} \times \frac{t}{10} = \frac{50}{40}$$

$$\Rightarrow t = \frac{5}{4} \times 12 = 15\text{ min}$$

96 (*a*) According to Newton's law of cooling, rate of fall in temperature is proportional to the difference in temperature of the body with surroundings, i.e.

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

$$\Rightarrow \quad \int \frac{d\theta}{\theta - \theta_0} = \int -k\, dt$$

$$\Rightarrow \quad \ln(\theta - \theta_0) = -kt + C$$

which is a straight line with negative slope.

Thus, the graph given in option (a) is correct.

97 (*d*) Temperature is the measure of degree of hotness of a body.

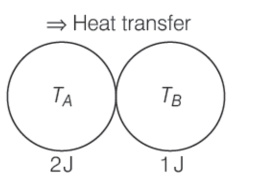
It is not true that a hotter body has more heat content than a colder body.

Therefore, Assertion is incorrect but Reason is correct.

98 (*d*) When heat transfer takes place between a system and surroundings, the total heat energy, i.e. the heat energy of the system and surrounding remains same or is conserved.

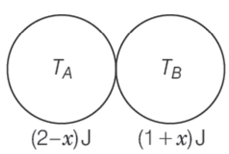
Using an example, we can find it as

Initially,



Total heat content of A and B = 3J

Finally,



Total heat content $= (2-x) + (1+x) = 3$ J

$\Rightarrow$ Total heat $(A+B)_{\text{initial}}$ = Total heat $(A+B)_{\text{final}}$

This is in accordance with the principle of conservation of energy.

But heat content of system A has decreased, i.e. total heat content of system or surroundings separately does not remain same.

Therefore, Assertion is incorrect but Reason is correct.

99 (*b*) Houses made of concrete roofs get very hot during summer days, because thermal conductivity of concrete (though much smaller than that of a metal) is still not small enough.

Therefore, Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

100 (*d*) Thermal conductivity of the wall depends only on nature of material of the wall and not on temperature difference across its two sides.

Therefore, Assertion is incorrect but Reason is correct.

101 (*d*) If equal amount of heat is added to equal masses of different substances, then the resulting temperature changes will not be the same.

It implies that every substance has a unique value for the amount of heat absorbed or rejected to change the temperature of unit mass of it by one unit.

Therefore, Assertion is incorrect but Reason is correct.

102 (*c*) As there is no atmosphere on the moon, so water kept in an open vessel quickly evaporates or boils, due to reduced pressure, which causes reduction in boiling point.

Therefore, Assertion is correct but Reason is incorrect.

103 (*d*) In freely heated rod, there is no thermal stress and no thermal strain, there is thermal expansion only.

When a rod (whose ends are fixed) is heated, thermal expansion of rod is prevented but this in turn, develops a compressive strain due to external forces provided by the rigid support at the ends.

The thermal stress, so set up is given by

$$\text{Stress} = \frac{\Delta F}{A} = Y\left(\frac{\Delta l}{l}\right)$$

where, Y is the Young's modulus of the rod.

Also, thermal strain $= \dfrac{\Delta l}{l} = \dfrac{l\alpha_l \Delta T}{l} = \alpha_l \Delta T$

which means that strain is a change in length per unit original length.

Therefore, Assertion is incorrect but Reason is correct.

104 (*a*) In desert, sand is dry and so, it gains heat quickly and also loses it quickly.

Due to this desert, regions are hotter in day and colder at night.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

105 (*a*) A gas can be liquified by applying pressure only when it is cooled below the critical temperature.

Critical temperature of NH_3 is more than CO_2, i.e.

$$T_{NH_3} = 405\text{K}$$

and $\quad T_{CO_2} = 304.1\text{ K}.$

Hence, NH_3 is liquified more easily than CO_2.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

106 (*a*) In modern thermometry, the triple point of water is taken as a standard fixed point because its value does not change under any condition.

Melting point of ice and the boiling point of water changes due to change in atmospheric pressure. Due to this factor, callibration of a thermometer is affected.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

107 (*c*) According to Stefan's law of radiation, $U \propto T^4$

$$\Rightarrow \quad \frac{U_1}{U_2} = \left(\frac{T_1}{T_2}\right)^4$$

$$\Rightarrow \quad \frac{U_1}{U_2} = \left(\frac{T}{T/3}\right)^4 \qquad \left(\because T_2 = \frac{T}{3}\right)$$

or $\quad \dfrac{U_1}{U_2} = \left(\dfrac{3}{1}\right)^4$ or $\dfrac{U_1}{U_2} = \left(\dfrac{81}{1}\right)$