CLASS – 11

WORKSHEET- THERMAL PROPERTIES OF MATTER

A. HEAT AND CALORIMETRY

(1 Mark Questions)

1. What is heat?

Sol. Heat is the transfer of kinetic energy from one medium or object to another, or from an energy source to a medium or object. Such energy transfer can occur in three ways: radiation, conduction, and convection.

2. What are the SI and CGS units of heat? How are they related?

Sol. SI unit of heat is joule and cgs unit of heat is calorie. 1 calorie = 4.18 joule.

(2 Marks Questions)

3. When 0.15 kg of ice at 0∘C is mixed with 0.30 kg of water at 50∘C in a container, the resulting temperature of the mixture is 6.7∘C. Calculate the latent heat of fusion of ice. (S_{water}=4186 J $kg^{-1}K^{-1}$)

Sol. Heat lost by water = $mS_w (\theta_f - \theta_i)_w$

= (0.30 kg) (4186 J kg-1°C^{-1}) x (50.0°C - 6.7°C) = 54376.14 J

Heat to melt ice = m_2L_f = (0.15 kg)L_f

Heat to raise temperature of ice water to final temperature = $m_1S_w (\theta_f - \theta_i)$

= (0.15 kg) (4188 J kg^{-1}°C^{-1}) (6.7°C - 0°C) = 4206.93 J

Heat lost = Heat gained

54.76.14 J = (0.15 kg) L_f + 4206.93 J

∴ $L_f = 3.34 \times 10^5$ Jkg^{-1}.

(3 Marks Questions)

4. A brass wire 1.8m long at 27°C is held taut with little tension between two rigid supports. If the wire is cooled to a temperature of – 39°C, what is the tension developed in the wire, if its diameter is 2.0mm? Coefficient of linear expansion of brass = 2.0×10^{-5} K^{-1}, Young's modulus of brass = 0.91×10^{11} Pa.

Sol. Given: Length of the brass wire,l=1.8 m,

Change in temperature, ΔT=(−39−27)=−66°C

α=2.0× 10 −5 K -1

Young's modulus, Y=0.91× 10^{11} Pa

Diameter, D=2.0 mm=2× 10^{-3} m

Area of the wire is,

A= π $D/^2$ × 4 A= 22/7 × 1.4 × (2.0× 10^{-3} $)^2$ A =3.142× 10 $^{-5}$ m ^{2}

Now,

$Y = (F/A)/(\Delta l/l) = Fl\ AY\ \alpha\ l\Delta T = Fl\ AY\ F = YA\alpha\Delta T$
Substitute the values
$F = 0.91\times 10^{11} \times 3.142\times 10^{-5} \times 2.0\times 10^{-5} \times (-66)\ F = -3774.2\ N\ F \simeq -3.78\times 10^{2}\ N$

5. A copper block of mass 2.5kg is heated in a furnace to a temperature of 500℃ and then placed on a large ice block. What is the maximum amount of ice that can melt? (Specific heat of copper = 0.39 J g^{-1} °C^{-1}, heat of fusion of water = 335 Jg^{-1}).

Sol. Mass of the copper block, m=2.5kg=2500g

Rise in the temperature of the copper block, =500℃

Specific heat of copper, C=0.39J/g℃

Heat of fusion of water, L=335J/g

The maximum heat the copper block can lose,

Q = mC

= 2500×0.39×500= 487500J

Let m_1 g be the amount of ice that melts when the copper block is placed on the ice block.

The heat gained by the melted ice, $Q = m_1L$

$m_1 = Q/L = 487500/335 = 1455.22g$

Hence, the maximum amount of ice that can melt is 1.45 kg.

6. 2 kg of ice at – 20°C is mixed with 5kg 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 the ice are 1 kcal/kg℃ and 0.5 kcal/kg℃ while the latent heat of fusion of ice is 80 kcal/kg.

Sol. Heat released by 5 kg of water when its temperature falls from 20 ℃ to 0℃ is
$Q_1 = c\ m(\Delta T) = 10^3 \times 5 \times 20 = 0.2\times 10^5$ cal.
This heat is used in raising the temp. of 2 kg of ice at – 20 ℃ to 0 ℃ and then melting it subsequently. Heat energy taken by 2 kg of ice at -20 ℃ to 0 ℃ and then melting it subsequently. Heat energy taken by 2 kg of ice at -20 ℃ in coming to 0 ℃ is
$Q_2 = c\ m\ (\Delta T) = 500 \times 2 \times 20 = 0.2 \times 10^5$ cal
The remaining heat, $Q = Q_1 - Q_2 = 0.8\times 10^5$ cal.
Mass of ice melted, $m' = Q/L = (0.8\times 10^5)/(80\times 10^3) = 1$ kg.
Temperature of mixture will become 0 ℃
Mass of water in it = 5 + 1 = 6 kg
Mass of ice left in it = 2 -1 = 1 kg.

7. A child running a temperature of 101°F is given an antipyrin (i.e. a medicine that lowers fever) which causes an increase in the rate of evaporation of sweat from his body. If the fever is brought down to 98°F in 20 min, what is the average rate of extra evaporation caused by the drug? Assume the evaporation mechanism to be the only way by which heat is lost. The mass of the child is 30kg. The specific heat of human body is approximately the same as that of water, and latent heat of evaporation of water at that temperature is about 580 cal g^{-1}.

Sol. Initial temperature of the body of the child, $T1=101°F$

Final temperature of the body of the child, $T2=98°F$

Change in temperature, $\Delta T=[(101-98)\times 5/9=5/3°C$

Time taken to reduce the temperature, t = 20 min

Mass of the child, $m=30kg=30\times 10^3 g$

Specific heat of the human body = Specific heat of water = c =1000cal/kg/°C

Latent heat of evaporation of water, $L=580calg^{-1}$

The heat lost by the child is given as: $\Delta\theta=mc\Delta T$

$=30\times 1000\times(101-98)\times(5/9)=50000cal$

Let m_1 be the mass of the water evaporated from the child's body in 20 min.

Loss of heat through water is given by: $\Delta\theta=m1L$

$\therefore m_1=\Delta\theta/L=(50000/580)=86.2g$

$\therefore$ Average rate of extra evaporation caused by the drug =m1/t

=86.2/20 =4.3g/min.

B. TEMPERATURE AND THERMAL EXPANSION

(1 Mark Questions)

1. What is thermometry?

Sol. The branch of physics dealing with the measurement of temperature is thermometry.

2. Define temperature.

Sol. Temperature: measure of hotness or coldness expressed in terms of any of several arbitrary scales and indicating the direction in which heat energy will spontaneously flow—i.e., from a hotter body (one at a higher temperature) to a colder body (one at a lower temperature).

3. State the principles of thermometer.

Sol. A thermometer works on the principle that solids and liquids tend to expand with temperature. When a thermometer lamp is immersed in a given solution or substance, mercury begins to rise. This increase in mercury is studied on a temperature scale.

4. What is temperature of the triple point of water on an absolute scale whose unit interval size is equal to that of the Fahrenheit scale?

Sol. Triple point of water =273 K

Unit interval size in Fahrenheit Scale =9/5 K. So, Let T be the triple point temp in absolute scale.

Then,

$(T-0)=9/5(273-0)$

$T=9/5\times 273=491.4$ unit

5. There is a hole in the middle of a copper plate. When heating the plate, diameter of hole would

(a) always increase (b) always decrease

(c) remains same (d) none of these

Ans. (a)

It can be explained by considering the air in the region of hole and that air will also expand on heating. Therefore, diameter of the hole increases always.

6. If α, β and γ are coefficients of linear, superficial and volume expansion respectively, then:

(a) $\frac{\beta}{\alpha}=\frac{1}{2}$ (b) $\frac{\beta}{\gamma}=\frac{2}{3}$ (c) $\frac{\gamma}{\alpha}=\frac{3}{2}$ (d) $\frac{\beta}{\alpha}=\frac{\gamma}{\beta}$

Sol. (b)

7. Why iron rims are heated red hot before being put on cart wheels?

Sol. They are heated red hot before fixing them on the cart wheels to expand them so that they can be easily fixed on the wheels and water is poured on them to cool them. As the rims cool they contract and take the shape of the wheel and get firmly fixed on the wheels.

8. Two identical rectangular strips one of copper and other of steel, are riverted to form a bimetallic strip. What will happen on heating?

Sol. Here, the two different material is used to form a single piece,also steel is heavier metal as compare to copper where thermal conductivity of copper is higher than that of steel, hence due to heating copper will start expanding but a layer of steel are overlapping on its surface which apply its weight on steel due to which convex shape will be occur in copper side.

Hence the strip will bend with coper on convex side.

(2 Marks Questions)

9. Distinguish clearly between heat and temperature.

Sol. Heat is the total energy of the motion of the molecules of a substance, whereas temperature refers to the measure of the average energy of the motions of the molecules in the substance. The heat is dependent on factors like the speed of the particles, the size of the particles and the number of particles, etc.

10. Why is mercury used in thermometer?

Sol. Mercury is used in thermometers because It has a high coefficient of expansion so that even a small rise in temperature brings about sufficient expansion which can be detected in the capillary of the calibrated part of the thermometer.

11. An object has a temperature of 50°F. What is the temperature in degrees Celsius and in Kelvin?

Sol. 1. $C = 5/9 \times (F-32)$

Putting $F=5$, we get $C=-15$℃

2. $K=5/9 \times (F-32) + 273$

Putting $F=5$, we get $K=258$ K

12. What do you mean by triple point of water? Why is it unique?

Sol. Triple point of water is defined as the temperature and pressure at which liquid water , solid ice and water vapour can coexist in a stable equilibrium . As , at triple point of water , both solid (ice) and vapour state are present so we can say that boiling point and freezing point become same .

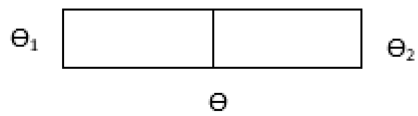
13. Two absolute scales A and B have triple point of water defined to be 200A and 350B. What is the relation between T_A and T_B?

Sol. $\frac{T_A}{T_B} = \frac{200}{350} = \frac{4}{7}$ or $T_A = \frac{4}{7} T_B$

14. A thin rod having L_0 of 0°C and coefficient of linear expansion α has its two ends maintained at temperatures $\square_1$ and $\square_2$ respectively. Find its new length.

Sol. From one end to another end the temperature of rod varies from Θ_1 to Θ_2

Mean temperature of rod= $\frac{\theta_1 + \theta_2}{2^\circ C}$



Here, the rate of flow of heat from A to C to B is equal

Thus, $\theta_1 > \theta > \theta_2$

Thus, $\frac{d\theta}{dt} = \frac{KA(\theta_1 - \theta)}{\frac{L_0}{2}}$

$$= \frac{KA(\theta - \theta_2)}{\frac{L_0}{2}}$$

Here K is the coefficient of thermal conductivity.

Therefore, $\theta_1 - \theta = \theta - \theta_2$

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

Thus, $L = L_0(1 + \alpha\theta)$

$$= L_0\left[1 + \alpha\left(\frac{\theta_1 + \theta_2}{2}\right)\right]$$

15. A large steel wheel is to be fitted on to a shaft of the same material. At 27°C, the outer diameter of the shaft is 8.70cm and the diameter of the central hole in the wheel is 8.69cm. The shaft is cooled using ;dry ice'. At what temperature of the shaft does the wheel slip on the shaft? Assume coefficient of linear expansion of the steel to be constant over the required temperature range: α_{steel}: 1.20×10^{-5} K^{-1}.

Sol. Here l_1 = 8.70cm, l_2 = 8.69cm, T_1 = 27+273 = 300K, T_2 = ?

As $l_2 - l_1 = \alpha l_1(T_2 - T_1)$

Therefore $T_2 - T_1 = \frac{l_2 - l_1}{\alpha l_1}$

Or $T_2 - 300 = \frac{8.69-8.70}{1.20\times10^{-5}\times8.70} = 95.8$

Or T_2 = 300 – 95.8 = 204.2K = - 68.8°C

16. Show that the coefficient of area expansions, $(\Delta A/A)/\Delta T$, of a rectangular sheet of the solid is twice its linear expansivity, α_1.

Sol. Consider a rectangular plate of length l and breath b when its temperature is increased by ΔT, its length increases by Δl and breath increased by Δb. Therefore, the change in area is,

$\Delta A=l\Delta b+b\Delta l+\Delta l\Delta b$

$=l[b\alpha\Delta T]+b[l\alpha\Delta T]+[l\alpha\Delta T][b\alpha\Delta T$

$=lb\alpha T+bl\alpha\Delta T+lb\alpha 2(\Delta T)2$

Here α being very small, $\alpha 2$ can be neglected.

Therefore,

$\Delta A=lb(\alpha+\alpha)\Delta T=A(2\alpha)\Delta T$

$\Longrightarrow \Delta T\Delta A/A=2\alpha$

17. A steel tape 1m long is correctly calibrated for a temperature of 27.0°C. The length of a steel rod measured by this tape is found to be 63.0 cm on a hot day when the temperature is 45.0°C. What is the actual length of the steel rod on that day? What is the length of the same steel rod on a day when the temperature is 27.0°C? Coefficient of linear expansion of steel = 1.20×10^{-5}°/C?

Sol. Here t_1 = 27°C, l_1 = 63cm, t_2 = 45°C, $\alpha = 1.20\times10^{-5}$°$C^{-1}$

Length of the rod on the hot day is $l_2 = l_1[1+\alpha(t_2 - t_1)]$

$= 63[1+1.20\times10^{-5}(45-27)] = 63.0136$cm

As the steel tape has been calibrated for a temperature of 27°C, so length of the steel rod at 27°C = 63cm.

(3 Marks Questions)

18. In an isotropic solid, has coefficients of linear expansions, α_x, α_y and α_z for three mutually perpendicular directions in the solid, what is the coefficient of volume expansion for the solid?

Sol. Let the initial volume be $V=L_xL_yL_z$.

Thus volume after expansion$=V'=L_x'L_y'L_z'$

$=Lx(1+\alpha_x\Delta T)Ly(1+\alpha_y\Delta T)L_z(1+\alpha z\Delta T)$

$=LxL_yL_z(1+\alpha_x\Delta T+\alpha_y\Delta T+\alpha_z\Delta T)$

(Neglecting higher powers of $\alpha_x,\alpha_y,\alpha_z$)

$=V(1+(\alpha_x+\alpha_y+\alpha_z)\Delta T)$

Thus the coefficient of volume expansion is $\alpha_x+\alpha_y+\alpha_z$

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

Sol. M.I. about its axis along perpendicular bisector = $1/12\ ml^2$

When temperature increased by ΔT, length of rod increases. $\Delta l = l\alpha\Delta T$

$\therefore$ New M.I., $I_1 = M/12(l + \Delta l)^2 = M/12\ (l^2 + \Delta l^2 + 2l\Delta l)$

Neglecting $(\Delta l)^2$ (very very small quantity)

$I_1 = M/12\ (l^2 + 2l\Delta l) = Ml^2/12 + Ml\Delta l/6 = I + Ml\ \Delta l/6$.

Therefore, moment of inertia, increase,

$\Delta I = I_1 - I = Ml\ \Delta\ l/6 = 2(Ml^2/12).\Delta\ l/l = 2l \propto \Delta T$.

20. The coefficient of volume expansion of glycerine is $49\times10^{-5}{}^\circ C^{-1}$. What is the fractional change in its density for a 30°C rise in temperature?

Sol. Coefficient of volume expansion of glycerin, $\alpha V = 49 \times 10^{-5}\ K^{-1}$

Rise in temperature, $\Delta T = 30°$, Fractional change in its volume = $\Delta V/V$

This change is related with the change in temperature as:

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

$$V_{T_2} - V_{T_1} = V_{T_1}\alpha_V \Delta T$$

$$\frac{m}{\rho_{T_2}} - \frac{m}{\rho_{T_1}} = \frac{m}{\rho_{T_1}}\alpha_V \Delta T$$

Where, m = Mass of

glycerine

ρ_{T_1} = Initial density at T_1

Fractional change in the density of glycerin = $49 \times10^{-5} \times 30 = 1.47 \times 10^{-2}$

21. A brass wire 1.8m long at 27°C is held taut with little tension between two rigid supports. If the wire is cooled to a temperature of – 39°C, what is the tension developed in the wire, if its diameter is 2.0mm? Coefficient of linear expansion of brass = $2.0\times10^{-5}{}^\circ C^{-1}$, Young's modulus of brass = 0.91×10^{11} Pa.

Sol. Here $l_1 = 1.8m$, $t_1 = 27°C$, $t_2 = -39°C$.

$\therefore \Delta T = T_2 - T_1 = -39 - 27 = -66°C = -66K$, l2 = length at t_2°C

For brass $\alpha = 2\times10^{-5}K^{-1}$, $Y = 0.91\times10^{11}Pa$, Diameter of wire, $d = 2.0mm = 2.0\times10^{-3}m$

If A be the area of cross section of the wire, then A = $\frac{\pi d^2}{4} = \pi(10^{-3})^2 m^2$

If F be the tension developed in the wire, then using the relation

Y = $\frac{F/A}{\Delta l/l}$, we get $\Delta l = \frac{Fl}{AY}$

Also $\Delta l = l\ \alpha\ \Delta T$, therefore, $\frac{Fl}{AY} = \alpha\ l\Delta T$

Or $F = \alpha\ \Delta\ T\ AY$

$= 2\times10^{-5}\ (-66) \times \frac{22}{7}(10^{-3})^2 \times 0.91\times10^{11} = -\ 3.8\times10^2 N$

Negative sign indicates that the force is inwards due to the contraction of the wire.

22. What is meant by coefficient of linear expansion and coefficient of cubical expansion? Derive relationship between them.

Sol. The ratio for 1 degree rise in temperature is called the coefficient of linear expansion, the ratio for 1 degree rise in temperature is called the coefficient of superficial expansion, and the ratio for 1 degree rise in temperature is called the coefficient of cubical expansion.

The following is the relationship between the coefficients of linear and real expansion:

At 0°C, consider a thin rectangular parallelopiped solid with the dimensions $l_o b_o h_o V_o$.

Let's imagine the solid is heated to a temperature of C.

Let l, b, h, V represent the length, width, height, and volume at C.

α=coefficient of linear expansion

First equation is as follows:

Then, The original volume $V_o = l_o b_o h_o$

Consider linear expansion, length $l = l_o(1+\alpha t)$, breadth $b = b_o(1+\alpha t)$, height $h = h_o(1+\alpha t)$

Final volume $V = lbh = l_o(1+\alpha t)\times b_o(1+\alpha t)\times h_o(1+\alpha t)$

$V = l_o b_o h_o(1+3\alpha t+3\alpha 2t2+\alpha 3t3)/a$

Now, because α is very small hence α_2 is still small, hence quantity $\alpha^2 t^2 \alpha^3 t^3$ can be ignored.

The second equation is as follows:

$V = V_o(1+3\alpha t)$

Consider the cubical expansion of the solid

$V = V_o(1+\gamma t)$

From (1) and (2),

$\gamma = 3\alpha$

Hence, the relation between the coefficient of linear and cubical expansion is derived.

C. HEAT TRANSFER

(1 Mark Questions)

1. For a perfectly black body, its absorptive power is

(a) 1 (b) 0.5 (c) 0 (d) infinity

Sol. (a)

A perfectly black body is a good absorber of radiations falls on it. So it's absorptive power is 1.

2. The unit of Stefan's constant in SI system will be

(a) Joule/m^2s (b) Joule/m^2sK^4 (c) Joule/msK^4 (d) Joule/m^2K^4

Sol. (b)

3. Animals curl into a ball, when they feel very cold why?

Sol. The animals curl their body in very cold environment so they can reduce their surface area, and reduce the heat leaving their body in form of radiation as heat emitted is directly proportional to surface area.

4. If the temperature of a blackbody is increased from 500K to 1000K, by what factor the rate of emission of energy from it changes?

Sol. From Stefan's Boltzmann relation we know that: $E \propto T^4$

So, $E \propto 500^4$

5. Pieces of copper and glass are heated to the same temperature. Why does the piece of copper feel hotter on touching?

Sol. Because the density of copper is more than that of glass.

6. Why it is much hotter above a fire than by its side?

Sol. It is hotter for the same distance over the top of the fire than it is by the side is mainly because. air conducts heat upward.

7. How can one determined the surface temperature of the stars?

Sol. Measure the brightness of a star through two filters and compare the ratio of red to blue light. Compare to the spectra of computer models of stellar spectra of different temperature and develop an accurate color-temperature relation.

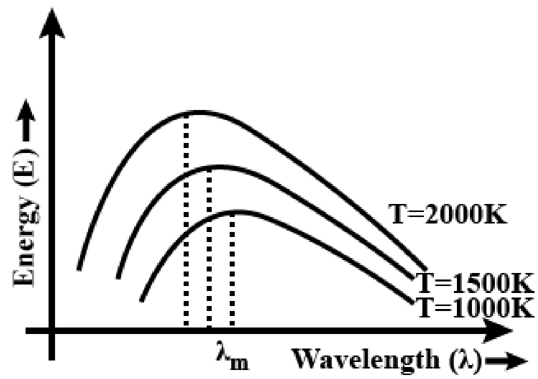
8. What are the basic requirements of a cooking utensils in respect of specific heat, thermal conductivity?

Sol. For the temperature of the utensil to rise quickly, it is necessary for the utensil to have low specific heat. In order for the heat to spread quickly to the vegetables, the utensil must have high thermal conductivity.

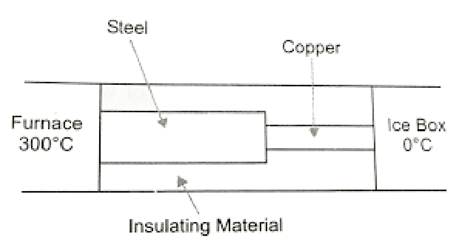
(2 Marks Questions)

9. Draw experimental curves between wavelength λ and intensity of radiation $E\,\lambda$ emitted by a black body maintained at different constant temperatures.

Sol.



10. What is the temperature of the steel-copper junction in the steady state of the system shown in the figure. Length of the steel rod = 15.0cm, length of the copper rod = 10.0cm, temperature of the furnace = 300°C, temperature of the other end = 0°C. The area of cross section of the steel rod is twice that of the copper rod. (Thermal conductivity of steel = 50.2 $Js^{-1}\,m^{-1}\,K^{-1}$ and of copper = 385$Js^{-1}\,m^{-1}\,K^{-1}$)



Sol. Relationship of thermal conductance & temperature:

Steel = Copper

$K_1A_1\,(300 - T) / L_1 = K_2\,A_2\,(T-0) / L_2$

Given Data : $A_2 = 1$, $A_1 = 2$, $L_1 = 15$ cm, $L_2 = 10$ cm, $K_2 =382$ J per smK

$K_1 = 50.2$ J per smK

<u>Solution :</u>

$50.2 \times 2\,(300 - T) / 15 = 382\,T / 10$

$100.4\,(300 - T) / 15 = 382\,T /10$

(30120 - 100.4 T) / 15 = 382 T / 10

Cross multiplying

[30120 - 100.4 T] x 10 = 382 T x 15

301200 - 1004 T = 5730 T

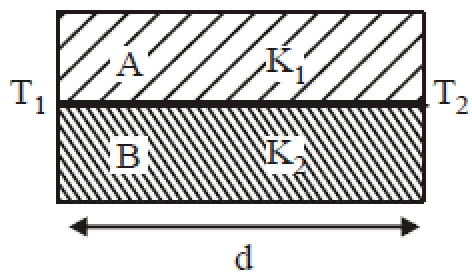
301200 = 5730 T + 1004 T

301200 = 6734 T

Hence,

T = 44.728 degree Celsius

11. Two rods A and B of different materials are welded together as shown in the figure. Their thermal conductivities are K_1 and K_2. Find the thermal conductivity of the composite rod.



Sol. In the question it is given that we have two rods of different materials and their thermal conductivities are also given. So we have to calculate the thermal conductivity of the composite rod.

Since both rods have the same temperature difference that means the rod is in parallel combination.

Therefore the total heat will be

$\Rightarrow H=H_1+H_2$

So for this, we will use the above heat equation which is total heat will be

$\Rightarrow H=H_1+H_2$

And since

$\Rightarrow H=KA\Delta T/l$

Therefore, according to the question

The value H will be,

$\Rightarrow KA(T_1-T)/d$

Which will be equal to the,

$\Rightarrow [K_1A(T_1-T_2)/d]+[K_2A(T_1-T_2)/d]$

Now on solving the above equation, we get

$\Rightarrow 2K=K_1+K_2$

$\Rightarrow K=K1+K2/2$

(3 Marks Questions)

12. Explain briefly the anomalous expansion of water. How the fishes can survive in extreme winter when lake ponds are frozen?

Sol. Only the top layer of the lake or river freezes. Underneath the frozen upper layer, the water remains in its liquid form and does not freeze. Also, oxygen is trapped beneath the layer of ice. As a result, fish and other aquatic animals find it possible to live comfortably in the frozen lakes and ponds.

13. A pan filled with hot food cools from 94°C to 86°C in 2 minutes, when the room temperature is 20°C, How long will it take to cool from 70°C to 69°C?

Sol. According to Newton's law of cooling, $\frac{T_1-T_2}{t}=K\left[\frac{T_1+T_2}{2}-T_s\right]$

Where T_s is the temperature of the surroundings.

For the first case, $\frac{94°C-86°C}{2\text{ min}}=K\left[\frac{94°C+86°C}{2}-20°C\right]$ or $\frac{8°C}{2\text{min}}=K[70°C]$ ...(i)

For the second case, $\frac{71°C-69°C}{t}=K\left[\frac{71°C+69°C}{2}-20°C\right]$ or $\frac{2°C}{t}=K[50°C]$ ...(ii)

Dividing (i) by (ii) we get

$\frac{8°C/2\text{min}}{2°C/t}=\frac{K[70°C]}{K[50°C]}$ or $t=0.7\text{mm}=42\text{s}$

14. A body cools in 7 minutes from 60°C to 40°C. What will be the temperature of the body after next 7 minutes? The temperature of the surroundings is 10°C. Assume that Newton's law of cooling holds good throughout the process.

Sol. In first case, T_1 = 60°, T_2 = 40°C, T_0 = 10°C, t = 7min = 420s

According to Newton's law of cooling,

$mc\frac{T_1-T_2}{t}=K\left(\frac{T_1+T_2}{2}-T_0\right)$

Therefore, $mc\frac{60-40}{420}=K\left(\frac{60+40}{2}-10\right)$ or $mc\frac{20}{420}=K\times 40$ ...(i)

In second case, T_1 = 40°C, T_2 = ?, T_0 = 10°C, t = 7min = 420s

Therefore, $mc\frac{40-T_2}{420}=K\left(\frac{40+T_2}{2}-10\right)$ ...(ii)

Dividing equation (i) by (ii) we get

$\frac{20}{40-T_2}=\frac{40}{\frac{40+T_2}{2}-10}$

On solving we get T_2 = 28°C

15. A 'thermocole' carbicoal icebox of side 30cm has a thickness of 5.0cm. If 4.0 kg of ice are put in the box, estimate the amount of ice remaining after 6h. The outside temperature is 45°C and coefficient of thermal conductivity of thermocle = 0.01 Js^{-1} $m^{-1°}$ C^{-1}. Given heat of fusion of water = 335×10^3 Jkg^{-1}.

Sol. Side of the given cubical ice box, s=30cm=0.3m

Thickness of the ice box, l=5.0cm=0.05m

Mass of ice kept in the ice box, m=4kg

Time gap, t=6h=6×60×60s

Outside temperature, T=45°C

Coefficient of thermal conductivity of thermacole, K=0.01$Js^{-1}m^{-1}k^{-1}$

Heat of fusion of water, L=335×10^3Jkg^{-1}

Let m be the total amount of ice that melts in 6 h.

The amount of heat lost by the food:

θ=KA(T−0)t/l

Where,

A= Surface area of the box =$6s^2=6\times(0.3)^2=0.54m^3$

θ=0.01×0.54×45×6×60/0.05=104976J

But θ=m′L

∴m′=θ/L

=104976/(335×10^3)=0.313kg

Mass of ice left =4–0.313=3.687kg

Hence, the amount of ice remaining after 6 h is 3.687 kg.

16. A brass boiler has a base area of 0.15 m^2 and thickness 1.0cm.It boils water at a\the rate of 6.0 kg min^{-1}, when placed on a glass stove. Estimate the temperature of the part of the flame in contact with the boiler. Thermal conductivity of brass = 109 Js^{-1} m^{-1} C^{-1} and heat of vaporization of water = 2256 Jg^{-1}.

Sol. Base area of the boiler, A = 0.15 m^2
Thickness of the boiler, l = 1.0 cm = 0.01 m
Boiling rate of water, R = 6.0 kg/min
Mass, m = 6 kg
Time, t = 1 min = 60 s
Thermal conductivity of brass, K = 109 J s^{-1} m^{-1} K^{-1}
Heat of vaporisation, L = 2256 × 10^3 J kg^{-1}
The amount of heat flowing into water through the brass base of the boiler is given by:

$$\theta = \frac{KA(T_1 - T_2)t}{l} \quad \ldots (i)$$

Where,
T_1 = Temperature of the flame in contact with the boiler
T_2 = Boiling point of water = 100°C
Heat required for boiling the water:

$\theta = mL$ … (ii)

Equating equations (i) and (ii), we get:

$$\therefore mL = \frac{KA(T_1 - T_2)t}{l}$$

$$T_1 - T_2 = \frac{mLl}{KAt}$$

$$= \frac{6 \times 2256 \times 10^3 \times 0.01}{109 \times 0.15 \times 60}$$

$$= 137.98°\text{C}$$

Therefore, the temperature of the part of the flame in contact with the boiler is 237.98°C.

(5 Marks Questions)

17. State Newton's law of cooling. Derive mathematical expression for it.

Sol. According to Newton's law of cooling, the rate of loss of heat, that is – dQ/dt of the body is directly proportional to the difference of temperature is, $\Delta T = (T_2 - T_1)$ of the body and the surroundings.

Mathematical expression: $dQ/dt \propto (q - q_s)]$, where q and q_s are temperature corresponding to object and surroundings. where, q_i = initial temperature of object, q_f = final temperature of object.

18. In an experiment on the specific heat of a metal, a 0.20kg of the metal at 150°C is dropped in a copper calorimeter (of water equivalent 0.025 kg) containing 150 cm^3 of water at 27°C. The final temperature is 40↑8C. Compute the specific heat of the metal.

Sol. Mass of metal block, m = 0.20kg = 200g

Fall in temperature of metal block, ΔT = 150-40 = 110°C

Let specific heat of metal block = c cal $g^{-1}°C^{-1}$

Therefore heat lost by metal block = $mc\Delta t$ = 200×c×110cal

Volume of water in calorimeter = 150cm^3

Mass of water, m' = 150g

Water equivalent of calorimeter, w = 0.025kg = 25g

Specific heat of water, c' = 1cal $g^{-1}°C^{-1}$

Therefore heat gained by water and calorimeter = (m' + w)c' $\Delta T'$

= (150+25)×1×(40-27)cal = 175×13cal

By principle of calorimetry, heat lost = heat gained

Therefore 200×c × 110 = 175 × 13 or c = $\frac{175\times13}{200\times110}$ = 0.1cal $g^{-1}°C^{-1}$.

D. ASSERTION REASON TYPE QUESTION:

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

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

(c) If assertion is true but reason is false **(d) If both assertion and reason are false**

(e) If assertion is false but reason is true

1. Assertion: A gas can be liquefied at any temperature by increase of pressure alone.
   Reason: On increasing pressure the temperature of gas decrease.

Ans. (d) Both assertion and reason are false

Gas and vapour are two distinct state of matter. Critical temperature is the distinguishing feature between the two. A vapour above the critical temperature is a gas and a gas below the critical temperature for a substance is a vapour. A gas cannot be liquefied by the application of pressure alone, however large the pressure may be white vapour can be liquefied under pressure alone. To liquefy a gas it must be cooled upto or below its critical temperature.

2. Assertion: A cloudy night sky is hotter than a clear sky night.
   Reason: In the cloudy night, temperature of earth does not fall

Ans. (a) both assertion and reason are true and reason is the correct explanation of assertion.

Since all the radiation from the earth is reflected back to the earth by the clouds due to which temperature of the earth does not fall.

3. Assertion: Animals curl into a ball, when they feel very cold.
   Reason: Animals by curling their body reduces the surface area.

Ans. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

When the animals feel cold, they curl their body into a ball so as to decrease the surface area of their bodies. As total energy radiated by body varies directly as the surface area of the body, the loss of heat due to radiation would be reduced.