# 11 Thermometry and Radiation

**QUICK LOOK**

**Heat**

The energy associated with configuration and random motion of the atoms and molecules with in a body is called internal energy and the part of this internal energy which is transferred from one body to the other due to temperature difference is called heat.

- As it is a type of energy, it is a scalar.
- Dimension: $[ML^2T^{-2}]$.
- Units: *Joule* (S.I.) and *calorie* (Practical unit)

One calorie is defined as the amount of heat energy required to raise the temperature of one *gm* of water through $1°C$ (more specifically from $14.5°C$ to $15.5°C$).

- As heat is a form of energy it can be transformed into others and *vice-versa*. *e.g.* Thermocouple converts heat energy into electrical energy, resistor converts electrical energy into heat energy. Friction converts mechanical energy into heat energy. Heat engine converts heat energy into mechanical energy. Here it is important that whole of mechanical energy *i.e.* work can be converted into heat but whole of heat can never be converted into work.
- When mechanical energy (work) is converted into heat, the ratio of work done ($W$) to heat produced ($Q$) always remains the same and constant, represented by $J$.

  $\frac{W}{Q} = J$ or $W = JQ$

  $J$ is called mechanical equivalent of heat and has value 4.2 *J/cal*. $J$ is not a physical quantity but a conversion factor which merely express the equivalence between *Joule* and *calories*. $1\ calorie = 4.186\ Joule \simeq 4.12\ Joule$
- Work is the transfer of mechanical energy irrespective of temperature difference, whereas heat is the transfer of thermal energy because of temperature difference only.
- Generally, the temperature of a body rises when heat is supplied to it. However the following two situations are also found to exist.

  When heat is supplied to a body either at its melting point or boiling point, the temperature of the body does not change. In this situation, heat supplied to the body is used up in changing its state.

  When the liquid in a thermos flask is vigorously shaken or gas in a cylinder is suddenly compressed, the temperature of liquid or gas gets raised even without supplying heat. In this situation, work done on the system becomes a source of heat energy.
- The heat lost or gained by a system depends not only on the initial and final states, but also on the path taken up by the process *i.e.* heat is a path dependent and is taken to be positive if the system absorbs it and negative if releases it.

**Temperature**

Temperature is defined as the degree of hotness or coldness of a body. The natural flow of heat is from higher temperature to lower temperature.

Two bodies are said to be in thermal equilibrium with each other, when no heat flows from one body to the other. That is when both the bodies are at the same temperature.

- Temperature is one of the seven fundamental quantities with dimension $[\theta]$.
- It is a scalar physical quantity with S.I. unit kelvin.
- When heat is given to a body and its state does not change, the temperature of the body rises and if heat is taken from a body its temperature falls *i.e.* temperature can be regarded as the effect of cause "heat".
- According to kinetic theory of gases, temperature (macroscopic physical quantity) is a measure of average translational kinetic energy of a molecule (microscopic physical quantity).

  Temperature $\propto$ kinetic energy $\left[\text{As } E = \frac{3}{2}RT\right]$
- Although the temperature of a body can to be raised without limit, it cannot be lowered without limit and theoretically limiting low temperature is taken to be zero of the kelvin scale.
- Highest possible temperature achieved in laboratory is about $10^8 K$ while lowest possible temperature attained is $10^{-8}\ K$.
- Branch of physics dealing with production and measurement of temperatures close to $0K$ is known as cryogenics while that dealing with the measurement of very high temperature is called as pyrometry.
- Temperature of the core of the sun is $10^7\ K$ while that of its surface is $6000\ K$.

- Normal temperature of human body is 310.15 $K$ (37°$C$ = 98.6°$F$).
- NTP or STP implies 273.15$K$ (0°$C$ = 32°$F$)

**Scales of Temperature:** If $X$ is temperature dependent property of substance varying linearly with temperature, then temperature $t = \dfrac{X_t - X_0}{X_{100} - X_0} \times 100°C$

Relation of change of reading of one thermometer to another is

$$\frac{C-1}{100} = \frac{F-32}{180} = \frac{K-273}{100} = \frac{R-0}{80} = \frac{R_n - 492}{180}$$

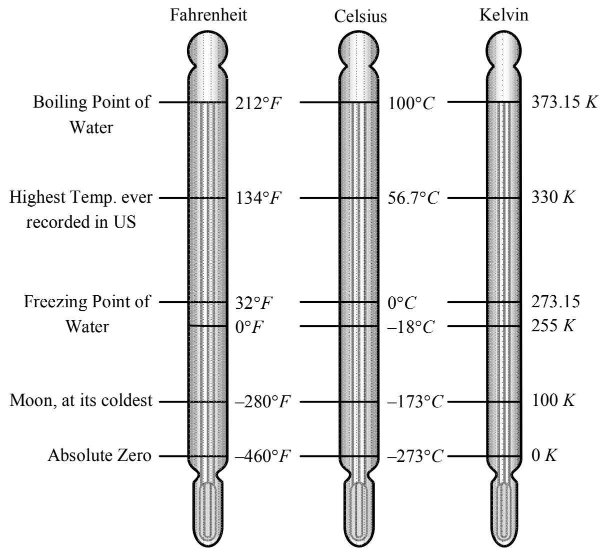



**Figure: 11.1**

**Table 11.1** Different Temperature Scales

| **Name of the scale** | **Symbol for each degree** | **Lower fixed point (LFP)** | **Upper fixed point (UEP)** | **Number of divisions on the scale** |
|---|---|---|---|---|
| Celsius | °$C$ | °$C$ | 100°$C$ | 100 |
| Fahrenheit | °$F$ | 32°$F$ | 212°$F$ | 180 |
| Reaumur | °$R$ | 0°$R$ | 80°$R$ | 80 |
| Rankine | °$Ra$ | 460 $Ra$ | 627 $Ra$ | 212 |
| Kelvin | $K$ | 273.15 $K$ | 373.15 $K$ | 100 |

- **Gas Thermometers:** In this thermometer a gas, assumed ideal, is used at constant volume.

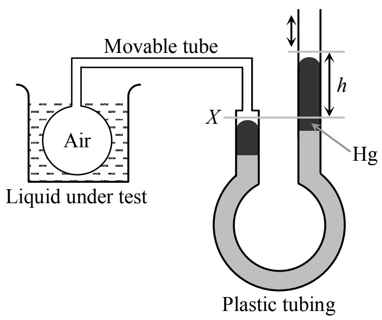



**Figure: 11.2**

This gas is filled at high temperature and low pressure. $t = \dfrac{P_t - P_0}{P_{100} - P_0} \times 100°C$

- **Resistance Thermometer:** $R_t - R_0\left(1 + \alpha t + \beta t^2\right), \alpha > \beta$

  The linear relation being $R_t - R_0\left(1 + \alpha t\right)$

$\therefore\ t = \dfrac{R_t - R_0}{R_{100} - R_0} \times 100°C$

- **Thermocouple Thermometer:** This is based on See beck effect $e = At + Bt^2$

  .For linear relation $e = At$, so $e_0 = 0$

$\therefore\ t = \dfrac{e_t}{e_{100}} \times 100°C$

- **Vapour Pressure Thermometer** $\log P = a + bt - \dfrac{C}{T}$

**Specific Heat**

- Debye's $T^3$ law: Specific heat of a solid varies with temperature. If is 3$R$ at higher temperature and near absolute zero $C_V \propto T^3$.
- The specific heat of a substance may very form 0 to ∞, depending on the process involved.
- Gases may have specific heat between 0 and ∞, being zero at constant heat and ∞ at constant temperature. But usually tow specific heats of gases are used, $C_P$ and $C_V$. Molar specific heat = molecular weight × specific heat

  For monatomic gas $C_V = \dfrac{3}{2}R, C_P = \dfrac{5}{2}R$

  For diatomic gas $C_V = \dfrac{5}{2}R, C_P = \dfrac{7}{2}R$

  For triaomic or polyatomic gas, $C_V = 3R, C_P = 4R$
- Mayer's Formula is $C_P - C_V = R$
- Clausius Clapeyron's equation (or $l$ latent heat equation) representing change of MP or BP with pressure is $\dfrac{dP}{dt} = \dfrac{JL}{T(V_2 - V_1)}$
- **Latent heat equation or** Relation between specific heats of liquids and gases $C_2 - C_1 = \dfrac{dP}{dt} = \dfrac{L}{T}$
- Relative humidity $= \dfrac{m}{M} \times 100\% = \dfrac{p}{p} \times 100°$

**Thermal Expansion:** The value of $\alpha$, $\beta$, $\gamma$ also depend on the unit of temperature, Values of $\alpha$, $\beta$ and $\gamma$ in unit of per °$C$ are equal to (9/5) times their numerical values in unit of per °$F$. The value of $\alpha$, $\beta$, $\gamma$ are independent of units of length, area and volume respectively. The three coefficients of expansion are not constant for a given solid. Their values depend on temperature range in which they are measured.

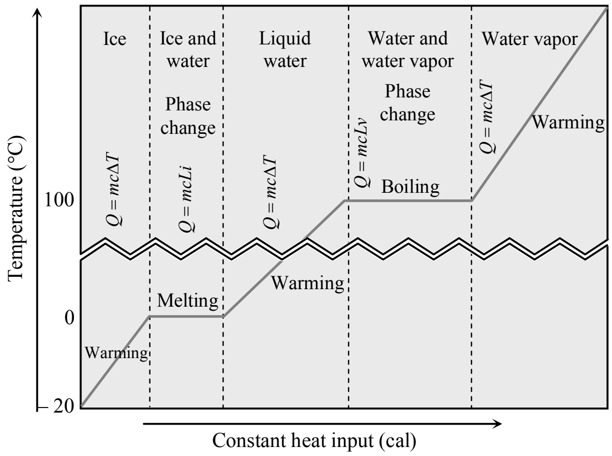



**Figure: 11.3**

Percentage change in length on heating $\alpha\Delta\theta\times100.$ Percentage change in area of heating $\beta\Delta\theta\times100,$ percentage change in volume heating $\gamma\Delta\theta\times100.$

$\alpha : \beta : \gamma = 1 : 2 : 3,$

Hence for same rise in temperature, Percentage change in area = 2 × percentage change in length and percentage change in volume = 3 × percentage change in length.

**Variation of Density with Temperature**.

Most substances expand when they are heated, *i.e.*, volume of a given mass of a substance increases on heating, so the density should decrease $\left(\text{as } \rho \propto \frac{1}{V}\right)$.

$$\rho = \frac{m}{V} \quad \text{or} \quad \rho \propto \frac{1}{V}$$

$$\therefore \quad \frac{\rho'}{\rho} = \frac{V}{V'} = \frac{V}{V+\Delta V} = \frac{V}{V+\gamma V\Delta T} = \frac{1}{1+\gamma\Delta T} \text{(For a given mass)}$$

$$\text{or} \quad \rho' = \frac{\rho}{1+\gamma\Delta T} = \rho(1+\gamma\,\Delta T)^{-1} = \rho(1-\gamma\,\Delta T)$$

[As $\gamma$ is small $\therefore$ using Binomial theorem]

$$\therefore \quad \rho' = \rho(1-\gamma\,\Delta T)$$

**Expansion of Liquid**

Liquids also expand on heating just like solids. Since liquids have no shape of their own, they suffer only volume expansion. If the liquid of volume $V$ is heated and its temperature is raised by $\Delta\theta$ then $V_L^{'} = V(1+\gamma_L\Delta\theta)$

[$\gamma_L$ = coefficient of real expansion or coefficient of volume expansion of liquid]

As liquid is always taken in a vessel for heating so if a liquid is heated, the vessel also gets heated and it also expands.

$V_S^{'} = V(1+\gamma_S\Delta\theta)$ [$\gamma_S$ = coefficient of volume expansion for solid vessel]

So the change in volume of liquid relative to vessel.

$$V_L^{'} - V_S^{'} = V[\gamma_L - \gamma_S]\Delta\theta$$

$\Delta V_{app} = V\,\gamma_{app}\Delta\theta$ [$\gamma_{app} = \gamma_L - \gamma_S =$ Apparent coefficient of volume expansion for liquid]

| | | | |
|---|---|---|---|
| $\gamma_L > \gamma_S$ | $\gamma_{app} > 0$ | $\Delta V_{app} =$ positive | Level of liquid in vessel will rise on heating. |
| $\gamma_L < \gamma_S$ | $\gamma_{app} < 0$ | $\Delta V_{app} =$ negative | Level of liquid in vessel will fall on heating. |
| $\gamma_L = \gamma_S$ | $\gamma_{app} = 0$ | $\Delta V_{app} = 0$ | level of liquid in vessel will remain same. |

**Effect of Temperature on up thrust**

The thrust on $V$ volume of a body in a liquid of density $\sigma$ is given by $Th = V\sigma g$

Now with rise in temperature by $\Delta\theta\ C°$, due to expansion, volume of the body will increase while density of liquid will decrease according to the relations

$$V' = \frac{V}{1+\gamma_S\Delta\theta} \text{ and } \sigma' = \frac{\sigma}{1+\gamma_L\Delta\theta}$$

So, the thrust will become $Th' = V'\sigma' g$

$\therefore \quad \frac{Th'}{Th} = \frac{V'\sigma' g}{V\sigma g} = \frac{(1+\gamma_S\Delta\theta)}{(1+\gamma_L\Delta\theta)}$ and apparent weight of the body

$W_{app}$ = Actual weight – Thrust

As $\gamma_S < \gamma_L$

$\therefore$ $Th' < Th$ with rise in temperature thrust also decreases and apparent weight of body increases.

**Anomalous Expansion of Water:** Generally matter expands on heating and contracts on cooling. In case of water, it expands on heating if its temperature is greater than 4°*C*. In the range 0°*C* to 4°*C*, water contracts on heating and expands on cooling, i.e., $\gamma$ is negative. At 4°*C*, density of water is maximum while its specific volume is minimum. This behaviour of water in the range from 0°*C* to 4°*C* is called anomalous expansion.

The anomalous behaviour of water arises due to the fact that water has three types of molecules, viz., $H_2O(H_2O_2)$ and $(H_2O)_3$ having different volume per unit mass and at different temperatures their properties in water are different.

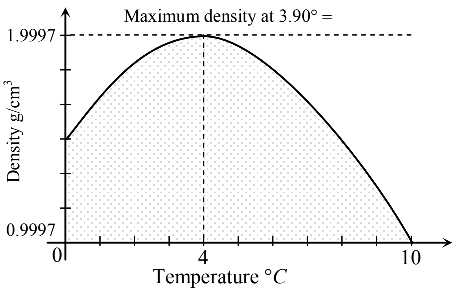



**Figure: 11.4**

**Expansion of Gases**

Gases have no definite shape, therefore gases have only volume expansion. Since the expansion of container is negligible in comparison to the gases, therefore gases have only real expansion.

**Coefficient of Volume Expansion:** At constant pressure, the unit volume of a given mass of a gas, increases with $1°C$ rise of temperature, is called coefficient of volume expansion.

$$\alpha = \frac{\Delta V}{V} \times \frac{1}{\Delta T}$$

$\therefore$ Final volume $V' = V(1 + \alpha \Delta T)$

**Coefficient of Pressure Expansion:** $\beta = \dfrac{\Delta P}{P} \times \dfrac{1}{\Delta T}$

$\therefore$ Final pressure $P' = P(1 + \beta \Delta T)$

For an ideal gas, coefficient of volume expansion is equal to the coefficient of pressure expansion. *i.e.* $\alpha = \beta = \dfrac{1}{273}\,°C^{-1}$

**Specific Heat**

- **Gram Specific Heat:** When heat is given to a body and its temperature increases, the heat required to raise the temperature of unit mass of a body through $1°C$ (or $K$) is called specific heat of the material of the body. If $Q$ heat changes the temperature of mass $m$ by $\Delta T$

  Specific heat $c = \dfrac{Q}{m\Delta T}$.

  Units: *Calorie*/*gm* × °*C* (practical), *J*/*kg* × *K* (S.I.)

  Dimension: $[L^2T^{-2}\theta^{-1}]$
- **Molar Specific Heat:** Molar specific heat of a substance is defined as the amount of heat required to raise the temperature of one gram mole of the substance through a unit degree it is represented by (capital) $C$.

  By definition, one mole of any substance is a quantity of the substance, whose mass $M$ grams is numerically equal to the molecular mass $M$.

$\therefore$ Molar specific heat $= M \times$ Gram specific heat

or $C = M\,c$

$$C = M\frac{Q}{m\Delta T} = \frac{1}{\mu}\frac{Q}{\Delta T} \quad \left[\text{As } c = \frac{Q}{m\Delta T} \text{ and } \mu = \frac{m}{M}\right]$$

$$\therefore\ C = \frac{Q}{\mu \Delta T}$$

Units: *calorie*/*mole* × °*C* (practical); *J*/*mole* × *kelvin* (S.I.)

Dimension: $[ML^2T^{-2}\theta^{-1}\mu^{-1}]$

**Note**

- Specific heat for hydrogen is maximum $(3.5\ cal/gm \times °C)$ and for water, it is $1 cal/gm \times °C$. For all other substances, the specific heat is less than $1 cal/gm \times °C$ and it is minimum for radon and actinium $(\simeq 0.022\,cal/gm \times °C)$.
- Specific heat of a substance also depends on the state of the substance *i.e.* solid, liquid or gas.

  For example, $c_{ice} = 0.5$ *cal*/*gm* × °*C* (Solid), $c_{\text{water}} = 1$ *cal*/*gm* × °*C* (Liquid) and $c_{\text{steam}} = 0.47$ *cal*/*gm* × °*C* (Gas)
- The specific heat of a substance when it melts or boils at constant temperature is infinite.

  As $C = \dfrac{Q}{m\Delta T} = \dfrac{Q}{m \times 0} = \infty$ [As $\Delta T = 0$]
- The specific heat of a substance when it undergoes adiabatic changes is zero.

  As $C = \dfrac{Q}{m\Delta T} = \dfrac{0}{m\Delta T} = 0$ [As $Q = 0$]
- Specific heat of a substance can also be negative. Negative specific heat means that in order to raise the temperature, a certain quantity of heat is to be withdrawn from the body. *Example*. Specific heat of saturated vapours.

**Specific Heat of Solids**

When a solid is heated through a small range of temperature, its volume remains more or less constant. Therefore specific heat of a solid may be called its specific heat at constant volume $C_v$.

From the graph it is clear that at $T = 0$, $C_v$ tends to zero

With rise in temperature, $C_v$ increases and becomes constant = $3R$ = 6 *cal*/*mole* × *kelvin* = 25 *J*/*mole* × *kelvin* at some particular temperature (Debye Temperature) For most of the solids, Debye temperature is close to room temperature.

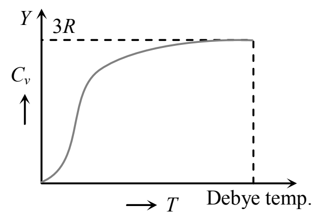



**Figure: 11.5** Specific Heat vs. Temperature

Debye's $T^3$ law: Specific heat of a solid varies with temperature. If is $3R$ at higher temperature and near absolute zero $C_v \propto T^3$

**Dulong and Petit Law:** Average molar specific heat of all metals at room temperature is constant, being nearly equal to $3R$ = 6 $cal.\ mole^{-1}\ K^{-1}$ = 25 $J\ mole^{-1}\ K^{-1}$, where $R$ is gas constant for one mole of the gas. This statement is known as Dulong and Petit law.

**Latent Heat**

When a substance changes from one state to another state (say from solid to liquid or liquid to gas or from liquid to solid or gas to liquid) then energy is either absorbed or liberated. This heat energy is called latent heat, the two types of latent heats

- Latent heat of fusion: The latent heat of fusion is the heat energy required to change 1 *kg* of the material in its solid state at its melting point to 1 *kg* of the material in its liquid state. It is also the amount of heat energy released when at melting point 1 *kg* of liquid changes to 1 *kg* of solid. For water at its normal freezing temperature or melting point (0°*C*), the latent heat of fusion (or latent heat of ice) is $L_F = L_{\text{ice}} \approx 80\, cal/g \approx 60\, kJ/mol \approx 336\, kilo\ joule/kg$ .
- Latent heat of vaporisation: The latent heat of vaporisation is the heat energy required to change 1 *kg* of the material in its liquid state at its boiling point to 1 *kg* of the material in its gaseous state. It is also the amount of heat energy released when 1 *kg* of vapour changes into 1 *kg* of liquid. For water at its normal boiling point or condensation temperature (100°*C*), the latent heat of vaporisation (latent heat of steam) is
  $L_V = L_{\text{steam}} \approx 540\, cal/g \approx 40.8\, kJ/mol \approx 2260\, kilo\ joule/kg$

**Principle of Caloriemetry**

When two bodies (one being solid and other liquid or both being liquid) at different temperatures are mixed, heat will be transferred from body at higher temperature to a body at lower temperature till both acquire same temperature. The body at higher temperature releases heat while body at lower temperature absorbs it, so that

Heat lost = Heat gained

*i.e.* principle of caloriemetry represents the law of conservation of heat energy.

- Temperature of mixture ($T$) is always ≥ lower temperature ($T_L$) and ≤ higher temperature ($T_H$), *i.e.*, $T_L \le T \le T_H$ *i.e.*, the temperature of mixture can never be lesser than lower temperatures (as a body cannot be cooled below the temperature of cooling body) and greater than higher temperature (as a body cannot be heated above the temperature of heating body). Furthermore usually rise in temperature of one body is not equal to the fall in temperature of the other body though heat gained by one body is equal to the heat lost by the other.
- When temperature of a body changes, the body releases heat if its temperature falls and absorbs heat when its temperature rises. The heat released or absorbed by a body of mass $m$ is given by, $Q = mc\,\Delta T$ where $c$ is specific heat of the body and $\Delta T$ change in its temperature in °*C* or *K*.
- When state of a body changes, change of state takes place at constant temperature [m.pt. or b.pt.] and heat released or absorbed is given by, $Q = mL$
  where $L$ is latent heat. Heat is absorbed if solid converts into liquid (at m.pt.) or liquid converts into vapours (at b.pt.) and is released if liquid converts into solid or vapours converts into liquid.
- If two bodies $A$ and $B$ of masses $m_1$ and $m_2$, at temperatures $T_1$ and $T_2$ ($T_1 > T_2$) and having gram specific heat $c_1$ and $c_2$ when they are placed in contact. Heat lost by $A$ = Heat gained by $B$ or $m_1c_1(T_1 - T) = m_2c_2(T - T_2)$ [where $T$ = Temperature of equilibrium]

$\therefore\ T = \dfrac{m_1c_1T_1 + m_2c_2T_2}{m_1c_1 + m_2c_2}$

If bodies are of same material $c_1 = c_2$ then $T = \dfrac{m_1T_1 + m_2T_2}{m_1 + m_2}$

If bodies are of same mass $(m_1 = m_2)$ then $T = \dfrac{T_1c_1 + T_2c_2}{c_1 + c_2}$

- If bodies are of same material and of equal masses $(m_1 = m_2, c_1 = c_2)$ then $T = \dfrac{T_1 + T_2}{2}$

**Heating Curve**

If to a given mass ($m$) of a solid, heat is supplied at constant rate $P$ and a graph is plotted between temperature and time, the graph is as shown in figure and is called heating curve. From this curve it is clear that

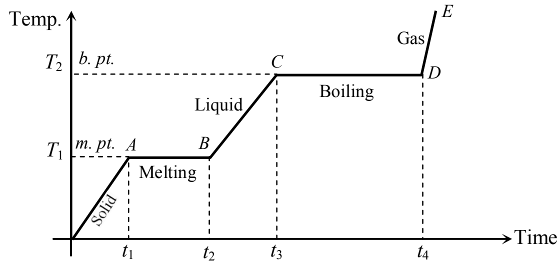



**Figure: 11.6** Heating Curve

- In the region $OA$ temperature of solid is changing with time so, $Q = mc_S\Delta T$ or $P\,\Delta t = mc_S\Delta T$ [as $Q = P\Delta t$]

  But as $(\Delta T/\Delta t)$ is the slope of temperature-time curve $c_S \propto$ (1/slope of line $OA$)

  *i.e.* specific heat (or thermal capacity) is inversely proportional to the slope of temperature-time curve.
- In the region $AB$ temperature is constant, so it represents change of state, *i.e.*, melting of solid with melting point $T_1$. At $A$ melting starts and at $B$ all solid is converted into liquid. So between $A$ and $B$ substance is partly solid and partly liquid. If $L_F$ is the latent heat of fusion.

  $Q = mL_F$ or $L_F = \dfrac{P(t_2 - t_1)}{m}$ [as $Q = P(t_2 - t_1)$]

  or $L_F \propto$ length of line $AB$

  *i.e.* Latent heat of fusion is proportional to the length of line of zero slope. [In this region specific heat $\propto \dfrac{1}{\tan 0} = \infty$ ]
- In the region $BC$ temperature of liquid increases so specific heat (or thermal capacity) of liquid will be inversely proportional to the slope of line $BC$ *i.e.*, $c_L \propto$ (1/slope of line $BC$)
- In the region $CD$ temperature is constant, so it represents the change of state, *i.e.*, boiling with boiling point $T_2$. At $C$ all substance is in liquid state while at $D$ in vapour state and between $C$ and $D$ partly liquid and partly gas. The length of line $CD$ is proportional to latent heat of vaporisation

  *i.e.*, $L_V \propto$ Length of line $CD$ [In this region specific heat $\propto \dfrac{1}{\tan 0} = \infty$ ]
- The line $DE$ represents gaseous state of substance with its temperature increasing linearly with time. The reciprocal of slope of line will be proportional to specific heat or thermal capacity of substance in vapour state.

### Conduction, Convection and Radiation

Heat energy transfers from a body at higher temperature to a body at lower temperature. The transfer of heat from one body to another may take place by one of the following modes.

**Table: 11.2** Conduction, Convection and Radiation

| Conduction | Convection | Radiation |
|---|---|---|
| Heat flows from hot end to cold end. Particles of the medium simply oscillate but do not leave their place. | Each particle absorbing heat is mobile | Heat flows without any intervening medium in the form of electromagnetic waves. |
| Medium is necessary for conduction | Medium is necessary for convection | Medium is not necessary for radiation |
| It is a slow process | It is also a slow process | It is a very fast process |
| Path of heat flow may be zig-zag | Path may be zig-zag or curved | Path is a straight line |
| Conduction takes place in solids | Convection takes place in fluids | Radiation takes place in gaseous and transparent media |
| The temperature of the medium increases through which heat flows | In this process also the temperature of medium increases | There is no change in the temperature of the medium |

### Conduction

The process of transmission of heat energy in which the heat is transferred from one particle to other particle without dislocation of the particle from their equilibrium position is called conduction. In metallic solids free electrons carry the heat energy, therefore they are good conductor of heat.

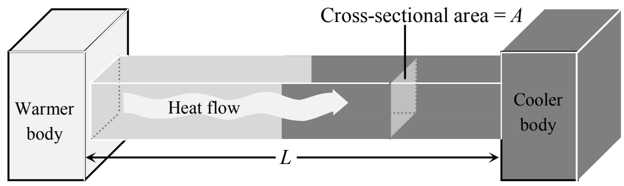



**Figure: 11.7** Transmission of Heat Energy

**Thermal Resistance:** The thermal resistance of a body is a measure of its opposition to the flow of heat through it. It is defined as the ratio of temperature difference to the heat current (= rate of flow of heat). Unit of thermal resistance is $°C \times$ sec/cal or $K \times$ sec/$k$-calorie.

Now, temperature difference $= (\theta_1 - \theta_2)$

Heat current, $H = \dfrac{Q}{t}$

$$\therefore \quad R_{Th} = \frac{\theta_1 - \theta_2}{H} = \frac{\theta_1 - \theta_2}{(Q/t)} = \frac{\theta_1 - \theta_2}{KA(\theta_1 - \theta_2)/d} = \frac{d}{KA}$$

**Table: 11.3** Electrical and Thermal Conduction.

| Electrical Conduction | Thermal Conduction |
|---|---|
| Electric charge flows from higher potential to lower potential | Heat flows from higher temperature to lower temperature |
| The rate of flow of charge is called the electric current, *i.e.* $I = \dfrac{dq}{dt}$ | The rate of flow of heat may be called as heat current *i.e.* $H = \dfrac{dQ}{dt}$ |
| The relation between the electric current and the potential difference is given by Ohm's law, that is $I = \dfrac{V_1 - V_2}{R}$ where $R$ is the electrical resistance of the conductor | Similarly, the heat current may be related with the temperature difference as $H = \dfrac{\theta_1 - \theta_2}{R}$ where $R$ is the thermal resistance of the conductor |

| | |
|---|---|
| The electrical resistance is defined as $R=\dfrac{\rho l}{A}=\dfrac{l}{\sigma A}$ where $\rho$ = Resistivity and $\sigma$ = Electrical conductivity $\dfrac{dq}{dt}=I=\dfrac{V_1-V_2}{R}=\dfrac{\sigma A}{l}(V_1-V_2)$ | The thermal resistance may be defined as $R=\dfrac{l}{KA}$ where $K$ = Thermal conductivity of conductor $\dfrac{dQ}{dt}=H=\dfrac{\theta_1-\theta_2}{R}=\dfrac{KA}{l}(\theta_1-\theta_2)$ |

**Series Combination of Conductors:**

Suppose two conductors of equal areas of cross-section (= $A$) and lengths $d_1$ and $d_2$ and coefficients of thermal conductivities $K_1$ and $K_2$ are connected in series. Let the temperatures of the two outer faces be $\theta_1$ and $\theta_2$ and the temperature of the junction be $\theta$ ; then heat current is the same in the two conductors: $\dfrac{K_1A(\theta_1-\theta)}{d_1}=\dfrac{K_2A(\theta_2-\theta)}{d_2}$

Or $\dfrac{K_1(\theta_1-\theta)}{d_1}=\dfrac{K_2(\theta-\theta_2)}{d_2}$ or $K_1G_1=K_2G_2$

Where $G_1$ and $G_2$ represent temperature gradients in first and second conductions. $G_1=\dfrac{(\theta_1-\theta)}{d_1}$ and $G_2=\dfrac{(\theta-\theta_2)}{d_1}$

Hence $KG$ = constant, i.e., temperature gradients are in the inverse ratio of thermal conductivities.

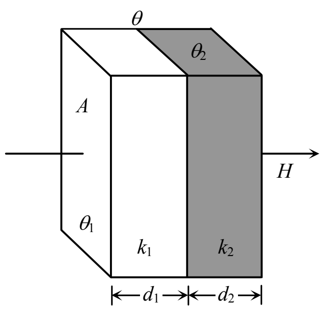



**Figure: 11.8**

**Parallel Combination of Conductors:** Suppose two conductors each of thickness d but with area of cross-section $A_1$ and $A_2$ are connected in parallel to give a plate of thickness or length $d$ and area of cross-section $(A_1+A_2)$. Let the temperature of the first and second faces be $\theta_1$ and $\theta_1$. The total heat current $H_p$ is the sum of heat currents $H_1$ and $H_2$ in the first and second conductors respectively,

i.e., $H_p=H_1+H_2$

Now, $H_1=\dfrac{K_1A_1(\theta_1-\theta)}{d}$ and $H_2=\dfrac{K_2A_2(\theta_1-\theta_2)}{d}$

And $H_P=\dfrac{K_P(A_1+A_2)(\theta_1-\theta_2)}{d}$

As $H_p=H_1+H_2$,

Hence, $\dfrac{K_P(A_1+A_2)(\theta_1-\theta_2)}{d}=\dfrac{K_1A_1(\theta_1-\theta_2)}{d}+\dfrac{K_2A_2(\theta_1-\theta_2)}{d}$

Or $K_P(A_1+A_2)=K_1A_1+K_2A_2$

Or $K_P=\dfrac{K_1A_1+K_2A_2}{A_1+A_2}$

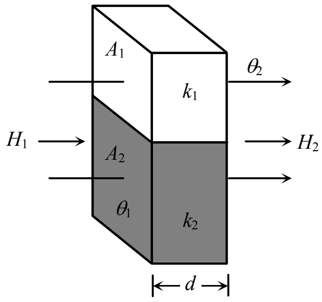



**Figure: 11.9**

**Growth of Ice on Lakes**

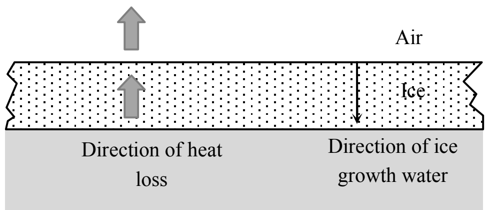



**Figure 11.10**

Water in a lake starts freezing if the atmospheric temperature drops below °$C$. Let $y$ be the thickness of ice layer in the lake at any instant t and atmospheric temperature is – $\theta$ °$C$. The temperature of water in contact lower surface of ice will be zero. If A is the are of lake, heat escaping through ice in time $dt$ is $dQ_1=\dfrac{KA[0-(\theta)]dt}{y}$

Now, suppose the thickness of ice layer increases by $dy$ in time $dt$, due to escaping of above heat.

Then $dQ_2=mL=\rho(dy\ A)L$

As $dQ_2=dQ_2$

Hence, rate of growth of ice will be $\dfrac{dy}{dt}=\dfrac{K\theta}{\rho Ly}$

So, time taken by ice to grow a thickness $y$ is $t=\dfrac{\rho L}{K\theta}\int_0^y y=\dfrac{\rho L}{2K\theta}y^2$

If follows from the above equation that time taken to double, triple the thickness will be in the ratio of

$t_1\ :\ t_1\ :\ t_3\ ::1^2\ :\ 2^2\ :\ 3^3$

*i.e.,* $t_1\ :\ t_1\ :\ t_3\ ::1\ :\ 4\ :\ 9$

And the time intervals to change the thickness form 0 to $y$, from $y$ to $2y$ and soon will be in the ratio

$$\Delta t_1 \ : \ \Delta t_1 \ : \ \Delta t_3 \ :: \left(1^2 - 0^2\right) \ : \ \left(2^2 - 1^2\right) \ : \ \left(2^2 - 2^2\right)$$

$$\Delta t_1 \ : \ \Delta t_1 \ : \ \Delta t_3 \ :: 1 \ : \ 3 \ : \ 5$$

- **Ingen-Hauz Experiment:** It is used to compare thermal conductivities of different materials. If $l_1$ and $l_2$ are the lengths of wax melted on rods, then the ratio of thermal conductivities is $\frac{K_1}{K_2} = \frac{l_1^2}{l_2^2}$

  *i.e.,* in this experiment, we observe Thermal conductivity $\propto$(length)$^2$
- **Searle's Experiment:** It is a method of determination of $K$ of a metallic rod. Here we are not much interested in the detailed description of the experimental setup. We will only understand its essence, which is the essence of solving many numerical Illustrations.

  In this experiment a temperature difference $(\theta_1 - \theta_2)$ is maintained across a rod of length $l$ and area of cross section A. If the thermal conductivity of the material of the rod is $K$, then the amount of heat transmitted by the rod from the hot end to the cold end in time $t$ is given by,

  $$Q = \frac{KA(\theta_1 - \theta_2)t}{l} \qquad \ldots (i)$$

  In Searle's experiment, this heat reaching the other end is utilized to raise the temperature of certain amount of water flowing through pipes circulating around the other end of the rod. If temperature of the water at the inlet is $\theta_3$ and at the outlet is $\theta_4$, then the amount of heat absorbed by water is given by,

  $$Q = mc(\theta_4 - \theta_3) \qquad \ldots (ii)$$

  Where, $m$ is the mass of the water which has absorbed this heat and temperature is raised and $c$ is the specific heat of the water

  Equating (*i*) and (*ii*), $K$ can be determined

  *i.e.* $K = \frac{mc(\theta_4 - \theta_3)l}{A(\theta_1 - \theta_2)t}$

**Note:**

In numericals we may have the situation where the amount of heat travelling to the other end may be required to do some other work *e.g.,* it may be required to melt the given amount of ice. In that case equation (i) will have to be equated to $mL$.

*i.e.* $mL = \frac{KA(\theta_1 - \theta_2)t}{l}$

**Radiation**

The process of the transfer of heat from one place to another place without heating the intervening medium is called radiation.

**Table: 11.4** Thermal radiation Frequency and Wavelength

| Radiation | Frequency | Wavelength |
|---|---|---|
| Cosmic rays | $> 10^{21}$ *Hz* | $< 10^{-13}$ *m* |
| Gamma rays | $10^{18}$ - $10^{21}$ *Hz* | $10^{-13}$ - $10^{-10}$ *m* |
| *X*-rays | $10^{16}$ - $10^{19}$ *Hz* | $10^{-11}$ - $10^{-8}$ *m* (0.1 Å - 100 Å) |
| Ultraviolet rays | $7.5 \times 10^{14}$ - $2 \times 10^{6}$ *Hz* | $1.4 \times 10^{-8}$ - $4 \times 10^{-7}$ *m* (140 Å - 4000 Å) |
| Visible rays | $4 \times 10^{14}$ - $7.5 \times 10^{14}$ *Hz* | $4 \times 10^{-7}$ - $7.8 \times 10^{-7}$ *m* (4000 Å - 7800 Å) |
| Infrared rays (Heat) | $3 \times 10^{11}$ - $4 \times 10^{14}$ *Hz* | $7.8 \times 10^{-7}$ - $10^{-3}$ (7800 Å - $3 \times 10^{5}$ Å) |
| Microwaves | $3 \times 10^{8}$ - $3 \times 10^{11}$ *Hz* | $10^{-3}$ *m* - 0.1 *m* |
| Radio waves | $10^{4}$ - $3 \times 10^{9}$ *Hz* | 0.1 *m* - $10^{4}$ *m* |

**Properties of Thermal Radiation**

- The wavelength of thermal radiations ranges from $7.8 \times 10^{-7}\ m$ to $4 \times 10^{-4}\ m$.

  They belong to *infra-red* region of the electromagnetic spectrum. That is why thermal radiations are also called *infra-red radiations*.
- Medium is not required for the propagation of these radiations.They produce sensation of warmth in us but we can't see them.
- Everybody whose temperature is above zero Kelvin emits thermal radiation.
- Their speed is equal to that of light *i.e.* $(= 3 \times 10^8\ m/s)$.
- Their intensity is inversely proportional to the square of distance of point of observation from the source (*i.e.* $I \propto 1/d^2$).
- Just as light waves, they follow laws of reflection, refraction, interference, diffraction and polarisation.
- When these radiations fall on a surface then exert pressure on that surface which is known as radiation pressure.
- While travelling these radiations travel just like photons of other electromagnetic waves. They manifest themselves as heat only when they are absorbed by a substance.
- Spectrum of these radiations cannot be obtained with the help of glass prism because it absorbs heat radiations. It is obtained by quartz or rock salt prism because these materials do not have free electrons and interatomic vibrational frequency is greater than the radiation frequency, hence they do not absorb heat radiations.

### Reflectance, Absorptance and Transmittance

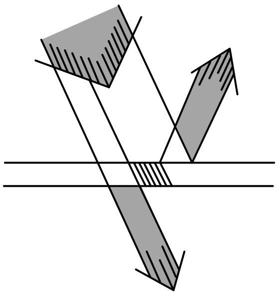


**Figure: 11.11** Reflectance, Absorptance and transmittance

When thermal radiations ($Q$) fall on a body, they are partly reflected, partly absorbed and partly transmitted.

- Reflectance or reflecting power ($r$): It is defined as the ratio of the amount of thermal radiations reflected ($Q_r$) by the body in a given time to the total amount of thermal radiations incident on the body in that time.
- Absorptance or absorbing power ($a$): It is defined as the ratio of the amount of thermal radiations absorbed ($Q_a$) by the body in a given time to the total amount of thermal radiatons incident on the body in that time.
- Transmittance or transmitting power ($t$): It is defined as the ratio of the amount of thermal radiations transmitted ($Q_t$) by the body in a given time to the total amount of thermal radiations incident on the body in that time.

  From the above definitions $r = \frac{Q_r}{Q}$,

  $a = \frac{Q_a}{Q}$ and $t = \frac{Q_t}{Q}$

  By adding we get

  $$r + a + t = \frac{Q_r}{Q} + \frac{Q_a}{Q} + \frac{Q_t}{Q} = \frac{(Q_r + Q_a + Q_t)}{Q} = 1$$

$\therefore \quad r + a + t = 1$

$r$, $a$ and $t$ all are the pure ratios so they have no unit and dimension.

For perfect reflector: $r = 1$, $a = 0$ and $t = 0$

For perfect absorber: $a = 1$, $r = 0$ and $t = 0$ (Perfectly black body)

For perfect transmitter: $t = 1$, $a = 0$ and $r = 0$

If body does not transmit any heat radiation, $t = 0$

$\therefore \quad r + a = 1$ or $a = 1 - r$

So, if $r$ is more, $a$ is less and vice-versa. It means good reflectors are bad absorbers.

**Emissivity ($e$):** Emissivity of a body at a given temperature is defined as the ratio of the total emissive power of the body ($E_{\text{practical}}$) to the total emissive power of a perfect black body ($E_{black}$) at that temperature.

*i.e.* $e = \frac{E_{practical}}{E_{black}}$

$e = 1$ for perfectly black body but for practical bodies emissivity ($e$) lies between zero and one ($0 < e < 1$).

**Perfectly Black Body:** A perfectly black body is that which absorbs completely the radiations of all wavelengths incident on it. As a perfectly black body neither reflects nor transmits any radiation, therefore the absorptance of a perfectly black body is unity *i.e.* $t = 0$ and $r = 0$

$\therefore a = 1$.

Ferry’s Black Body: A perfectly black body can’t be realised in practice. The nearest example of an ideal black body is the Ferry’s black body. It is a doubled walled evacuated spherical cavity whose inner wall is blackened. There is a fine hole in it. All the radiations incident upon this hole are absorbed by this black body. If this black body is heated to high temperature then it emits radiations of all wavelengths.

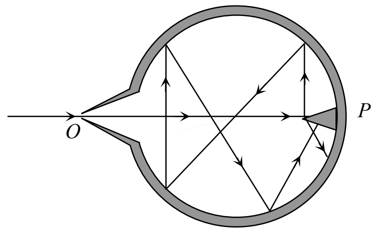



**Figure: 11.12** Ferry’s Black Body

### Prevost Theory of Heat Exchange

Everybody emits heat radiations at all finite temperature (Except 0 $K$) as well as it absorbs radiations from the surroundings. Exchange of energy along various bodies takes place via radiation.The process of heat exchange among various bodies is a continuous phenomenon.

- If the amount of radiation absorbed by a body is greater than that emitted by it then the temperature of body increases and it appears hotter.
- If the amount of radiation absorbed by a body is less than that emitted by it, then the temperature of the body decreases and consequently the body appears colder.
- If the amount of radiation absorbed by a body is equal to that emitted by the body, then the body will be in thermal equilibrium and the temperature of the body remains constant.
- At absolute zero temperature (0 $K$ or – 273°$C$) this law is not applicable because at this temperature the heat exchange among various bodies ceases.

**Kirchoff's Law:** The ratio of emissive power to absorptive power is same for all surfaces at the same temperature and is equal to the emissive power of a perfectly black body at that temperature.

Thus if $a_{\text{practical}}$ and $E_{\text{practical}}$ represent the absorptive and emissive power of a given surface, while $a_{black}$ and $E_{black}$ for a perfectly black body, then according to law $\frac{E_{\text{practical}}}{a_{\text{practical}}} = \frac{E_{\text{black}}}{a_{\text{black}}}$

But for a perfectly black body $a_{\text{black}} = 1$

So, $\frac{E_{\text{practical}}}{a_{\text{practical}}} = E_{\text{black}}$

If emissive and absorptive powers are considered for a particular wavelength $\lambda$, $\left(\frac{E_\lambda}{a_\lambda}\right)_{\text{practical}} = (E_\lambda)_{\text{black}}$

Now since $(E_\lambda)_{\text{black}}$ is constant at a given temperature, according to this law if a surface is a good absorber of a particular wavelength it is also a good emitter of that wavelength.

This in turn implies that a good absorber is a good emitter (or radiator)

**Law of Distribution of Energy**

The theoretical explanation of black body radiation was done by Planck. If the walls of hollow enclosure are maintained at a constant temperature, then the inside of enclosure are filled with the electromagnetic radiation. The radiation coming out from a small hole in the enclosure are called black body radiation. According to Max Planck, the radiation inside the enclosure may be assumed to be produced by a number of harmonic oscillators.

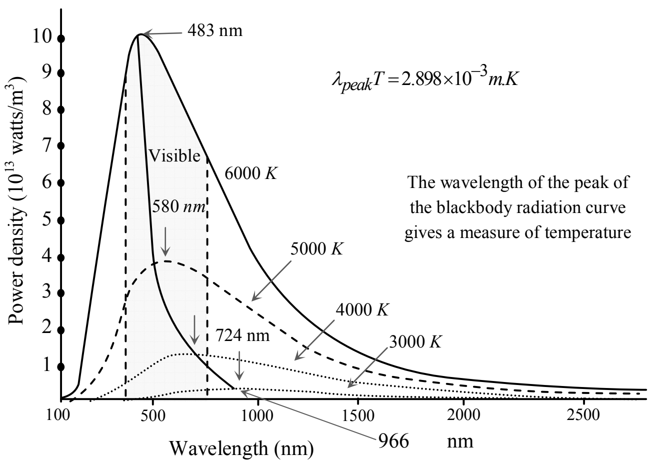



**Figure: 11.13** Power Density vs. Wavelength

Figure: The Wavelength of the Peak of the Blackbody Radiation Curve Gives a Measure of Temperature

According to Planck's law $E_\lambda d\lambda = \frac{8\pi hc}{\lambda^5}\frac{1}{[e^{hc/\lambda KT} - 1]}d\lambda$

This law is valid for radiations of all wavelengths ranging from zero to infinite.

For radiations of short wavelength $\left(\lambda << \frac{hc}{KT}\right)$

Planck's law reduces to *Wien's energy distribution law*

$E_\lambda d\lambda = \frac{A}{\lambda^5}e^{-B/\lambda T}d\lambda$

For radiations of long wavelength $\left(\lambda >> \frac{hc}{KT}\right)$

Planck's law reduces to *Rayleigh-Jeans energy distribution law*

$E_\lambda d\lambda = \frac{8\pi KT}{\lambda^4}d\lambda$

**Wien's Law:** With increase in temperature wavelength $\lambda_m$ corresponding to most intense radiation decreases in such a way that $\lambda_m \times T =$ constant. $\lambda_m T = b$; Where $b$ is Wien's constant and has value $2.89\times10^{-3} m\text{-}K$

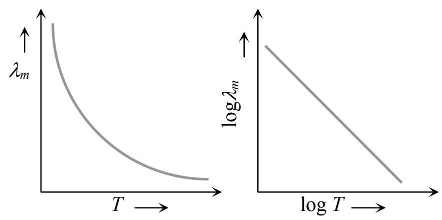



**Figure: 11.14** Wavelength vs. $T$ and log $T$

**Stefan's Law**

According to it the radiant energy emitted by a perfectly black body per unit area per sec (*i.e.* emissive power of black body) is directly proportional to the fourth power of its absolute temperature, *i.e.* $E \propto T^4$ or $E = \sigma T^4$

where $\sigma$ is a constant called Stefan's constant having dimension $[MT^{-3}\theta^{-4}]$ and value $5.67\times10^{-8} W/m^2K^4$.

- If a body at temperature $T$ is surrounded by a body at temperature $T_0$, then Stefan's law may be put as $E = e\sigma(T^4 - T_0^4)$
- Cooling by radiation: If a body at temperature $T$ is in an environment of temperature $T_0(< T)$, the body is loosing as well as receiving so net rate of loss of energy

$$\frac{dQ}{dt} = eA\sigma(T^4 - T_0^4) \qquad \ldots (i)$$

Now if $m$ is the mass of body and $c$ its specific heat, the rate of loss of heat at temperature $T$ must be

$$\frac{dQ}{dt} = mc\frac{dT}{dt} \qquad \ldots (ii)$$

From equation ($i$) and ($ii$) $mc\frac{dT}{dt} = eA\sigma(T^4 - T_0^4)$

$\therefore$ Rate of fall of temperature or rate of cooling,

$$\frac{dT}{dt} = \frac{eA\sigma}{mc}(T^4 - T_0^4) \qquad \ldots (iii)$$

*i.e.* when a body cools by radiation the rate of cooling depends on nature, area, mass, specific heat, temperature of radiating body and temperature of surrounding.

**Rayleigh-Jeans Law:** The energy ($E_{max}$) emitted corresponding to the wavelength of maximum emission ($\lambda_m$) increases with fifth power of the absolute temperature of the black body *i.e.*, $E_{max} \propto T^5$

**Temperature of The Sun and Solar Constant.**

If $R$ is the radius of the sun and $T$ its temperature, then the energy emitted by the sun per sec through radiation in accordance with Stefan's law will be given by

$$P = eA\sigma T^4 = 4\pi R^2 \sigma T^4$$

In reaching earth this energy will spread over a sphere of radius $r$ (= average distance between sun and earth); so the intensity of solar radiation at the surface of earth (called solar constant $S$) will be given by

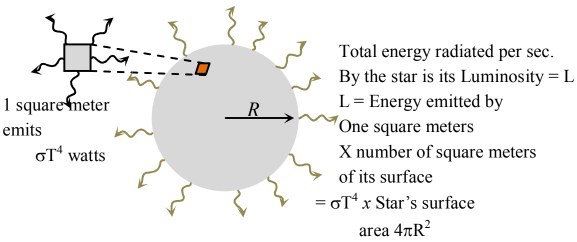



**Figure: 11.15** Energy Emitted by the Sun

$$S = \frac{P}{4\pi r^2} = \frac{4\pi R^2 \sigma T^4}{4\pi r^2}$$

*i.e.* $T = \left[\left(\frac{r}{R}\right)^2 \frac{S}{\sigma}\right]^{1/4}$

$$= \left[\left(\frac{1.5\times10^8}{7\times10^5}\right)^2 \times \frac{1.4\times10^3}{5.67\times10^{-8}}\right]^{1/4} \simeq 5800\,K$$

As $r = 1.5\times10^8\,km,\ R = 7\times10^5\,km,$

$$S = 2\frac{cal}{cm^2 min} = 1.4\frac{kW}{m^2}$$

$$\sigma = 5.67\times10^{-8}\frac{W}{m^2K^4}$$

This result is in good agreement with the experimental value of temperature of sun, *i.e.*, 6000 $K$. The difference in the two values is attributed to the fact that sun is not a perfectly black body.

**Newton's Law of Cooling**

If the temperature of body is not very different from surrounding, rate of cooling is proportional to temperature difference between the body and its surrounding.

This law is called Newton's law of cooling.

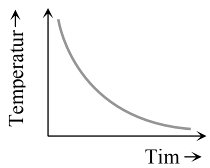
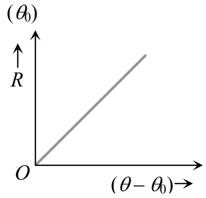
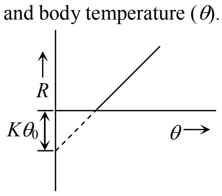
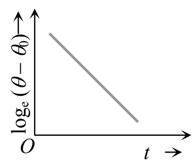
- If a body cools by radiation from $\theta_1^o C$ to $\theta_2^o C$ in time $t$, then $\frac{d\theta}{dt} = \frac{\theta_1 - \theta_2}{t}$ and $\theta = \theta_{av} = \frac{\theta_1 + \theta_2}{2}$

  The Newton's law of cooling becomes

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

  This form of law helps in solving numericals.

**Cooling curves**

| | |
|---|---|
| Curve between temperature of body $\theta$ and time.<br><br><br>$\theta - \theta_0 = Ae^{-kt}$, which indicates temperature decreases exponentially with increasing time. | Curve between rate of cooling ($R$) and temperature difference between body ($\theta$) and surrounding ($\theta_0$)<br><br><br>$R \propto (\theta - \theta_0)$. This is a straight line passing through origin. |
| Curve between the rate of cooling ($R$) and body temperature ($\theta$).<br><br><br>$R = K(\theta - \theta_0) = K\theta - K\theta_0$<br>This is a straight line intercept $R$-axis at $-K\theta_0$ | Curve between log($\theta$ – $\theta_0$) and time<br><br><br>As $\frac{d\theta}{dt} \propto -(\theta - \theta_0)$<br>$\Rightarrow \frac{d\theta}{(\theta - \theta_0)} = -Kdt$<br>Integrating<br>$\log_e(\theta - \theta_0) = -Kt + C$<br>$\log_e(\theta - \theta_0) = -Kt + \log_e A$<br>This is a straight line with negative slope |

## MULTIPLE CHOICE QUESTIONS

### Thermometry

**1.** The freezing point on a thermometer is marked as 20° and the boiling point at as 150°. A temperature of 60°$C$ on this thermometer will be read as:

**a.** 40° **b.** 65°
**c.** 98° **d.** 110°

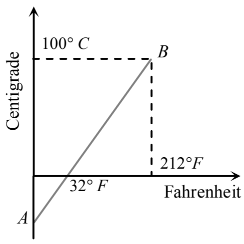
**2.** A thermometer is graduated in $mm$. It registers – 3$mm$ when the bulb of thermometer is in pure melting ice and 22$mm$ when the thermometer is in steam at a pressure of one $atm$. The temperature in °$C$ when the thermometer registers 13$mm$ is:

**a.** $\frac{13}{25}\times 100$ **b.** $\frac{16}{25}\times 100$
**c.** $\frac{13}{22}\times 100$ **d.** $\frac{16}{22}\times 100$

**3.** The temperature coefficient of resistance of a wire is 0.00125 $per$ °$C$. At 300$K$ its resistance is 1Ω. The resistance of wire will be 2Ω at:

**a.** 1154$K$ **b.** 1100$K$
**c.** 1400$K$ **d.** 1127$K$

**4.** The graph $AB$ shown in figure is a plot of temperature of a body in degree celsius and degree Fahrenheit. Then:




**a.** Slope of line $AB$ is 9/5 **b.** Slope of line $AB$ is 5/9
**c.** Slope of line $AB$ is 1/9 **d.** Slope of line $AB$ is 3/9

### Thermal Expansion

**5.** The design of a physical instrument requires that there be a constant difference in length of 10 $cm$ between an iron rod and a copper cylinder laid side by side at all temperatures. If $\alpha_{Fe} = 11\times 10^{-6}\ {}^\circ C^{-1}$ and $\alpha_{cu} = 17\times 10^{-6}\ {}^\circ C^{-1}$, their lengths are:

**a.** 28.3 $cm$, 18.3 $cm$ **b.** 23.8 $cm$, 13.8 $cm$
**c.** 23.9 $cm$, 13.9 $cm$ **d.** 27.5 $cm$, 17.5 $cm$

**6.** Two rods of length $L_2$ and coefficient of linear expansion $\alpha_2$ are connected freely to a third rod of length $L_1$ of coefficient of linear expansion $\alpha_1$ to form an isosceles triangle. The arrangement is supported on the knife edge at the midpoint of $L_1$ which is horizontal. The apex of the isosceles triangle is to remain at a constant distance from the knife edge if:

**a.** $\frac{L_1}{L_2} = \frac{\alpha_2}{\alpha_1}$ **b.** $\frac{L_1}{L_2} = \sqrt{\frac{\alpha_2}{\alpha_1}}$
**c.** $\frac{L_1}{L_2} = 2\frac{\alpha_2}{\alpha_1}$ **d.** $\frac{L_1}{L_2} = 2\sqrt{\frac{\alpha_2}{\alpha_1}}$

**7.** A brass rod and lead rod each 80 $cm$ long at 0°$C$ are clamped together at one end with their free ends coinciding. The separation of free ends of the rods if the system is placed in a steam bath is:

$(\alpha_{brass} = 18\times 10^{-6}/{}^\circ C$ and $\alpha_{lead} = 28\times 10^{-6}/{}^\circ C)$

**a.** 0.2 $mm$ **b.** 0.8 $mm$
**c.** 1.4 $mm$ **d.** 1.6 $mm$

**8.** A uniform solid brass sphere is rotating with angular speed $\omega_0$ about a diameter. If its temperature is now increased by 100°$C$. What will be its new angular speed. (Given $\alpha_B = 2.0\times 10^{-5}$ per°$C$ )

**a.** 1.1 $\omega_0$ **b.** 1.01 $\omega_0$
**c.** 0.996 $\omega_0$ **d.** 0.824 $\omega_0$

### Anomalous Expansion of Water

**9.** A glass flask of volume one $litre$ at 0°$C$ is filled, level full of mercury at this temperature. The flask and mercury are now heated to 100°$C$. How much mercury will spill out, if coefficient of volume expansion of mercury is $1.82\times 10^{-4}/{}^\circ C$ and linear expansion of glass is $0.1\times 10^{-4}/{}^\circ C$ respectively?

**a.** 21.2 $cc$ **b.** 15.2 $cc$
**c.** 1.52 $cc$ **d.** 2.12 $cc$

**10.** Liquid is filled in a flask up to a certain point. When the flask is heated, the level of the liquid:

**a.** Immediately starts increasing
**b.** Initially falls and then rises
**c.** Rises abruptly
**d.** Falls abruptly

**11.** The absolute coefficient of expansion of a liquid is 7 times that the volume coefficient of expansion of the vessel. Then the ratio of absolute and apparent expansion of the liquid is:

**a.** $\frac{1}{7}$ **b.** $\frac{7}{6}$
**c.** $\frac{6}{7}$ **d.** None of these

12. In cold countries, water pipes sometimes burst, because:
**a.** Pipe contracts
**b.** Water expands on freezing
**c.** When water freezes, pressure increases
**d.** When water freezes, it takes heat from pipes

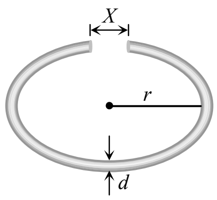
13. A solid whose volume does not change with temperature floats in a liquid. For two different temperatures $t_1$ and $t_2$ of the liquid, fractions $f_1$ and $f_2$ of the volume of the solid remain submerged in the liquid. The coefficient of volume expansion of the liquid is equal to:

**a.** $\frac{f_1 - f_2}{f_2 t_1 - f_1 t_2}$ **b.** $\frac{f_1 - f_2}{f_1 t_1 - f_2 t_2}$
**c.** $\frac{f_1 + f_2}{f_2 t_1 + f_1 t_2}$ **d.** $\frac{f_1 + f_2}{f_1 t_1 + f_2 t_2}$

## Application of Thermal Expansion

14. Two metal strips that constitute a thermostat must necessarily differ in their:
**a.** Mass
**b.** Length
**c.** Resistivity
**d.** Coefficient of linear expansion

15. A cylindrical metal rod of length $L_0$ is shaped into a ring with a small gap as shown. On heating the system:

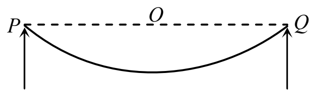



**a.** $x$ decreases, $r$ and $d$ increase
**b.** $x$ and $r$ increase, $d$ decreases
**c.** $x$, $r$ and $d$ all increase
**d.** Data insufficient to arrive at a conclusion

16. A clock with a metal pendulum beating seconds keeps correct time at 0°$C$. If it loses 12.5 seconds a day at 25°$C$, the coefficient of linear expansion of metal of pendulum is:

**a.** $\frac{1}{86400} per\,°C$ **b.** $\frac{1}{43200} per\,°C$
**c.** $\frac{1}{14400} per\,°C$ **d.** $\frac{1}{28800} per\,°C$

17. Span of a bridge is 2.4 $km$. At 30°$C$ a cable along the span sags by 0.5 $km$. Taking $\alpha = 12 \times 10^{-6}$ $per$ °C, change in length of cable for a change in temperature from 10°$C$ to 42°$C$ is:




**a.** 9.9 $m$ **b.** 0.099 $m$
**c.** 0.99 $m$ **d.** 0.4 $km$

## Specific Heat

18. Two spheres made of same substance have diameters in the ratio 1 : 2. Their thermal capacities are in the ratio of:
**a.** 1 : 2 **b.** 1 : 8
**c.** 1 : 4 **d.** 2 : 1

19. When 300 $J$ of heat is added to 25 $gm$ of sample of a material its temperature rises from 25°$C$ to 45°$C$. the thermal capacity of the sample and specific heat of the material are respectively given by:
**a.** 15 $J$/°$C$, 600 $J/kg$ °$C$ **b.** 600 $J$/°$C$, 15 $J°/kg$ °$C$
**c.** 150 $J$/°$C$, 60 $J/kg$ °$C$ **d.** None of these

20. The specific heat of a substance varies with temperature $t$(°$C$) as $c = 0.20 + 0.14\,t + 0.023\,t^2\,(cal/gm\,°C)$ The heat required to raise the temperature of 2 $gm$ of substance from 5°$C$ to 15°$C$ will be:
**a.** 24 *calorie* **b.** 56 *calorie*
**c.** 82 *calorie* **d.** 100 *calorie*

## Latent Heat

21. 2 $kg$ of ice at – 20°$C$ is mixed with 5 $kg$ of water at 20°$C$ in an insulating vessel having a negligible heat capacity. Calculate the final mass of water remaining in the container. It is given that the specific heats of water and ice are 1 $kcal/kg$ $per$ °$C$ and 0.5 $kcal/kg$/°$C$ while the latent heat of fusion of ice is 80 $kcal/kg$:
**a.** 7 $kg$ **b.** 6 $kg$
**c.** 4 $kg$ **d.** 2 $kg$

22. If mass energy equivalence is taken into account, when water is cooled to form ice, the mass of water should:
**a.** Increase
**b.** Remain unchanged
**c.** Decrease
**d.** First increase then decrease

23. Compared to a burn due to water at 100°$C$, a burn due to steam at 100°$C$ is:
**a.** More dangerous **b.** Less dangerous
**c.** Equally dangerous **d.** None of these

24. Latent heat of ice is 80 *calorie/gm*. A man melts 60 $g$ of ice by chewing in 1 *minute*. His power is:
**a.** 4800 $W$ **b.** 336 $W$
**c.** 1.33 $W$ **d.** 0.75 $W$

## Heating Curve

**25.** 50 $g$ of copper is heated to increase its temperature by 10°$C$. If the same quantity of heat is given to 10 $g$ of water, the rise in its temperature is: (Specific heat of copper = 420 Julke-kg$^{-1}$ °$C^{-1}$)

**a.** 5°$C$ **b.** 6°$C$
**c.** 7°$C$ **d.** 8°$C$

**26.** Two liquids $A$ and $B$ are at 32°$C$ and 24°$C$. When mixed in equal masses the temperature of the mixture is found to be 28°$C$. Their specific heats are in the ratio of:

**a.** 3 : 2 **b.** 2 : 3
**c.** 1 : 1 **d.** 4 : 3

**27.** A beaker contains 200 $gm$ of water. The heat capacity of the beaker is equal to that of 20 $gm$ of water. The initial temperature of water in the beaker is 20°$C$. If 440 $gm$ of hot water at 92°$C$ is poured in it, the final temperature (neglecting radiation loss) will be nearest to :

**a.** 58°$C$ **b.** 68°$C$
**c.** 73°$C$ **d.** 78°$C$

**28.** A liquid of mass $m$ and specific heat $c$ is heated to a temperature 2$T$. Another liquid of mass $m$/2 and specific heat 2$c$ is heated to a temperature $T$. If these two liquids are mixed, the resulting temperature of the mixture is:

**a.** $\frac{2}{3}T$ **b.** $\frac{8}{5}T$ **c.** $\frac{3}{5}T$ **d.** $\frac{3}{2}T$

**29.** A caloriemeter contains 0.2$kg$ of water at 30°$C$. 0.1 $kg$ of water at 60°$C$ is added to it, the mixture is well stirred and the resulting temperature is found to be 35°$C$. The thermal capacity of the caloriemeter is:

**a.** 6300 $J/K$ **b.** 1260 $J/K$
**c.** 4200 $J/K$ **d.** None of these

**30.** Consider two rods of same length and different specific heats ($s_1$ and $s_2$), conductivities $K_1$ and $K_2$ and areas of cross-section ($A_1$ and $A_2$) and both giving temperature $T_1$ and $T_2$ at their ends. If the rate of heat loss due to conduction is equal, then:

**a.** $K_1A_1 = K_2A_2$ **b.** $K_2A_1 = K_1A_2$

**c.** $\frac{K_1A_1}{s_1} = \frac{K_2A_2}{s_2}$ **d.** $\frac{K_2A_1}{s_2} = \frac{K_1A_2}{s_1}$

**31.** A heat flux of 4000 $J/s$ is to be passed through a copper rod of length 10 $cm$ and area of cross-section 100 $cm^2$. The thermal conductivity of copper is 400 $W/m$°$C$. The two ends of this rod must be kept at a temperature difference of:

**a.** 1 °$C$ **b.** 10 °$C$
**c.** 100 °$C$ **d.** 1000 °$C$

**32.** A point source of heat of power $P$ is placed at the centre of a spherical shell of mean radius $R$. The material of the shell has thermal conductivity $K$. If the temperature difference between the outer and the inner surface of the shell is not to exceed $T$, then the thickness of the shell should not be less than:

**a.** $\frac{2\pi R^2KT}{P}$ **b.** $\frac{4\pi R^2KT}{P}$

**c.** $\frac{\pi R^2KT}{P}$ **d.** $\frac{\pi R^2KT}{4P}$

## Conduction, Convection and Radiation

**33.** The heat is flowing through a rod of length 50 $cm$ and area of cross-section 5$cm^2$. Its ends are respectively at 25°$C$ and 125°$C$. The coefficient of thermal conductivity of the material of the rod is 0.092 $kcal/m$ × $s$ × °$C$. The temperature gradient in the rod is:

**a.** 2 °$C/cm$ **b.** 2 °$C/m$
**c.** 20 °$C/cm$ **d.** 10 °$C/m$

**34.** A room is maintained at 20°$C$ by a heater of resistance 20 $ohm$ connected to 200 $volt$ mains. The temperature is uniform throughout the room and heat is transmitted through a glass window of area 1 $m^2$ and thickness 0.2 $cm$. What will be the temperature outside? Given that thermal conductivity $K$ for glass is 0.2 $cal/m$ × °$C$ × $sec$ and $J$ = 4.2 $J/cal$:

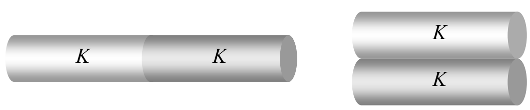
**a.** 15.24 °$C$ **b.** 15.00 °$C$
**c.** 24.15 °$C$ **d.** None of the above

**35.** There are three thermometers – one in contact with the skin of the man, other in between the vest and the shirt and third in between the shirt and coat. The readings of the thermometers are 30°$C$, 25°$C$ and 22°$C$ respectively. If the vest and shirt are of the same thickness, the ratio of their thermal conductivities is:

**a.** 9 : 25 **b.** 25 : 9
**c.** 5 : 3 **d.** 3 : 5

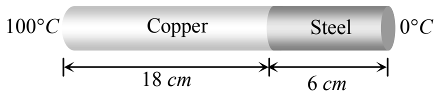
## Combination of Conductors and Temperature Difference

**36.** Two rods of same length and material transfer a given amount of heat in 12 seconds, when they are joined end to end. But when they are joined lengthwise, then they will transfer same heat in same conditions in:



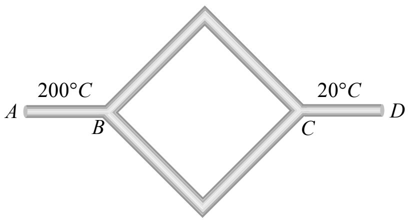

**a.** 24 $s$ **b.** 3 $s$
**c.** 1.5 $s$ **d.** 48 $s$

**37.** The coefficient of thermal conductivity of copper is nine times that of steel. In the composite cylindrical bar shown in the figure. What will be the temperature at the junction of copper and steel?




**a.** $75°C$ **b.** $67°C$
**c.** $33°C$ **d.** $25°C$

**38.** Six identical conducting rods are joined as shown in figure. Points $A$ and $D$ are maintained at temperatures $200°C$ and $20°C$ respectively. The temperature of junction $B$ will be:




**a.** $120^{o}C$ **b.** $100^{o}C$
**c.** $140^{o}C$ **d.** $80^{o}C$

**39.** If the ratio of coefficient of thermal conductivity of silver and copper is 10 : 9, then the ratio of the lengths upto which wax will melt in Ingen Hausz experiment will be:

**a.** 6 : 10 **b.** $\sqrt{10}$ : 3
**c.** 100 : 81 **d.** 81 : 100

**40.** An ice box used for keeping eatables cool has a total wall area of 1 *metre*$^2$ and a wall thickness of 5.0 *cm*. The thermal conductivity of the ice box is $K = 0.01$ $J/m^{o}C$. It is filled with ice at $0^{o}C$ along with eatables on a day when the temperature is $30^{o}C$. The latent heat of fusion of ice is $334\times10^{3}$ $J/kg$. The amount of ice melted in one day is: (1 *day* = 86,400 *seconds*)

**a.** 776 *g* **b.** 7760 *g*
**c.** 11520 *g* **d.** 1552 *g*

**41.** There is ice formation in a tank of water of thickness 10 *cm*. How much time it will take to have a layer of 0.1 *cm* below it? The outer temperature is $-5^{o}C$, the thermal conductivity of ice $K = 0.005$ $cal/cm\text{-}sec^{o}C$, the latent heat of ice is 80 *cal/gm* and the density of ice is 0.91 *gm/cc*:

**a.** 46.39 *minutes* **b.** 47.63 *minutes*
**c.** 48.77 *minutes* **d.** 49.31 *minutes*

**42.** A cylinder of radius $R$ made of a material of thermal conductivity $K_1$ is surrounded by a cylindrical shell 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:

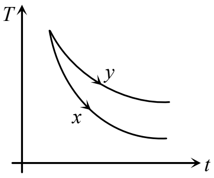
**a.** $K_1 + K_2$ **b.** $\frac{K_1K_2}{K_1+K_2}$
**c.** $\frac{K_1+3K_2}{4}$ **d.** $\frac{3K_1+K_2}{4}$

### Convection

**43.** Certain substance emits only the wavelengths $\lambda_1, \lambda_2, \lambda_3$ and $\lambda_4$ when it is at a high temperature. When this substance is at a colder temperature, it will absorb only the following wavelengths:

**a.** $\lambda_1$ **b.** $\lambda_2$
**c.** $\lambda_1$ and $\lambda_2$ **d.** $\lambda_1, \lambda_2, \lambda_3$ and $\lambda_4$

**44.** The graph. Shown in the adjacent diagram, represents the variation of temperature ($T$) of two bodies, $x$ and $y$ having same surface area, with time ($t$) due to the emission of radiation. Find the correct relation between the emissivity ($e$) and absorptivity ($a$) of the two bodies:




**a.** $e_x > e_y$ and $a_x < a_y$ **b.** $e_x < e_y$ and $a_x > a_y$
**c.** $e_x > e_y$ and $a_x > a_y$ **d.** $e_x < e_y$ and $a_x < a_y$

### Law of Distribution of Energy

**45.** A black body at 200 $K$ is found to emit maximum energy at a wavelength of 14 $\mu m$. When its temperature is raised to 1000 $K$, the wavelength at which maximum energy is emitted is:

**a.** 14 $\mu m$ **b.** 70 $\mu F$
**c.** 2.8 $\mu m$ **d.** 2.8 *mm*

**46.** The wavelength of maximum energy released during an atomic explosion was $2.93\times10^{-10}$ *m*. Given that Wien's constant is $2.93\times10^{-3}$ *m–K*, the maximum temperature attained must be of the order of:

**a.** $10^{-7}$ $K$ **b.** $10^{7}$ $K$
**c.** $10^{-13}$ $K$ **d.** $5.86\times10^{7}$ $K$

**47.** Two spheres made of same material have radii in the ratio 1 : 2. Both are at same temperature. Ratio of heat radiation energy emitted per second by them is:

**a.** 1 : 2 **b.** 1 : 8
**c.** 1 : 4 **d.** 1 : 16

**48.** Two spherical black bodies of radii $r_1$ and $r_2$ and with surface temperature $T_1$ and $T_2$ respectively radiate the same power. Then the ratio of $r_1$ and $r_2$ will be:

**a.** $\left(\frac{T_2}{T_1}\right)^2$ **b.** $\left(\frac{T_2}{T_1}\right)^4$

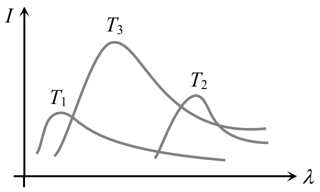
**c.** $\left(\frac{T_1}{T_2}\right)^2$ **d.** $\left(\frac{T_1}{T_2}\right)^4$

**49.** Two black metallic spheres of radius 4m, at 2000 $K$ and 1m at 4000 $K$ will have ratio of energy radiation as:

**a.** 1 : 1 **b.** 4 : 1

**c.** 1 : 4 **d.** 2 : 1

**50.** The plots of intensity versus wavelength for three black bodies at temperatures $T_1$, $T_2$ and $T_3$ respectively are as shown. Their temperature are such that:




**a.** $T_1 > T_2 > T_3$ **b.** $T_1 > T_3 > T_2$

**c.** $T_2 > T_3 > T_1$ **d.** $T_3 > T_2 > T_1$

**51.** A sphere, a cube and a thin circular plate, all made of same substance and all have same mass. These are heated to 200°$C$ and then placed in a room, then the:

**a.** Temperature of sphere drops to room temperature at last

**b.** Temperature of cube drops to room temperature at last

**c.** Temperature of thin circular plate drops to room temperature at last

**d.** Temperature of all the three drops to room temperature at the same time

## Newton's Law of Cooling

**52.** A bucket full of hot water cools from 75°$C$ to 70°$C$ in time $T_1$, from 70°$C$ to 65°$C$ in time $T_2$ and from 65°$C$ to 60°$C$ in time $T_3$, then:

**a.** $T_1 = T_2 = T_3$ **b.** $T_1 > T_2 > T_3$

**c.** $T_1 < T_2 < T_3$ **d.** $T_1 > T_2 < T_3$

**53.** A body takes $T$ minutes to cool from 62°$C$ to 61°$C$ when the surrounding temperature is 30°$C$. The time taken by the body to cool from 46°$C$ to 45.5°$C$ is:

**a.** Greater than $T$ minutes **b.** Equal to $T$ minutes

**c.** Less than $T$ minutes **d.** Equal to $T$/2 minutes

**54** Hot water cools from 60°$C$ to 50°$C$ in the first 10 *minutes* and to 42°$C$ in the next 10 *minutes*. The temperature of the surrounding:

**a.** 5°$C$ **b.** 10°$C$

**c.** 15°$C$ **d.** 20°$C$

**55.** How many grams of a liquid of specific heat 0.2 at a temperature 40°$C$ must be mixed with 100 *gm* of a liquid of specific heat of 0.5 at a temperature 20°$C$, so that the final temperature of the mixture becomes 32°$C$:

**a.** 175 *gm* **b.** 300 *g*

**c.** 295 *gm* **d.** 375 *g*

## NCERT EXEMPLAR PROBLEMS

### More than One Answer

**56.** Two bodies $A$ and $B$ have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are equal. The two bodies emit total radiant power at the same rate. The wavelength $\lambda_B$ corresponding to maximum spectral radiancy in the radiation form $B$ is shifted from the wavelength corresponding to maximum spectral radiancy in the radiation form $A$, by 1.00$\mu m$. If the temperature of $A$ is 5802 $K$:

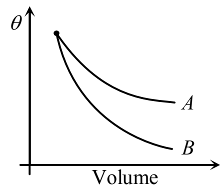
**a.** the temperature of $B$ is 1934 $K$

**b.** $\lambda_B = 1.5\mu m$

**c.** the temperature of $B$ is 1160 $K$

**d.** the temperature of $B$ is 2901 $K$

**57.** Which of the following statements are not correct?




**a.** A temperature change of 1°$C$ on the Celsius scale is equal to a temperature change of 274 $K$ on the Kelvin scale

**b.** A sphere, a cube and a thin circular plate have the same mass and are made of same material. All of them are heated to the same temperature. The plane and minimum for the sphere

**c.** Two spheres of the same material have radii 1 $m$ and 4 $m$ and temperature 4000 $K$ and 2000 $K$ respectively. The energy radiated per second sphere

**d.** Two identical calorimeters contain equal volumes of liquids $A$ and $B$. Both are heated to 25°$C$ above the room temperature and left to cool. From the cooling curves shown in figure, it follows that the specific heat of $A$ is greater than that of $B$

**58.** 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 $\alpha_C$ and $\alpha_B$. On heating, the temperature of the strip goes up by $\Delta T$ and the strip bends to form an arc of radius of curvature *R*. Then *R* is:

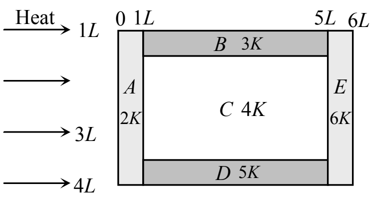
**a.** Proportional to $\Delta T$

**b.** Inversely proportional to $\Delta T$

**c.** Proportional to $|\alpha_B - \alpha_C|$

**d.** Inversely proportional to $|\alpha_B - \alpha_C|$

**59.** A composite block is made of slabs *A, B, C, D* and *E* of different thermal conductivities (given in terms of a constant *K*) and size (given in terms of length, *L*) as show in the figure. All slabs are of same width. Heat *Q* flows only form left to right through the blocks. Then in steady state:



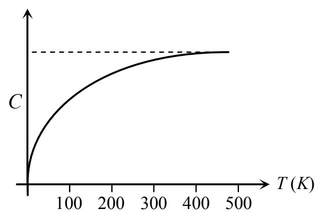

**a.** heat flow through *A* and *E* slabs are same

**b.** heat flow through slab *E* is maximum

**c.** temperature difference across slab *E* is smallest

**d.** heat flow through *C* = heat flow through *B* + heat flow through *D*

**60.** The figure below shows the variation of specific heat capacity (*C*) of a solid as a function of temperature (*T*). The temperature is increased continuously form 0 to 500 K at a constant rate. Ignoring any volume change, the following statements(s) is (are) correct to reasonable approximation:




**a.** the rate at which heat is absorbed in the range 0–100 *K* varies linearly with temperature *T*

**b.** heat absorbed in increasing the temperature form 0–100 *K* is less than the heat required for increasing the temperature form 400–500 *K*

**c.** there is no change in the rate of heat absorbtion in the range 400–500 *K*

**d.** the rate of heat absorption increases in the range 200-300 *K*

**61.** Two bodies *A* and *B* have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are the same. The two bodies emit total radiant power at the same rate. The wavelength $\lambda_B$ corresponding to maximum spectral radiancy in the radiation from *B* is shifted from the wavelength corresponding to maximum spectral radiancy in the radiation from *A*, by 1.00 $\mu m$. If the temperature of *A* is 5802 *K*

**a.** The temperature of *B* is 1934 *K*

**b.** $\lambda_B = 1.5$ μm

**c.** The temperature of *B* is 11604 *K*

**d.** The temperature of *B* is 2901 *K*

**62.** A bimetallic strip is formed out of two identical strips-one of copper and the other of brass. The coefficients of linear expansion of the two metals are $\alpha_C$ and $\alpha_B$. On heating, the temperature of the strip goes up by $\Delta T$ and the strip bends to from an arc of radius of curvature *R*. Then, *R* is:

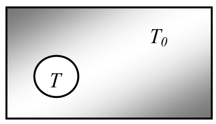
**a.** proportional to $\Delta T$

**b.** inversely proportional to $\Delta T$

**c.** proportional to $|\alpha_B - \alpha_C|$

**d.** inversely proportional to $|\alpha_B - \alpha_C|$

**63.** A black body of temperature *T* is inside a chamber of temperature $T_0$. Now the closed chamber is slightly opened to sun such that temperature of black body (*T*) and chamber ($T_0$) remains constant:



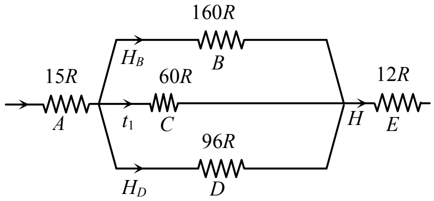

**a.** Black body will absorb more radiation

**b.** Black body will absorb less radiation

**c.** Black body emit more energy

**d.** Black body emit energy equal to energy absorbed by it

**64.** A composite block is made of slabs *A,B,C,D* and *E* of different thermal conductivities (given in terms of a constant *K*) and sizes (given in terms of length, *L*) as shown in the figure. All slabs are of same width. Heat *Q* flows only from left to right through the blocks. Then in steady state:



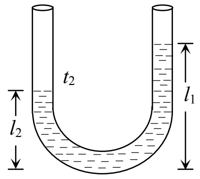

**a.** heat flow through *A* and *E* slabs are same

**b.** heat flow through slab *E* is maximum

**c.** temperature difference across slab $E$ is smallest

**d.** heat flow through $C$ = heat flow through $B$ + heat flow through $D$

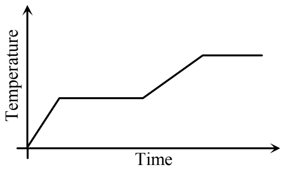
**65.** In a vertical U-tube containing a liquid, the two arms are maintained at different temperatures $t_1$ and $t_2$. The liquid columns in the two arms have heights $l_1$ and $l_2$ respectively. The coefficient of volume expansion of the liquid is equal to




**a.** $\frac{l_1 - l_2}{l_2 t_1 - l_1 t_2}$ **b.** $\frac{l_1 - l_2}{l_1 t_1 - l_2 t_2}$

**c.** $\frac{l_1 + l_2}{l_2 t_1 + l_1 t_2}$ **d.** $\frac{l_1 + l_2}{l_1 t_1 + l_2 t_2}$

**66.** Heat is supplied to a certain homogenous sample of matter, at a uniform rate. Its temperature is plotted against time, as shown. Which of the following conclusions can be drawn




**a.** Its specific heat capacity is greater in the solid state than in the liquid state

**b.** Its specific heat capacity is greater in the liquid state than in the solid state

**c.** Its latent heat of vaporization is greater than its latent heat of fusion

**d.** Its latent heat of vaporization is smaller than its latent of fusion

**67.** The relative humidity on a day, when partial pressure of water vapour is $0.012\times10^5\ Pa$ at $12°C$ is (take vapour pressure of water at this temperature as $0.016\times10^5\ Pa$)

**a.** 70% **b.** 40% **c.** 75% **d.** 25%

**68.** A body of mass 5 *kg* falls from a height of 30 *metre*. If its all mechanical energy is changed into heat, then heat produced will be:

**a.** 350 *cal* **b.** 150 *cal*

**c.** 60 *cal* **d.** 6 *cal*

**69.** Two liquids $A$ and $B$ are at $32°C$ and $24°C$. When mixed in equal masses the temperature of the mixture is found to be $28°C$. Their specific heats are in the ratio of

**a.** 3 : 2 **b.** 2 : 3

**c.** 1 : 1 **d.** 4 : 3

**70.** The latent heat of vaporization of a substance is always

**a.** Greater than its latent heat of fusion

**b.** Greater than its latent heat of sublimation

**c.** Equal to its latent heat of sublimation

**d.** Less than its latent heat of fusion

## Assertion and Reason

**Note:** Read the Assertion (A) and Reason (R) carefully to mark the correct option out of the options given below:

**a.** If both assertion and reason are true and the reason is the correct explanation of the assertion.

**b.** If both assertion and reason are true but reason is not the correct explanation of the assertion.

**c.** If assertion is true but reason is false.

**d.** If the assertion and reason both are false.

**e.** If assertion is false but reason is true.

**71.** **Assertion:** The coefficient of volume expansion has dimension $K^{-1}$.
**Reason:** The coefficient of volume expansion is defined as the change in volume per unit change in temperature.

**72.** **Assertion:** A beaker is completely filled with water at $4°C$ It will overflow, both when heated or cooled.
**Reason:** There is expansion of water below and above $4°C$.

**73.** **Assertion:** The melting point of ice decreases with increase of pressure.
**Reason:** Ice contracts on melting.

**74.** **Assertion:** Melting of solid causes no change in internal energy.
**Reason:** Latent heat is the heat required to melt a unit mass of solid.

**75.** **Assertion:** Specific heat of a body is always greater than its thermal capacity.
**Reason:** Thermal capacity is the heat required for raising temperature of unit mass of the body through unit degree.

**76.** **Assertion:** Water kept in a open vessel will quickly evaporate on the surface of moon.
**Reason:** The temperature at the surface of the moon is much higher than boiling point of the water.

**77.** **Assertion:** The molecules at $0°C$ ice and $0°C$ water will have same potential energy
**Reason:** Potential energy depends only on temperature of the system.

**78.** **Assertion:** A hollow metallic closed container maintained at a uniform temperature can act as a source of black body radiation.
**Reason:** All metals acts as a black body

79. **Assertion:** If the temperature of a star is doubled then the rate of loss of heat from it becomes 16 times.
**Reason:** Specific heat varies with temperature.

80. **Assertion:** The radiation from the sun's surface varies as the fourth power of its absolute temperature.
**Reason:** The sun is not a black body.

81. **Assertion:** Blue star is at high temperature than red star.
**Reason:** Wein's displacement law states that $T \propto (1/\lambda m)$.

82. **Assertion:** A body that is a good radiator is also a good absorber of radiation at a given wavelength.
**Reason:** According to Kirchoff's law the absorptivity of a body is equal to its emissivity at a given wavelength.

83. **Assertion:** Temperatures near the sea coast are moderate.
**Reason:** Water has a high thermal conductivity.

84. **Assertion:** It is hotter over the top of a fire than at the same distance on the sides.
**Reason:** Air surrounding the fire conducts more heat upwards.

85. **Assertion:** For higher temperature, the peak emission wavelength of a black body shifts to lower wavelengths.
**Reason:** Peak emission wavelength of a blackbody is proportional to the fourth power of temperature.

## Comprehension Based

**Paragraph –I**

Particular thermometers have been designed to measure temperatures in various ranges. Answer the following questions to select type of thermometers for the desired range.

86. Which of the following thermometers will you prefer to measure temperatures below 1 $K$?
**a.** Gas thermometers
**b.** Thermoelectric thermometers
**c.** Magnetic thermometers
**d.** Vapour pressure thermometers

87. Which of the following thermometer is preferred to measure temperatures between 4$K$ to 77 $K$?
**a.** Gas thermometers
**b.** Magnetic thermometers
**c.** Thermoelectric thermometers
**d.** Germanium resistance thermometers

88. Which of the following thermometer can be used to measure low temperatures between 1$K$ to 120 $K$?
**a.** Gas thermometers
**b.** Pyrometers
**c.** Vapour pressure thermometers
**d.** Thermoelectric thermometers

**Paragraph –II**

When we heat a substance, the heat absorbed $\Delta Q = m \times C \times \Delta T$ where $C$ is specific heat of substance. When gases are heated, the heat absorbed depends on the conditions under which the gas is being heated. The specific heat of gas as defined for liquids and solids should be: $C = \dfrac{\Delta Q}{m \times \Delta T}$

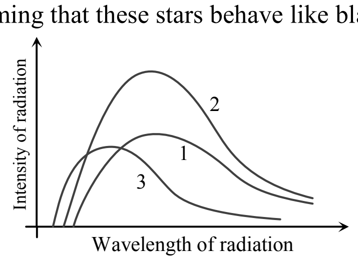
89. The specific heat of gas defined as that of solid or liquid is:
**a.** constant **b.** zero
**c.** $\infty$
**d.** may have any value for 0 to $\infty$, position or – *ve*

90. The specific heat of gas does not remain constant when heated freely. The gas when heated may expand in volume and pressure. To measure specific heat of gas we must keep either volume constant or pressure constant. The specific heat of gas is denoted by $C_P$. Then which of the following relations is not correct
**a.** $C_p > C_v$ **b.** $C_p - C_v = R$
**c.** $\dfrac{C_v}{C_p} = \gamma$ **d.** $C_p - C_v = \dfrac{R}{M}$

91. The ratio of specific heats of gas γ is related to the following relations as:
**a.** $\gamma = \dfrac{\text{Adiabatic Elasticity}}{\text{Isothermal Elasticity}}$
**b.** $\gamma = \dfrac{\text{Sope of Adiabatic curve}}{\text{Slope of Isothermal}}$
**c.** $\gamma = 1 + \dfrac{2}{f}$, where f is number of degrees of freedom
**d.** $\gamma = \dfrac{\text{Specific Heat of gas at Constant Volume}}{\text{Specific Heat of Constant Pressure}}$ which of the above relation is not correct?

**Paragraph –III**

The intensity of radiation emitted by sun has its maximum value at wavelength of 540 nm and that emitted by north star is 360 nm. Assuming that these stars behave like black bodies




92. The ratio of surface temperature of sun and star is:
**a.** $\dfrac{2}{3}$ **b.** $\dfrac{3}{2}$ **c.** $\dfrac{16}{81}$ **d.** $\dfrac{81}{16}$

**93.** If temperature of sun is 6000 K, what will be ratio of energy emitted per sec per unit area by sun and North Star?

**a.** $\frac{2}{3}$ **b.** $\frac{3}{2}$ **c.** $\frac{16}{81}$ **d.** $\frac{81}{16}$

**94.** The graphs which will represent the radiation spectrum of North Star is:

**a.** 1 **b.** 2

**c.** 3 **d.** None

## Match the Column

**95.** To determine specific heat of different substances we use different types of calorimeters. Can you match the type of colorimeter used named in column I to the substance whose specific heat is determined by corresponding calorimeter in column II.

| Column I | Column II |
|---|---|
| **(A)** Regnault's calorimeter | **1.** To determine specific heat of solids at very low temperatures |
| **(B)** Joly's differential calorimeter | **2.** To determine specific heat of solids or gases at constant pressures |
| **(C)** Calender and Barmer's calorimeter | **3.** Used to measure specific heat at constant volume |
| **(D)** Nernst's vacuum calorimeter | **4.** Specific heat of liquids and gases at constant pressure |

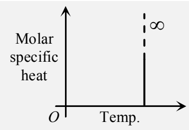
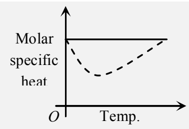
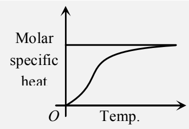
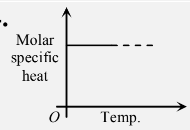
**a.** A → 1, B → 2, C → 3, D → 4
**b.** A → 2, B → 3, C → 4, D → 1
**c.** A → 3, B → 4, C → 1, D → 2
**d.** A → 4, B → 3, C → 2, D → 1

**96.** Column I given some devices and Column II gives some processes on which the functioning of these devices depend. Match the devices in Column I with the processes in Column II.

| Column I | Column II |
|---|---|
| **(A)** Bimetallic strip | **1.** Radiation from a hot body |
| **(B)** Steam engine | **2.** Energy conversion |
| **(C)** Incandescent lamp | **3.** Melting |
| **(D)** Electric fuse | **4.** Thermal expansion of solids |

**a.** A → 4, B → 2, C → 1,2, D → 2,3
**b.** A → 4, B → 3, C → 1,2, D → 3
**c.** A → 4, B → 2, C → 2, D → 2,3
**d.** A → 4, B → 2, C → 1 D → 2,3

**97.** Molar specific heat or molar heat capacity is the amount of heat required to raise the temperature of 1 mole of substance through $1°C$. Molar specific heat of substance depends on state of matter. It also varies with temperature of substances depending on the state of matter. It also varies with temperature of substances depending on the state of matter, external conditions and nature of substance. Column I give the state of matter and the substance. Column I give the state of matter and the substance with other conditions. Column II gives the graph showing variation of specific heat with temperature. Match the proper graph in column II with proper substance mentioned in column I.

| Column I | Column II |
|---|---|
| **(A)** Molar specific heat of water vs temperature | **1.**   |
| **(B)** Molar specific heat of metal vs temperature | **2.**   |
| **(C)** Molar specific heat gas at constant pressure vs temperature | **3.**   |
| **(D)** Molar specific heat during change of state form solid to liquid or liquid to vapour vs temperature | **4.**   |

**a.** A → 2, B → 3, C → 4, D → 1
**b.** A → 3, B → 4, C → 1, D → 2
**c.** A → 4, B → 3, C → 2, D → 1
**d.** A → 1, B → 2, C → 3, D → 4

## Integer

**98.** Two rods of same material and length have their radii in ratio of 3:1, the ratio of expansion when same amount of heat is supplied will be.

**99.** In a compensated pendulum two rods of different metals are used with their length in the ratio of 1:2. The coefficients of linear expansions for metals are in the ratio.

**100.** The ends of two rods of different materials with their thermal conductivities, radii of cross-sections and lengths all are in the ratio 1:2 are maintained at the same temperature difference. If the rate of flow of heat in the larger rod is $4\,cal/\sec$, that in the shorter rod in $cal/\sec$ will be:

## ANSWER

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** | **2.** | **3.** | **4.** | **5.** | **6.** | **7.** | **8.** | **9.** | **10.** |
| c | b | d | b | a | d | b | c | c | b |
| **11.** | **12.** | **13.** | **14.** | **15.** | **16.** | **17.** | **18.** | **19.** | **20.** |
| b | b | a | d | c | a | c | b | a | c |
| **21.** | **22.** | **23.** | **24.** | **25.** | **26.** | **27.** | **28.** | **29.** | **30.** |
| b | b | a | b | a | c | b | d | b | a |
| **31.** | **32.** | **33.** | **34.** | **35.** | **36.** | **37.** | **38.** | **39.** | **40.** |
| c | b | a | a | d | b | a | c | b | d |
| **41.** | **42.** | **43.** | **44.** | **45.** | **46.** | **47.** | **48.** | **49.** | **50.** |
| c | c | d | c | c | b | c | a | a | b |
| **51.** | **52.** | **53.** | **54.** | **55.** | **56.** | **57.** | **58.** | **59.** | **60.** |
| a | c | b | b | d | a,b | a,c,d | b,d | a,c,d | b,c,d |
| **61.** | **62.** | **63.** | **64.** | **65.** | **66.** | **67.** | **68.** | **69.** | **70.** |
| a,b | b,d | d | a,c,d | b,c,d | b,c | c | a | c | a |
| **71.** | **72.** | **73.** | **74.** | **75.** | **76.** | **77.** | **78.** | **79.** | **80.** |
| a | a | a | e | e | c | d | c | b | c |
| **81.** | **82.** | **83.** | **84.** | **85.** | **86.** | **87.** | **88.** | **89.** | **90.** |
| a | a | c | b | c | c | d | c | d | c |
| **91.** | **92.** | **93.** | **94.** | **95.** | **96.** | **97.** | **98.** | **99.** | **100.** |
| d | a | c | b | a | a | a | 9 | 2 | 1 |

## SOLUTION

### Multiple Choice Questions

**1.** **(c)** Temperature on any scale can be converted into other scale by $\dfrac{X-LFP}{UFP-LFP}=$ Constant for all scales

$$\therefore \quad \frac{X-20^\circ}{150^\circ-20^\circ}=\frac{C-0^\circ}{100^\circ-0^\circ}$$

$$\Rightarrow \quad X=\frac{C\times 130^\circ}{100^\circ}+20^\circ=\frac{60^\circ\times 130^\circ}{100^\circ}+20^\circ=98^\circ$$

**2.** **(b)** For a constant volume gas thermometer temperature in $^\circ centigrade$ is given as $T_c=\dfrac{P-P_0}{P_{100}-P_0}\times 100^\circ C$

$$\Rightarrow \quad T_c=\frac{13-(-3)}{22-(-3)}\times 100^\circ C=\frac{16}{25}\times 100$$

**3.** **(d)** Resistance of wire varies with temperature as $R=R_0(1+\alpha T_c)$ where $\alpha$ is temperature coefficient of resistance

$$\Rightarrow \quad \frac{R_{27}}{R_{T_c}}=\frac{R_0(1+27\alpha)}{R_0(1+\alpha T_c)}=\frac{1}{2}$$

$$\Rightarrow \quad T_c=\frac{1+54\alpha}{\alpha}=\frac{1+54\times 0.00125}{0.00125}=854^\circ C$$

**4.** **(b)** Relation between Celsius and Fahrenheit scale of temperature is $\dfrac{C}{5}=\dfrac{F-32}{9}$

By rearranging we get, $C=\dfrac{5}{9}F-\dfrac{160}{9}$

By equating above equation with standard equation of line $y=mx+c$ we get $m=\dfrac{5}{9}$ and $c=\dfrac{-160}{9}$

*i.e.* Slope of the line $AB$ is $\dfrac{5}{9}$.

**5.** **(a)** Since a constant difference in length of 10 *cm* between an iron rod and a copper cylinder is required therefore

$$L_{Fe}-L_{Cu}=10cm \qquad \ldots (i)$$

or $\quad \Delta L_{Fe}-\Delta L_{Cu}=O$

$\therefore \quad \Delta L_{Fe}=\Delta L_{Cu}$

*i.e.*, Linear expansion of iron rod = Linear expansion of copper cylinder

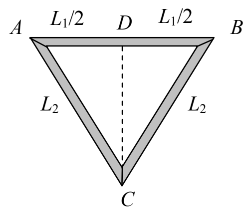
$$\Rightarrow \quad L_{Fe}\times\alpha_{Fe}\times\Delta T=L_{Cu}\times\alpha_{Cu}\times\Delta T$$

$$\Rightarrow \quad \frac{L_{Fe}}{L_{Cu}}=\frac{\alpha_{Cu}}{\alpha_{Fe}}=\frac{17}{11}$$

$$\therefore \quad \frac{L_{Fe}}{L_{Cu}}=\frac{17}{11} \qquad \ldots (ii)$$

From (*i*) and (*ii*) $L_{Fe}=28.3cm,\ L_{Cu}=18.3cm$.

**6.** **(d)** The apex of the isosceles triangle to remain at a constant distance from the knife edge $DC$ should remains constant before and after heating.




Before expansion: In triangle $ADC$

$$(DC)^2=L_2^2-\left(\frac{L_1}{2}\right)^2 \qquad \ldots (i)$$

After expansion:

$$(DC)^2=[L_2(1+\alpha_2 t)]^2-\left[\frac{L_1}{2}(1+\alpha_1 t)\right]^2 \qquad \ldots (ii)$$

Equating (*i*) and (*ii*) we get $L_2^2-\left(\dfrac{L_1}{2}\right)^2$

$$=[L_2(1+\alpha_2 t)]^2-\left[\frac{L_1}{2}(1+\alpha_1 t)\right]^2$$

$\Rightarrow \quad L_2^2 - \frac{L_1^2}{4} = L_2^2 + L_2^2 \times 2\alpha_2 \times t - \frac{L_1^2}{4} - \frac{L_1^2}{4} \times 2\alpha_1 \times t$

[Neglecting higher terms]

$\Rightarrow \quad \frac{L_1^2}{4}(2\alpha_1 t) = L_2^2(2\alpha_2 t) \Rightarrow \frac{L_1}{L_2} = 2\sqrt{\frac{\alpha_2}{\alpha_1}}$

7. **(b)** The Brass rod and the lead rod will suffer expansion when placed in steam bath.

$\therefore$ Length of brass rod at $100°C$ $L'_{brass} = L_{brass}(1 + \alpha_{brass}\,\Delta T)$

$= 80[1 + 18 \times 10^{-6} \times 100]$

and the length of lead rod at $100°C$ $L'_{lead} = L_{lead}(1 + \alpha_{lead}\,\Delta T) = 80[1 + 28 \times 10^{-6} \times 100]$

Separation of free ends of the rods after heating

$= L'_{lead} - L'_{brass} = 80[28 - 18] \times 10^{-4}$

$= 8 \times 10^{-2}\,cm = 0.8\,mm$

8. **(c)** Due to increase in temperature, radius of the sphere changes.

Let $R_0$ and $R_{100}$ are radius of sphere at $0°C$ and $100°C$

$R_{100} = R_0[1 + \alpha \times 100]$

Squaring both the sides and neglecting higher terms

$R_{100}^2 = R_0^2[1 + 2\alpha \times 100]$

By the law of conservation of angular momentum $I_1\omega_1 = I_2\omega_2$

$\Rightarrow \quad \frac{2}{5}MR_0^2\omega_1 = \frac{2}{5}MR_{100}^2\omega_2$

$\Rightarrow \quad R_0^2\omega_1 = R_0^2[1 + 2 \times 2 \times 10^{-5} \times 100]\omega_2$

$\Rightarrow \quad \omega_2 = \frac{\omega_1}{[1 + 4 \times 10^{-3}]} = \frac{\omega_0}{1.004} = 0.996\omega_0$

9. **(c)** Due to volume expansion of both liquid and vessel, the change in volume of liquid relative to container is given by $\Delta V = V[\gamma_L - \gamma_S]\Delta\theta$

Given $V = 1000\,cc$, $\alpha_g = 0.1 \times 10^{-4}/°C$

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

$\therefore \quad \Delta V = 1000\,[1.82 \times 10^{-4} - 0.3 \times 10^{-4}] \times 100 = 15.2\,cc$

10. **(b)** Since both the liquid and the flask undergoes volume expansion and the flask expands first therefore the level of the liquid initially falls and then rises.

11. **(b)** Apparent coefficient of Volume expansion $\gamma_{app.} = \gamma_L - \gamma_s = 7\,\gamma_s - \gamma_s = 6\gamma_s$ (given $\gamma_L = 7\,\gamma_s$)

Ratio of absolute and apparent expansion of liquid $\frac{\gamma_L}{\gamma_{app.}} = \frac{7\gamma_s}{6\gamma_s} = \frac{7}{6}$.

12. **(b)** In anomalous expansion, water contracts on heating and expands on cooling in the range $0°C$ to $4°C$. Therefore water pipes sometimes burst, in cold countries.

13. **(a)** As with the rise in temperature, the liquid undergoes volume expansion therefore the fraction of solid submerged in liquid increases.

Fraction of solid submerged at $t_1°C = f_1$ = Volume of displaced liquid

$= V_0(1 + \gamma t_1)$ . . . ($i$)

and fraction of solid submerged at $t_2°C = f_2$ = Volume of displaced liquid

$= V_0(1 + \gamma t_2)$ . . . ($ii$)

From ($i$) and ($ii$) $\frac{f_1}{f_2} = \frac{1 + \gamma t_1}{1 + \gamma t_2}$

$\Rightarrow \quad \gamma = \frac{f_1 - f_2}{f_2 t_1 - f_1 t_2}$

14. **(d)** Thermostat is used in electric apparatus like refrigerator, Iron *etc* for automatic cut off. Therefore for metallic strips to bend on heating their coefficient of linear expansion should be different.

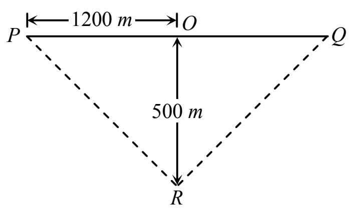
15. **(c)** On heating the system; *x, r, d* all increases, since the expansion of isotropic solids is similar to true photographic enlargement

16. **(a)** Loss of time due to heating a pendulum is given as $\Delta T = \frac{1}{2}\alpha\Delta\theta T$

$\Rightarrow \quad 12.5 = \frac{1}{2} \times \alpha \times (25 - 0)°C \times 86400$

$\Rightarrow \quad \alpha = \frac{1}{86400}\,per\,°C$

17. **(c)** Span of bridge = 2400 $m$ and Bridge sags by 500 $m$ at 30° (given)




From the figure $L_{PRQ} = 2\sqrt{1200^2 + 500^2} = 2600m$

But $L = L_0(1 + \alpha\,\Delta t)$ [Due to linear expansion]

$\Rightarrow \quad 2600 = L_0(1 + 12 \times 10^{-6} \times 30)$

$\therefore$ Length of the cable $L_0 = 2599m$

Now change in length of cable due to change in temperature from $10^oC$ to $42^oC$

$\Delta L = 2599 \times 12 \times 10^{-6} \times (42-10) = 0.99m$

**18.** **(b)** Thermal capacity = Mass × Specific heat

Due to same material both spheres will have same specific heat

$\therefore$ Ratio of thermal capacity $= \frac{m_1}{m_2} = \frac{V_1\rho}{V_2\rho}$

$$= \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{2}\right)^3 = 1:8$$

**19.** **(a)** Thermal capacity = $mc$ =

$$\frac{Q}{\Delta T} = \frac{300}{45-25} = \frac{300}{20} = 15J/°C$$

Specific heat $= \frac{\text{Thermal capacity}}{\text{Mass}}$

$$= \frac{15}{25 \times 10^{-3}} = 600J/kg°C$$

**20.** **(c)** Heat required to raise the temperature of $m$ *gm* of substance by $dT$ is given as

$dQ = mc\,dT$

$\Rightarrow$ $Q = \int mc\,dT$

$\therefore$ To raise the temperature of 2 *gm* of substance from $5°C$ to $15°C$ is $Q = \int_5^{15} 2 \times (0.2 + 0.14t + 0.023t^2)dT$

$$= 2 \times \left[0.2t + \frac{0.14t^2}{2} + \frac{0.023t^3}{3}\right]_5^{15} = 82\ calorie$$

**21.** **(b)** Initially ice will absorb heat to raise it's temperature to $0^oC$ then it's melting takes place

If $m$ = Initial mass of ice, $m'$ = Mass of ice that melts and $m_w$ = Initial mass of water, By Law of mixture Heat gain by ice = Heat loss by water

$\Rightarrow$ $m \times c \times (20) + m' \times L = m_w c_w[20]$

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

$\Rightarrow$ $m' = 1kg$

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

**22.** **(b)** When water is cooled at $0^oC$ to form ice then 80 *calorie/gm* (latent heat) energy is released. Because potential energy of the molecules decreases. Mass will remain constant in the process of freezing of water.

**23.** **(a)** Steam at $100^oC$ contains extra 540 *calorie/gm* energy as compare to water at $100^oC$. So it's more dangerous to burn with steam then water.

**24.** **(b)** Work done by man = Heat absorbed by ice = $mL$ = 60 × 80 = 4800 *calorie* = 20160 *J*

$\therefore$ Power $= \frac{W}{t} = \frac{20160}{60} = 336W$

**25.** **(a)** Same amount of heat is supplied to copper and water

So, $m_c c_c \Delta T_c = m_\omega c_\omega \Delta T_\omega$

$$\Rightarrow \quad \Delta T_\omega = \frac{m_c c_c \Delta T_c}{m_\omega c_\omega} = \frac{50 \times 10^{-3} \times 420 \times 10}{10 \times 10^{-3} \times 4200} = 5°C$$

**26.** **(c)** Heat lost by $A$ = Heat gained by $B$

$\Rightarrow$ $m_A \times c_A \times (T_A - T) = m_B \times c_B \times (T - T_B)$

Since $m_A = m_B$ and Temperature of the mixture ($T$) = $28°C$

$\therefore$ $c_A \times (32-28) = c_B \times (28-24)$

$\Rightarrow$ $\frac{c_A}{c_B} = 1 : 1$

**27.** **(b)** Heat lost by hot water = Heat gained by cold water in beaker + Heat absorbed by beaker

$\Rightarrow$ 440 (92 – $T$) = 200 × ($T$ – 20) + 20 × ($T$ – 20)

$\Rightarrow$ $T = 68°C$

**28.** **(d)** Temperature of mixture is given by $T$

$$= \frac{m_1c_1T_1 + m_2c_2T_2}{m_1c_1 + m_2c_2} = \frac{m.c.2T + \frac{m}{2}.2.c.T}{m.c. + \frac{m}{2}.2c} = \frac{3}{2}T$$

**29.** **(b)** Let $X$ be the thermal capacity of calorimeter and specific heat of water = 4200 *J/kg-K*

Heat lost by 0.1 *kg* of water = Heat gained by water in calorimeter + Heat gained by calorimeter

$\Rightarrow$ $0.1 \times 4200 \times (60-35) = 0.2 \times 4200 \times (35-30) + X(35-30)$

10500 = 4200 + 5$X$

$\Rightarrow$ $X$ = 1260 *J/K*

**30.** **(a)** According to Illustration, rate of heat loss in both rods are equal *i.e* $\left(\frac{dQ}{dt}\right)_1 = \left(\frac{dQ}{dt}\right)_2$

$\Rightarrow$ $\frac{K_1A_1\Delta\theta_1}{l_1} = \frac{K_2A_2\Delta\theta_2}{l_2}$

$\therefore$ $K_1A_1 = K_2A_2$

[As $\Delta\theta_1 = \Delta\theta_2 = (T_1 - T_2)$ and $l_1 = l_2$ given]

31. **(c)** From $\frac{dQ}{dt} = \frac{KA\Delta\theta}{l}$

$$\Rightarrow \quad \Delta\theta = \frac{l}{K \times A} \times \frac{dQ}{dt}$$

$$= \frac{0.1}{400 \times (100 \times 10^{-4})} \times 4000 = 100°C$$

32. **(b)** Rate of flow of heat or power

$$(P) = \frac{KA\Delta\theta}{\Delta x} = \frac{K4\pi R^2 T}{\Delta x}$$

$\therefore$ Thickness of shell $\Delta x = \frac{4\pi R^2 KT}{P}$.

33. **(a)** Temperature gradient

$$= \frac{\Delta\theta}{\Delta x} = \frac{\theta_2 - \theta_1}{\Delta x}$$

$$= \frac{125 - 25}{50} = 2°C/cm.$$

34. **(a)** As the temperature of room remain constant therefore the rate of heat generation from the heater should be equal to the rate of flow of heat through a glass window

$$\frac{1}{J}\left(\frac{V^2}{R}t\right) = KA\frac{\Delta\theta}{l}.t$$

$$\Rightarrow \quad \frac{1}{4.2} \times \frac{(200)^2}{20} = \frac{0.2 \times 1 \times (20 - \theta)}{0.2 \times 10^{-2}}$$

$\Rightarrow$ $\theta$ = 15.24°$C$ [where $\theta$ = temperature of outside]

35. **(d)** Rate of flow of heat will be equal in both vest and shirt

$$\therefore \quad \frac{K_{vest} A.\Delta\theta_{vest} t}{l} = \frac{K_{shirt} A\Delta\theta_{shirt} t}{l}$$

$$\Rightarrow \quad \frac{K_{vest}}{K_{shirt}} = \frac{\Delta\theta_{shirt}}{\Delta\theta_{vest}}$$

$$\Rightarrow \quad \frac{K_{vest}}{K_{shirt}} = \frac{25 - 22}{30 - 25} = \frac{3}{5}.$$

36. **(b)** $Q = K\,A\frac{\Delta\theta}{l}.t$

$\therefore$ $t \propto \frac{l}{A}$ [As $Q$, $K$ and $\Delta\theta$ are constant]

$$\frac{t_1}{t_2} = \frac{l_1}{l_2} \times \frac{A_2}{A_1} = \left(\frac{l_1}{l_1/2}\right) \times \left(\frac{2A_1}{A_1}\right)$$

$$\frac{t_1}{t_2} = 4$$

$$\Rightarrow \quad t_2 = \frac{t_1}{4} = \frac{12}{4} = 3$$

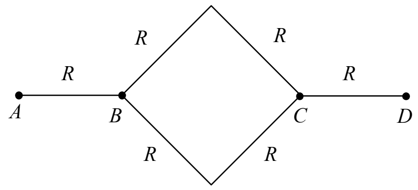
37. **(a)** $K_1 = 9K_2$, $l_1 = 18cm$, $l_2 = 6\ cm$,

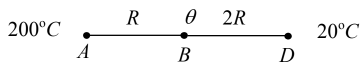
$\theta_1 = 100°C$, $\theta_2 = 0°C$

Temperature of the junction $\theta = \dfrac{\frac{K_1}{l_1}\theta_1 + \frac{K_2}{l_2}\theta_2}{\frac{K_1}{l_1} + \frac{K_2}{l_2}}$

$$\Rightarrow \quad \theta = \frac{\frac{9K_2}{18}100 + \frac{K_2}{6} \times 0}{\frac{9K_2}{18} + \frac{K_2}{6}} = \frac{50 + 0}{8/12} = 75°C$$

38. **(c)** Let the thermal resistance of each rod is $R$




Effective thermal resistance between $B$ and $D = 2R$

Temperature of interface $\theta = \frac{R_1\theta_2 + R_2\theta_1}{R_1 + R_2}$

$$\Rightarrow \quad \theta = \frac{R \times 20 + 2R \times 200}{R + 2R} = \frac{420}{3} = 140°C.$$

39. **(b)** According to Ingen Hausz, $K \propto l^2$

$$\therefore \quad \frac{l_1}{l_2} = \sqrt{\frac{K_1}{K_2}} = \sqrt{\frac{10}{9}} = \frac{\sqrt{10}}{3}.$$

40. **(d)** Quantity of heat transferred through wall will be utilized in melting of ice.

$$\Rightarrow \quad Q = \frac{KA\Delta\theta\, t}{\Delta x} = mL$$

$\therefore$ Amount of ice melted $m = \frac{KA\Delta\theta\, t}{\Delta x\ L}$

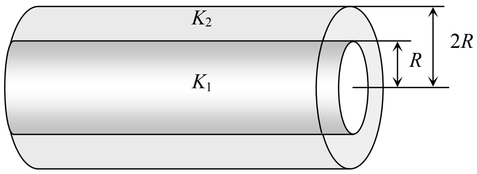
$$\therefore \quad m = \frac{0.01 \times 1 \times (30 - 0) \times 86400}{5 \times 10^{-2} \times 334 \times 10^3} = 1.552\,kg$$

or 1552$g$

41. **(c)** $t = \frac{\rho l}{2k\theta}\left(y_2^2 - y_1^2\right)$

$$= \frac{0.91 \times 80}{2 \times 0.005 \times 5}[(10.1)^2 - (10)^2] = 2926\,sec = 48.77\,\text{min}.$$

42. **(c)** We can consider this arrangement as a parallel combination of two materials having different thermal conductivities $K_1$ and $K_2$




For parallel combination $K = \dfrac{K_1A_1 + K_2A_2}{A_1 + A_2}$

$A_1$ = Area of cross-section of internal cylinder = $\pi R^2$,

$A_2$ = Area of cross-section of outer cylinder = $\pi\,(2R)^2 - \pi(R)^2 = 3\pi R^2$

$\therefore \quad K = \dfrac{K_1.\pi R^2 + K_2\ 3\pi R^2}{\pi R^2 + 3\pi R^2} = \dfrac{K_1 + 3K_2}{4}$

**43.** **(d)** If a body emits wavelength $\lambda_1$, $\lambda_2$, $\lambda_3$ and $\lambda_4$ at a high temperature then at a lower temperature it will absorbs the radiation of same wavelength. This is in accordance with Kirchoff's law.

**44.** **(c)** From the graph it is clear that initially both the bodies are at same temperature but after that at any instant temperature of body $x$ is less then the temperature of body $y$. It means body $x$ emits more heat *i.e.* emissivity of body $x$ is more than body $y$

$\therefore \quad e_x > e_y$ and according to Kirchoff's law good emitter are also good absorber.

So, $\quad a_x > a_y$.

**45.** (c) $\lambda_m T$ = constant

$\Rightarrow \quad \dfrac{(\lambda_m)_2}{(\lambda_m)_1} = \dfrac{T_1}{T_2} = \dfrac{200}{1000} = \dfrac{1}{5}$

$\Rightarrow \quad (\lambda_m)_2 = \dfrac{(\lambda_m)_1}{5} = \dfrac{14\mu m}{5} = 2.8\,\mu\,m.$

**46.** **(b)** From Wien's displacement law $\lambda_m T = b$

$\therefore \quad T = \dfrac{b}{\lambda_m} = \dfrac{2.93 \times 10^{-3}}{2.93 \times 10^{-10}} = 10^7\,K$ .

**47.** **(c)** $P = \dfrac{Q}{t} = A\sigma T^4$

$\therefore \quad \dfrac{P_1}{P_2} = \dfrac{A_1}{A_2} = \dfrac{r_1^2}{r_2^2} = \left(\dfrac{1}{2}\right)^2 = \dfrac{1}{4}$ [If $T$ = constant]

**48.** **(a)** $P = A\,\sigma T^4 = 4\pi r^2 \sigma T^4$

$\Rightarrow \quad P \propto r^2 T^4$

or $\quad r^2 \propto \dfrac{1}{T^4}$ [As $P$ = constant] $\therefore\ \dfrac{r_1}{r_2} = \left(\dfrac{T_2}{T_1}\right)^2$

**49.** **(a)** $Q = \sigma A\,t\,T^4$

$\Rightarrow \quad \dfrac{Q_1}{Q_2} = \dfrac{A_1}{A_2}\left(\dfrac{T_1}{T_2}\right)^4 = \dfrac{\pi r_1^2}{\pi r_2^2}\left(\dfrac{T_1}{T_2}\right)^4$

$= \left(\dfrac{4}{1}\right)^2 \times \left(\dfrac{2000}{4000}\right)^4 = 16 \times \dfrac{1}{16} = 1:1$

**50.** **(b)** According to Wien's law $\lambda_m \propto \dfrac{1}{T}$ and from the figure $(\lambda_m)_1 < (\lambda_m)_3 < (\lambda_m)_2$

Therefore $T_1 > T_3 > T_2$.

**51.** **(a)** $\dfrac{dT}{dt} = \dfrac{eA\sigma}{mc}(T^4 - T_0^4)$

$= \dfrac{eA\sigma}{V\rho c}(T^4 - T_0^4)$

$\therefore \quad$ Rate of cooling $R \propto A$ As masses are equal then volume of each body must be equal because materiel is same

*i.e.* rate of cooling depends on the area of cross-section and we know that for a given volume the area of cross-section will be minimum for sphere. It means the rate of cooling will be minimum in case of sphere. So the temperature of sphere drops to room temperature at last.

**52.** **(c)** According to Newton's law of cooling rate of cooling depends upon the difference of temperature between the body and the surrounding. It means that when the difference of temperature between the body and the surrounding is small then time required for same fall in temperature is more in comparison with the same fall at higher temperature difference between the body and surrounding.

So, According to Illustration $T_1 < T_2 < T_3$.

**53.** **(b)** According to Newton's law of cooling

$\dfrac{\theta_1 - \theta_2}{t} \propto \left[\dfrac{\theta_1 + \theta_2}{2} - \theta\right]$

For first condition $\dfrac{62 - 61}{T} \propto \left[\dfrac{62 + 61}{2} - 30\right] \quad \ldots (i)$

and for second condition

$\dfrac{46 - 45.5}{t} \propto \left[\dfrac{46 + 45.5}{2} - 30\right] \quad \ldots (ii)$

By solving ($i$) and ($ii$) we get $t = T\,sec$.

**54.** **(b)** $\dfrac{\theta_1 - \theta_2}{t} \propto \left[\dfrac{\theta_1 + \theta_2}{2} - \theta\right]$

For first condition $\dfrac{60 - 50}{10} \propto \left[\dfrac{60 + 50}{2} - \theta\right]$

$\Rightarrow \quad 1 = K\,[55 - \theta]$ . . . $(i)$

For second condition $\dfrac{50-42}{10} \propto \left[\dfrac{50+42}{2} - \theta\right]$

$\Rightarrow \quad 0.8 = K\,(46 - \theta)$ . . . $(ii)$

From $(i)$ and $(ii)$ we get $\theta = 10^{\circ}C$

**55.** **(d)** Temperature of mixture $\theta = \dfrac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2\theta_2}$

$$\Rightarrow \quad 32 = \frac{m_1 \times 0.2 \times 40 + 100 \times 0.5 \times 20}{m_1 \times 0.2 + 100 \times 0.5}$$

$$\Rightarrow \quad m_1 = 375\,gm$$

## NCERT Exemplar Problems

### More than One Answer

**56.** **(a, b)** $P = e\sigma A T^4$

According to question $P_A = P_B$ with $A_A = A_B$

or, $\quad e_A T_A^4 = e_B T_B^4$ or, $0\cdot 01 \times (5802)^4 = 0\cdot 81 (T_B)^4$

$\therefore \quad T_B = 1934$ K

According to Wien's law $\lambda_A T_A = \lambda_B T_B$ i.e.,

$$\lambda_B = \left(\frac{5802}{1934}\right)\lambda_A = 3\lambda_A$$

Also, $\lambda_B - \lambda_B = 1\,\mu m$ or $\lambda_B = 1\cdot 5\,\mu m$

**57.** **(a, c, d)** Statement (a) is incorrect, Since the size of a degree on the tow scales is the same, a temperature change of $1°C$ corresponds to a temperature change of 1 $K$. Statement (b) is correct.

Since, the mass and the material are the same, the volumes are equal. For the same volume, the surface area of the plate is the largest and of the sphere the smallest. The rate of loss of heat by radiation being proportional to the surface area, the plate cools fastest and the sphere is slowest.

Statement (c) is incorrect.

The energy radiated by the first sphere is

$$E_1 = \sigma\pi R^2 T^4 = \sigma\pi (4000)^4 = 256 \times 10^{12}\,\pi\sigma$$

and that by the second sphere is

$$E_2 = \sigma\pi (4)^4 (2000)^4 = 256 \times 10^{12}\,\pi\sigma$$

Hence, $E_1 = E_2$.

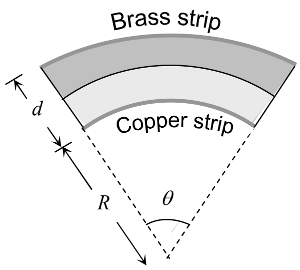
Statement (d) is also incorrect.

The loss of heat by a body is given by $\dfrac{dQ}{dt} = ms\dfrac{d\theta}{dt} = K(\theta - \theta_0)$

If $s$ is more $\dfrac{d\theta}{dt}$ will be less.

Since, $\dfrac{d\theta}{dt}$ is larger for $A$, its specific heat will be smaller.

**58.** **(b, d)** Let $L_0$ be the initial length of each strip before heating.




Length after heating will be $L_B = L_0(1 + \alpha_B \Delta T) = (R + d)\theta$

$L_C = L_0(1 + \alpha_C \Delta T) = R\theta$

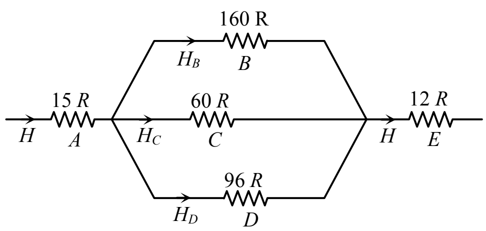
$$\Rightarrow \quad \frac{R+d}{R} = \frac{1+\alpha_B\Delta T}{1+\alpha_C\Delta T}$$

$$\Rightarrow \quad 1 + \frac{d}{R} = 1 + (\alpha_B - \alpha_C)\Delta T$$

$$\Rightarrow \quad R = \frac{d}{(\alpha_B - \alpha_C)\Delta T}$$

$$\Rightarrow \quad R \propto \frac{1}{\Delta T} \text{ and } R \propto \frac{1}{(\alpha_B - \alpha_C)}$$

**59.** **(a, c, d)** The resistance $R = \dfrac{l}{KA}$




$$\therefore \quad R_A = \frac{L}{(2K)(4Lw)} = \frac{1}{5Kw'} \text{ (Here } w = \text{width)}$$

$$\Rightarrow \quad R_B = \frac{4L}{3K(Lw)} = \frac{4}{3Kw}$$

$$R_C = \frac{4L}{(4K)(2Lw)} = \frac{1}{2Kw}$$

$$R_D = \frac{4L}{(5K)(Lw)} = \frac{4}{5Kw}$$

$$R_E = \frac{L}{(6K)(Lw)} = \frac{1}{6Kw}$$

$$\Rightarrow \quad R_A : R_B : R_C : R_D : R_E = 15 : 160 : 60 : 96 : 12$$

So, let us write, $R_A = 15, R_B = 160R$ etc and draw a simple electrical circuit as show in figure

$H$ = Heat current = Rate of heat flow. $H_A = H_E = H$

In parallel current distributes in inverse ratio of resistance

$\therefore \quad H_B : H_C : H_D = \dfrac{1}{R_B} : \dfrac{1}{R_C} : \dfrac{1}{R_D}$

$= \dfrac{1}{160} : \dfrac{1}{60} : \dfrac{1}{96} = 9 : 24 : 15$

$\therefore \quad H_B = \left(\dfrac{9}{9+24+15}\right)H = \dfrac{3}{16}H$,

$H_C = \left(\dfrac{24}{9+24+15}\right)H = \dfrac{1}{2}H$,

$H_D = \left(\dfrac{15}{9+24+15}\right)H = \dfrac{5}{16}H$

Temperature difference (let us call it $T$) = (Heat current) × (Thermal resistance)

$T_A = H_A R_A = (H)(15R) = 15HR$

$T_B = H_B R_B = \left(\dfrac{3}{16}H\right)(160R) = 30HR$

$T_C = H_C R_C = \left(\dfrac{1}{2}H\right)(60R) = 30HR$

$T_D = H_D R_D = \left(\dfrac{5}{16}H\right)(96R) = 30HR$

Here, $T_E$ is minimum. Therefore option (c) is also correct

**60.** **(b, c, d)** $Q = mCT \Rightarrow \dfrac{dQ}{dt} = mc\dfrac{dT}{dt}$

$R$ = rate of absortion of heat

($i$) In 1–100 $K$ $C$ increase, so $R$ increases but not linearly

($ii$) $\Delta Q = mC\Delta T$ as $C$ in more in $(400K - 500K)$ then $(0 - 100K)$ so heat is increases

($iii$) $C$ remains constant so there no change in $R$ from $(400K - 500K)$

($iv$) $C$ is increase so R increases in range $(200K - 300K)$

**61.** **(a, b)** According to Stefan's law

$E = eA\sigma T^4 \Rightarrow E_1 = e_1 A\sigma T_1^4$

$E_2 = e_2 A\sigma T_2^4$

$\because \quad E_1 = E_2$

$\therefore \quad e_1 T_1^4 = e_2 T_2^4$

$\Rightarrow \quad T_2 = \left(\dfrac{e_1}{e_2}T_1^4\right)^{\frac{1}{4}} = \left(\dfrac{1}{81}\times(5802)^4\right)^{\frac{1}{4}}$

$\Rightarrow \quad T_B = 1934\ K$ and, from Wein's law

$\lambda_A \times T_A = \lambda_B \times T_B$

$\Rightarrow \quad \dfrac{\lambda_A}{\lambda_B} = \dfrac{T_B}{T_A}$

$\Rightarrow \quad \dfrac{\lambda_B - \lambda_A}{\lambda_B} = \dfrac{T_A - T_B}{T_A}$

$\Rightarrow \quad \dfrac{1}{\lambda_B} = \dfrac{5802 - 1934}{5802} = \dfrac{3968}{5802} \Rightarrow \lambda_B = 1.5\ \mu m$

**62.** **(b, d)** Let $l_0$ be the initial length of each strip before heating.

Length after heating will be

$l_B = l_0(1+\alpha_B\Delta T) = (R+d)\theta$

$l_C = l_0(1+\alpha_C\Delta T) = R\theta$

$\therefore \quad \dfrac{R+d}{R} = \left(\dfrac{1+\alpha_B\Delta T}{1+\alpha_C\Delta T}\right)$

$\therefore \quad 1+\dfrac{d}{R} = 1+(\alpha_B - \alpha_C)\Delta T$ [From binomial expansion]

$\therefore \quad R = \dfrac{d}{(\alpha_B - \alpha_C)\Delta T}$

or $\quad R \propto \dfrac{1}{\Delta T} \propto \dfrac{1}{|\alpha_B - \alpha_C|}$

**63.** **(d)** Since, the temperature of black body is constant, total heat absorbed = total heat radiated.

**64.** **(a, c, d)** Thermal resistance $R = \dfrac{l}{KA}$

$\therefore \quad R_A = \dfrac{L}{(2K)(4Lw)} = \dfrac{1}{8Kw'}$ (Here $w$ = width)

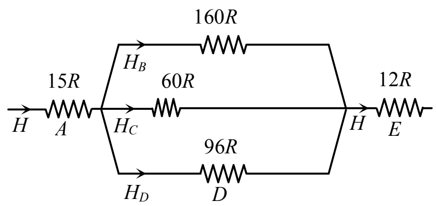
$R_B = \dfrac{4L}{3K(Lw)} = \dfrac{4}{3Kw}$

$R_C = \dfrac{4L}{(4K)(2Lw)} = \dfrac{1}{2Kw}$

$R_D = \dfrac{4L}{(5K)(Lw)} = \dfrac{4}{5Kw}$

$R_E = \dfrac{L}{(6K)(Lw)} = \dfrac{1}{6Kw}$

$R_A : R_B : R_C : R_D : R_E = 15 : 160 : 60 : 96 : 12$




So, let us write, $R_A$ = 15 $R$, $R_B$ = 160 $R$ etc and draw a simple electrical circuit as shown in figure

$H$ = Heat current = Rate of heat flow.

$H_A = H_E = H$

$\therefore$ Option (a) is correct.

In parallel current distributes in inverse ration of resistance.

$$\therefore \quad H_B : H_C : H_D = \frac{1}{R_B} : \frac{1}{R_C} : \frac{1}{R_D}$$

$$= \frac{1}{160} : \frac{1}{60} : \frac{1}{96} = 9 : 24 : 15$$

$$\therefore \quad H_B = \left(\frac{9}{9+24+15}\right) H = \frac{3}{16} H$$

$$H_C = \left(\frac{24}{9+24+15}\right) H = \frac{1}{2} H$$

$$H_D = \left(\frac{15}{9+24+15}\right) H = \frac{5}{16} H$$

$\Rightarrow \quad H_C = H_B + H_D$

$\therefore$ Option (d) is correct. Temperature difference (let us call it $T$)

$$T_A = H_A R_A = (H)(15R) = 15HR$$

$$T_B = H_B R_B = \left(\frac{3}{16} H\right)(160R) = 30\,HR$$

$$T_C = H_C R_C = \left(\frac{1}{2} H\right)(60R) = 30HR$$

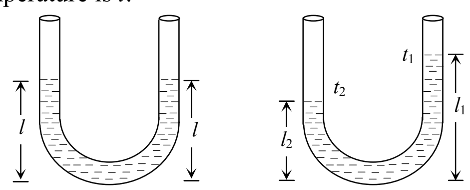
$$T_D = H_D R_D = \left(\frac{5}{16} H\right)(96R) = 30HR$$

$T_E = H_E R_E = (H)(12R) = 12HR$ c

Here, $T_E$ is minimum.

Therefore option (c) is also correct.

**65.** **(a)** Suppose, height of liquid in each arm before rising the temperature is $l$.




With temperature rise height of liquid in each arm increases *i.e.* $l_1 > l$ and $l_2 > l$

Also $l = \dfrac{l_1}{1+\gamma t_1} = \dfrac{l_2}{1+\gamma t_2}$

$\Rightarrow \quad l_1 + \gamma l_1 t_2 = l_2 + \gamma l_2 t_1$

$$\Rightarrow \quad \gamma = \frac{l_1 - l_2}{l_2 t_1 - l_1 t_2}$$

**66.** **(b,c)** The horizontal parts of the curve, where the system absorbs heat at constant temperature must depict changes of state. Here the latent heats are proportional to lengths of the horizontal parts. In the sloping parts, specific heat capacity is inversely proportional to the slopes.

**67.** **(c)** Partial pressure of water vapour

$P_W = 0.012 \times 10^5\ Pa$

Vapour pressure of water

$P_V = 0.016 \times 10^5\ Pa$

The relative humidity at a given temperature is given by

$$= \frac{\text{Partial pressure of water vapour}}{\text{Vapour pressure of water}}$$

$$= \frac{0.012 \times 10^5}{0.016 \times 10^5} = 0.75 = 75\%$$

**68.** **(a)** $W = JQ$

$\Rightarrow \quad mgh = J \times H$

$$\Rightarrow \quad Q = \frac{mgh}{J} = \frac{5 \times 9.8 \times 30}{4.2} = 350\,cal$$

**69.** **(c)** Temperature of mixture

$$\theta_{mix} = \frac{\theta_A c_A + \theta_B c_B}{c_A + c_B}$$

$$\Rightarrow \quad 28 = \frac{32 \times c_A + 24 \times c_B}{c_A + c_B}$$

$\Rightarrow \quad 28c_A + 28c_B = 32c_A + 24c_B$

$$\Rightarrow \quad \frac{c_A}{c_B} = \frac{1}{1}$$

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

### Assertion and Reason

**71.** **(a)** As, $\gamma = \dfrac{\Delta V}{V \cdot \Delta T}$, *i.e.,* units of coefficient of volume expansion is $K^{-1}$.

**72.** **(a)** Water has maximum density at $4°C$. On heating above $4°C$ or cooling below $4°C$, density of water decrease and its volume increase. Therefore, overflows in both the cases.

**73.** **(a)** With rise in pressure melting point of ice decreases. Also ice contracts on melting.

**74.** **(e)** Melting is associated with increasing of internal energy without change in temperature. In view of the reason being correct the amount of heat absorbed or given out during change of state is expressed as $Q = mL$, where $m$ is the mass of the substance and L is the latent heat of the substance.

**75.** **(e)** Specific heat of a body is the amount of heat required to raise the temperature of unit mass of the body through unit degree. When mass of a body is less than unity, then its thermal capacity is less than its specific heat and *vice-versa*.

**76.** **(c)** Water evaporates quickly because of lack of atmospheric pressure. Also temperature of moon is much higher during day time but it is very low at night.

**77.** **(d)** The potential energy of water molecules is more. The heat given to melt the ice at 0°*C* is used up in increasing the potential energy of water molecules formed at 0°*C*.

**78.** **(c)** Hollow metallic closed container maintained at a uniform temperature can act as source of black body. It is also well-known that all metals cannot act as black body because if we take a highly metallic polished surface. It will not behave as a perfect black body.

**79.** **(b)** This is in accordance with the Stefan's law $E \propto T^4$.

**80.** **(c)** At a high temperature (6000 *K*), the sun acts like a perfect blackbody emitting complete radiation. That's why the radiation coming from the sun's surface follows Stefan's law $E = \sigma T^4$.

**81.** **(a)** From Wein's displacement law, temperature $(T) \propto 1/\lambda_m$ (where $\lambda_m$ is the maximum wavelength). Thus temperature of a body is inversely proportional to the wavelength. Since blue star has smaller wavelength and red star has maximum wavelength, therefore blue star is at higher temperature then red star.

**82.** **(a)** According to Kirchoff's law $\frac{e_\lambda}{a_\lambda} = E_\lambda$

If for a particular wave length $E_\lambda = 1$

$\Rightarrow \quad e_\lambda = a_\lambda$

*i.e.,* aborptivity of a body is equal to its emissivity. This statement also reveals that a good radiator is also a good absorber and vice versa.

**83.** **(c)** According to Weins law $\lambda_m T = \text{constant}$ *i.e.,* peak emission wavelength $\lambda_m \propto \frac{1}{T}$.

Also as $T$ increases $\lambda_m$ decreases.

Hence assertion is true but reason is false.

**84.** **(b)** During the day when water is cooler than the land, the wind blows off the water onto the land (as warm air rises and cooler air fills the place). Also at night, the effect is reversed (since the water is usually warmer than the surrounding air on land). Due to this wind flow the temperature near the sea coast remains moderate.

**85.** **(c)** Heat is carried away from a fire sideways mainly by radiations. Above the fire, heat is carried by both radiation and by convection of air. The latter process carries much more heat.

**Comprehension Based**

**86.** **(c)** Magnetic thermometers are based on Curie law which states that susceptibility ($\chi$) of paramagnetic salts $\chi \propto \frac{C}{T}$

or $\quad T \propto \frac{C}{\chi}$

The magnetic resonance at temperatures near absolute zero helps to know the rise in susceptibility and gives super conducting properties to substances.

**87.** **(d)** Resistance of semiconductors at lower temperature (4K to 77K, melting point of helium nitrogen) called cryogenic temperatures, increases because charge carriers in them become immobile.

So, this property can help to measure temperatures.

**88.** **(c)** Liquid vapour pressure $P$ depends on $T$ as follows:

$\log P = A + BT + \frac{C}{T}$

These thermometers are used to measure temperature in the range 1K to 120 K by measuring vapour pressure of different liquids.

**89.** **(d)** (*i*) Heat is given to gas and its temperature rise. Then C = +ve

(*ii*) Heat is given and gas is allowed to expand so that temperature remains constant. Then $C = \infty$

(iii) Small amount of heat is given and gas expands fast so that temperature falls. Then $C = -ve$

(iv) Gas is compressed and no heat is given but temperature rises. Then $C = 0$

Thus specific heat of gas can have any value between 0 to $\infty$, positive or negative.

**90.** **(c)** $\gamma = \dfrac{\text{Specific heat at constant pressure}}{\text{Specific heat at constant volume}}$

$\Rightarrow \quad \dfrac{C_p}{C_v}$

**91.** **(d)** Theory based question. Relation (d) is not correct.

**92.** **(a)** Using Wien's displacement law

$$\frac{\lambda_S}{\lambda_N} = \frac{T_S}{T_N}$$

$$\Rightarrow \quad \frac{T_S}{T_N} = \frac{\lambda_N}{\lambda_S} = \frac{360}{540} = \frac{2}{3}$$

**93.** **(c)** Using Stefan's Boltzman's law

$$\frac{E_S}{E_N} = \frac{T_S^4}{T_N^4} = \left(\frac{2}{3}\right)^4 = \frac{16}{81}$$

**94.** **(b)** North star is at higher temperature so, more shorter wavelength and more energy will be emitted by it.

**Match the Column**

**95.** **(a)** A→1, B→2, C→3, D→4
The particular names of calorimeters are after the names of scientists who designed them for specific heat measurements in different conditions.

**96.** **(a)** A→4, B→2, C→1,2, D→2,3

**97.** **(a)** A→2, B→3, C→4, D→1
Specific heat of water shows anamo lous behaviour. It is 1 at 14.5 to 15.5°$C$ and increases both with increase or decrease in temperature. Specific heat of metals is directly proportional to temperature at ordinary temperatures according to Dulong and Petit's law.
At very low temperatures it increases proportional to $T^3$ and obeys Debye theory. During change of state, heat is absorbed but temperature remains constant so specific heat approaches infinity during change of state.

**Integer**

**98.** **(9)** For same heat $\dfrac{\Delta L_1}{\Delta L_2} = \left(\dfrac{r_2}{r_1}\right)^2 = \dfrac{9}{1}$

**99.** **(2)** We have $\alpha_1 l_1 = \alpha_2 l_2$

$$\therefore \quad \frac{\alpha_1}{\alpha_2} = \frac{l_2}{l_1} = \frac{2}{1}$$

**100.** **(1)** $\dfrac{dQ}{dt} = \dfrac{K(\pi r^2)d\theta}{dl} \Rightarrow \dfrac{\left(\dfrac{dQ}{dt}\right)_s}{\left(\dfrac{dQ}{dt}\right)_l} = \dfrac{K_s \times r_s^2 \times l_l}{K_l \times r_l^2 \times l_s} = \dfrac{1}{2} \times \dfrac{1}{4} \times \dfrac{2}{1}$

$$\Rightarrow \quad \left(\frac{dQ}{dt}\right)_s = \frac{\left(\dfrac{dQ}{dt}\right)_l}{4} = \frac{4}{4} = 1$$

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