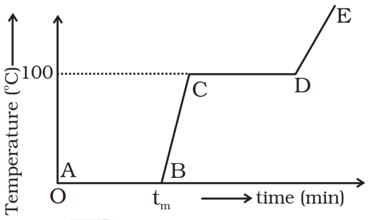
KD EDUCATION ACADEMY [9582701166]

Time : 7 Hour | STD 11 Science Physics | Total Marks : 320

kd 90+ ch-10 thermal properties of matter

* Choose The Right Answer From The Given Options.[1 Marks Each] [25]

1. Refer to the plot of temperature versus time showing the changes in the state of ice on heating (not to scale). Which of the following is correct?



(A) The region AB represents ice and water in thermal equilibrium.

(B) At B water starts boiling.

(C) At C all the water gets converted into steam.

(D) C to D represents water and steam in equilibrium at boiling point.

Ans. :

a. The region AB represents ice and water in thermal equilibrium.

d. C to D represents water and steam in equilibrium at boiling point.

Explanation:

In region AB, a phase change takes place, heat is supplied and ice melts but temperature of the system is 0°C. it remains constant during process. The heat supplied is used to break bonding between molecules.

In region CD, again a phase change takes place from a liquid to a vapour state during which temperature remains constant. It shows water and steam are in equilibrium at boiling point.

2. Time taken to heat water upto a temperature of 40°C (from room temperature) is t_1 and time taken to heat mustard oil (of same mass and at room temperature) upto a temperature of 40°C is t_2, then (given mustard oil has smaller heat capacity).

(A) $t_1 = t_2$

(B) $t_1 > t_2$

(C) $t_2 > t_1$

(D) t_1 and t_2 both are less than 10min.

Ans. :

b. $t_1 > t_2$

3. The high thermal conductivity of metal is due to free electrons. The relevant electron property is

(A) Its being charged.

(B) Its high average energy.

(C) Its high average thermal speed.

(D) Its low volume.

Ans. :

c. Its high average thermal speed.

Explanation:

The average thermal speed of electron is high. This gives high thermal conductivity to metals.

4. It is hotter at the some distance over the top of a fire than it is on the side of it mainly because:

(A) Heat is radiated upwards.

(B) Air conducts heat upwards.

(C) Convection takes more heat upwards.

(D) Conduction, convection and radiation all contribute significantly in transferring heat up wards.

Ans. :

c. Convection takes more heat upwards.

5. At about 4°C, a certain amount of water has maximum:

(A) Energy. (B) Specific heat. (C) Density. (D) Volume.

Ans. :

c. Density.

6. A cup of tea cools from 65.5°C to 62.5°C in one minute in a room of 22.5°CC. How long will the same cup of tea take to cool from 46.5°C to 40.5°C in the same room. (Choose the nearest value in min.)

(A) 1. (B) 2. (C) 3. (D) 4.

Ans. :

d. 4.

Explanation:

According to Newton' law of cooling

$\frac{\mathrm{dT}}{\mathrm{dt}} = -\mathrm{K}(\mathrm{T}\text{-}\mathrm{T}_0)$

where $\mathrm{T} = \frac{\mathrm{T}_1+\mathrm{T}_2}{2}$

Case: I $\mathrm{dT} = 65.5 - 62.5 = 3^{\circ}\mathrm{C}; \mathrm{dt} = 1\ \mathrm{min};$

$\mathrm{T} = \frac{65.5+62.5}{2} = 64^{\circ}\mathrm{C}$

$\therefore \frac{3}{1} = \mathrm{K}(64 - 22.5) = \mathrm{K} \times 41.5$

Case: II $\mathrm{dT} = 46.5 - 40.5 = 6^{\circ}\mathrm{C}; \mathrm{dt} = ?$

$\mathrm{T} = \frac{46.5+40.5}{2} = 43.5^{\circ}\mathrm{C}$

$\therefore \frac{6}{\mathrm{dt}} = -\mathrm{K}(43.5 - 22.5) = -\mathrm{K} \times 21.0$

Dividing (i)by (ii) , we have

$\frac{3\times\mathrm{dt}}{6} = \frac{41.5}{21.0}$

or

$\mathrm{dt} = \frac{41.5}{21.0} \times \frac{6}{3} = 4\mathrm{min}.$

7. If there are no heat losses, the heat released by the condensation of x gram of steam at 100°C into water at 100°C can be used to convert y gram of ice at 0°C into water at 100°C. Then the ratio y : x is nearly:

(A) 1 : 1 (B) 2 : 1 (C) 3 : 1 (D) 2.5 : 1

Ans. :

c. 3 : 1

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

(A) Its speed of rotation increases.

(B) Its speed of rotation decreases.

(C) Its speed of rotation remains same.

(D) Its speed increases because its moment of inertia increases.

Ans. :

b. Its speed of rotation decreases.

Explanation:

On heating a uniform metallic rod its length will increase so moment of inertia of rod increased from I_1 to I_2 (i.e., $I_1 < I_2$). Due to law of conservation of angular momentum,

$$I_1\omega_1 = I_2\omega_2$$

$\because\ I_1 < I_2 \Rightarrow \omega_1 > \omega_2$, so angular speed decreases.

9. The latent heat of vaporisation of a substance is always:

(A) Greater than its latent heat of fusion.

(B) Greater than its latent heat of sublimation.

(C) Equals to its latent heat of sublimation.

(D) Less than its latent heat of fusion.

Ans. :

a. Greater than its latent heat of fusion.

10. Change of state from solid to vapour state without passing through the liquid state is called:

(A) Regelation. (B) Sublimation.

(C) Condensation. (D) Sedimentation.

Ans. :

b. Sublimation.

11. 70 calories of heat are required to increase the temperature of 2 moles of an ideal gas from 30°C to 35°C at constant pressure. The amount of heat required to increase the temperature of the same gas through same temperature range (30°C to 35°C) at constant volume will be (R = 2cal/ mole/ K).

(A) 30 cals. (B) 50 cals. (C) 70 cals. (D) 90 cals.

Ans. :

b. 50 cals.

Explanation:

$$dQ = nC_P\Delta T;\ \text{so } 70 = 2 \times C_P \times 5$$

$$\therefore C_P = 7\text{cal mol}^{-1\circ}C^{-1}$$

$$C_v = C_P - R = 7 - 2 = 5\text{cal mol}^{-1\circ}C^{-1}$$

$$\therefore dQ = nC_v\Delta T = 2 \times 5 \times 5 = 50cal$$

12. A spherical body with radius 12cm radiates 450W power at 500K. If the radius were halved and the temperature doubled, what would be the power radiated?

(A) 2000W (B) 1500W (C) 1800W (D) 2500W

Ans. :

c. 1800W

13. Temperature of atmosphere in Kashmir falls below -10°Cin winter. Due to this water animal and plant life of Dal-lake:

(A) Is destroyed in winters.

(B) Frozen in winter and regenerated in summers.

(C) Survives as only top layer of lake in frozen.

(D) None of the above.

Ans. :

c. Survives as only top layer of lake in frozen.

14. As the temperature is increased, the time period of a pendulum:

(A) Increases as its effective length increases even though its centre of mass still remains at the centre of the bob.

(B) Decreases as its effective length increases even though its centre of mass still remains at the centre of the bob.

(C) Increases as its effective length increases due to shifting of centre of mass below the centre of the bob.

(D) Decreases as its effective length remains same but the centre of mass shifts above the centre of the bob.

Ans. :

a. Increases as its effective length increases even though its centre of mass still remains at the centre of the bob.

Explanation:

As the temperature increased the length L increase due to expansion (Linear) and,

$$T = \sqrt{\frac{L}{g}} \text{ or } T \, \alpha \, \sqrt{L}$$

So on increasing temperature, its effective length increases hence T also increases.

15. The amount of heat that a body can absorb by radiation:

(A) Depends on colour and temperature both of body.

(B) Depends on colour of body only.

(C) Depends on temperature of body only.

(D) Depend on density of body.

Ans. :

a. Depends on colour and temperature both of body.

Explanation:

The thermal radiation that falls on a body partly reflected and partly absorbed. The amount of heat that a body can absorb, by radiation depends on the colour of the body and temperature of body.

16. The scale on a steel meter rod is calibrated at 20°C. What will be the error in the reading of 50cm at 27°C? Take, $\alpha = 1.2 \times 10^{-5}\ ^{\circ}\mathrm{C}^{-1}$.

(A) 0.042cm. (B) 0.0042cm. (C) 0.021cm. (D) 0.0021cm.

Ans. :

b. 0.0042cm.

17. The temperature of water at the surface of a deep lake is 2˚C. The temperature expected at the bottom is:

a. 0˚C
b. 2˚C
c. 4˚C
d. 6˚C

Ans. :

c. 4˚C

Explanation:

The density of water is maximum at 4˚C, and the water at the bottom of the lake is most dense, compared to the layers of water above. Therefore, the temperature expected at the bottom is 4˚C.

18. A metal sheet with a circular hole is heated. The hole:

a. Gets larger.
b. Gets smaller.
c. Remains of the same size.
d. Gets deformed.

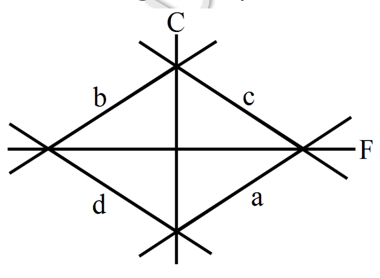
Ans. :

a. Gets larger

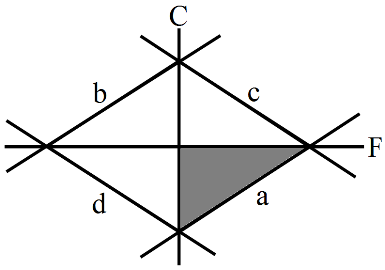
Explanation:

When a metal sheet is heated, it starts expanding and its surface area will start increasing, which will lead to an increase in the radius of the hole. Hence, the circular hole will become larger.

19. Which of the curves in figure represents the relation between Celsius and Fahrenheit temperatures.



Ans. :



Explanation:

Celsius and Fahrenheit temperatures are related in the following way:

$\mathrm{C} = 59\mathrm{F} - \frac{160}{9}$

Here, F = temperature in Fahrenheit

C = temperature in Celsius

If this equation is plotted on the graph, then the curve will be represented by curve 'a' lying in the fourth quadrant with slope $\frac{5}{9}$.

So, the correct option is (a).

20. An aluminium sphere is dipped into water at 10°C. If the temperature is increased, the force of buoyancy:

a. Will increase.
b. Will decrease.
c. Will remain constant.
d. May increase or decrease depending on the radius of the sphere.

Ans. :

b. Will decrease.

Explanation:

When an aluminium sphere is dipped in water and the temperature of water is increased, the aluminium will start expanding leading to increase in its volume. This will lead to increase in the surface area of the shell and it'll exert less pressure on the water such that the volume of the sphere submerged in water will decrease and it'll start float easily on water. Now, the volume of water displaced will be less compared to what was displaced initially. Therefore, the force of buoyancy will decrease, as it is directly proportional to the volume of water displaced.

21. If the temperature of a uniform rod is slightly increased by $\Delta \mathrm{t}$, its moment of inertia I about a perpendicular bisector increases by:

a. Zero
b. $\alpha \mathrm{I} \Delta \mathrm{t}$
c. $2\alpha \mathrm{I} \Delta \mathrm{t}$
d. $3\alpha \mathrm{I} \Delta \mathrm{t}$

Ans. :

c. $2\alpha \mathrm{I} \Delta \mathrm{t}$

Explanation:

The change in moment of inertia of uniform rod with change is temperature is given by,

$$I' = I(1 + 2\alpha\Delta t)$$

Here, I = initial moment of inertia

I' = new moment of inertia due to change in temperature

$\alpha = \text{expansion coefficient}$

$\Delta t = \text{change in temperature}$

$\text{so}, I' - I = 2\alpha I\Delta t$

22. If the temperature of a uniform rod is slightly increased by Δt, its moment of inertia Iabout a line parallel to itself will increase by:
    a. Zero
    b. $\alpha I\Delta t$
    c. $2\alpha I\Delta t$
    d. $3\alpha I\Delta t$

Ans. :

c. $2\alpha I\Delta t$

Explanation:

The moment of inertia of a solid body of any shape changes with temperature as

$$I' = I(1 + 2\alpha\Delta t)$$

Here, I = initial moment of inertia

I' = new moment of inertia due to change in temperature

$\alpha = \text{expansion coefficient}$

$\Delta t = \text{change in temperature}$

$\text{So}, I' - I = 2\alpha I\Delta t$

23. Two bodies A and B having equal surface areas are maintained at temperatures 10°C and 20°C. The thermal radiation emitted in a given time by A and B are in the ratio:
    a. 1 : 1.15
    b. 1 : 2
    c. 1 : 4
    d. 1 : 16

Ans. :

a. 1 : 1.15

Explanation:

From Stefan-Boltzmann law, energy of the thermal radiation emitted per unit time by a blackbody of surface area A is given by,

$$u = \sigma A T^4$$

Here, σ is Stefan-Boltzmann constant.

The thermal radiation emitted in a given time by A and B will be in the ratio.

$$\frac{u_A}{u_B} = \frac{T_A^4}{T_n^4}$$

$$\frac{u_A}{u_B} = \frac{(273+10)^4}{(273+20)^4}$$

$$\frac{u_A}{u_B} = \frac{1}{1.15}$$

24. A body cools down from 65˚C to 60˚C in 5 minutes. It will cool down from 60˚C to 55˚C in:

a. 5 Minutes.
b. Less than 5 minutes.
c. More than 5 minutes.
d. Less than or more than 5 minutes depending on whether its mass is more than or less than 1kg.

Ans. :

c. More than 5 minutes.

Explanation:

Let the temperature of the surrounding be T˚C.

Average temperature of the liquid in first case = 62.5˚C

From newton law of cooling,

$$1^{\circ}\mathrm{C}\ \mathrm{min}^{-}1 = -\mathrm{bA}(62.5 - \mathrm{T})^{\circ}\mathrm{c}$$

$$\Rightarrow -\mathrm{bA} = \frac{1}{62.5\mathrm{T}}\mathrm{min}^{-}1\ \ldots(1)$$

From Newton's law of cooling and equation (1),

$$5^{\circ}\mathrm{C} = -\mathrm{bA}(57.5 - \mathrm{T})^{\circ}\mathrm{C}$$

$$\Rightarrow \frac{5^{\circ}\mathrm{C}}{\mathrm{t}} = \frac{1}{62.5-\mathrm{T}}(57.5 - \mathrm{T})^{\circ}\mathrm{C}$$

$$\Rightarrow \mathrm{t} = \frac{5(62.5-\mathrm{T})}{(57.5-\mathrm{T})}$$

$$\mathrm{t} > 5\ \mathrm{minutes.}$$

25. The thermal conductivity of a rod depends on:

a. Length.
b. Mass.
c. Area of cross section.
d. Material of the rod.

Ans. :

d. Material of the rod.

Explanation:

The thermal conductivity of a rod depends only on the material of the rod. For example, metals are much better conductors than non-metals because metals have large number of free electron that can move freely anywhere in the body of the metal and carry thermal energy from one place to other.

Also, 2 copper rods having different lengths and areas of cross-section have same thermal conductivity that depends only on the number of free electrons in copper.

*** Answer The Following Questions In One Sentence.[1 Marks Each] [10]**

26. A blacksmith fixes iron ring on the rim of the wooden wheel of a horse cart. The diameter of the rim and the iron ring are 5.243 m and 5.231 m, respectively at 27 °C. To what temperature should the ring be heated so as to fit the rim of the wheel?

Ans. : Given,

$T_1 = 27^\circ C$

$L_{T1} = 5.231m$

$L_{T2} = 5.243m$

So,

$L_{T2} = L_{T1}\left[1 + \alpha_1\left(T_2 - T_1\right)\right]$

$5.243m = 5.231m\left[1 + 1.2010^{-5}K^{-1}\left(T_2 - 27^\circ C\right)\right]$

or $T_2 = 218^\circ C.$

27. Answer the following : The triple-point of water is a standard fixed point in modern thermometry. Why? What is wrong in taking the melting point of ice and the boiling point of water as standard fixed points (as was originally done in the Celsius scale)?

Ans. : Melting and boiling points of water aren't considered as the standard fixed points because they vary with change in pressure, the temperature of triple point of water is unique and it does not vary with pressure.

28. What is the value of latent heat of ice?

Ans. : Latent heat of ice has a value 3.33×10^5J/ kg or 80kcal/ kg.

29. Why is a gap left between the ends of two railway lines in a railway track?

Ans. : It is done to accommodate the linear expansion of railway line during summer. If the gap is not left in summer, the lines will bend causing a threat of derailment.

30. Why the temperature above 1200°C cannot be measured accurately by a platinum resistance thermometer?

Ans. : This is because platinum begins to evaporate above 1200°C.

31. What is the shift in the colour of light when the temperature increases?

Ans. : As temperature increases, the wavelength decreases and frequency increases.

32. Each side of a cube increases by 0.01% on heating. How much is the area of its faces and volume increased?

Ans. : The area of the faces will increased by 0.02% and the volume by 0.03%.

33. Tea gets cooled when sugar is added to it. Why?

Ans. : The sugar absorbs heat energy from the tea and hence temperature of the tea decreases.

34. Can we boil water inside in the earth satellite?

Ans. : No, the process of transfer of heat by convection is based on the fact that a liquid becomes lighter on becoming hot and rise up. In condition of weightlessness, this is not possible. So, transfer of heat by convection is not possible in the earth satellite.

35. Why birds are often seen to swell their feathers in winter?

Ans. : When the birds swell their feathers, they are able to enclose air in the feathers. Air, being a poor conductor of heat, so it prevents the loss of heat from the bodies of the birds to the surroundings and as such they do not feel cold in winter.

*** Given Section consists of questions of 2 marks each.** **[36]**

36. When $0.15kg$ of ice at $0^{\circ}C$ is mixed with $0.30kg$ of water at $50^{\circ}C$ in a container, the resulting temperature is $6.7^{\circ}C$. Calculate the heat of fusion of ice. $\left(s_{\text{water}} = 4186Jkg^{-1}K^{-1}\right)$

Ans. :

$$\text{Heat lost by water } = ms_w(\theta_f - \theta_i)_w$$
$$= (0.30kg)\left(4186Jkg^{-1}K^{-1}\right)(50.0^{\circ}C - 6.7^{\circ}C)$$
$$= 54376.14J$$
$$\text{Heat required to melt ice } = m_2L_f = (0.15kg)L_f$$
$$\text{Heat required to raise temperature of ice}$$
$$\text{water to final temperature } = m_I s_w(\theta_f - \theta_i)_I$$
$$= (0.15kg)\left(4186Jkg^{-1}K^{-1}\right)(6.7^{\circ}C - 0^{\circ}C)$$
$$= 4206.93J$$
$$\text{Heat lost} = \text{ heat gained}$$
$$54376.14J = (0.15kg)L_f + 4206.93J$$
$$L_f = 3.3410^5 Jkg^{-1}.$$

37. Distinguish the radiation and convection methods of heat transfer.

Ans. :

S. No.	Radiation	Convection
i.	No material medium is required.	Requires medium.
ii.	Fastest method.	Decided by various parameters like wind flow.
iii.	Depends on the nature of the surface and fourth power of temperature.	Always rises up from hot region.

38. A copper calorimeter of mass 100g contains a lump of ice at 4°C. When 520 calories of heat are given to the calorimeter and its contents, the temperature rises from -4°C to -2°C. The addition of another 41540 calories of heat brings the temperature of the calorimeter and its contents to 2°C. Determine the specific heat capacity of copper and the mass of ice present in the calorimeter. Given: Latent heat of fusion of ice = 80cal/ g^{-1} Specific heat capacity of ice = 0.5cal/ $g^{-1}(°C)^{-1}$

Ans. : Let s be the specific heat capacity of copper and m the mass of ice present in the calorimeter. We then have,

100 × s × [-2 - (-4)] + m × 0.5 × [-2 - (-4)] = 520

or 200s + m = 520 .....(i)

Also 100s × 2 - (-2) + m × 0.5 × (-2) + m × 80 + m × 1 × (2 - 0) = 41540 .....(ii)

or 400s + 83m = 41540

Splving eqn. (i) and (ii), we get,

m = 500g and s = 0.1cal/ $g^{-1}(ºC)^{-1}$.

39. Calculate the power developed by a person, while eating 100g of ice per minute. Latent heat of ice = 80cal/ g^{-7}.

Ans. : Mass of ice eaten per second,

$\mathrm{m} = \frac{100}{60}\mathrm{gs}^{-1} = \frac{5}{3}\mathrm{gs}^{-1}$

$\therefore$ Power developed by a person,

$= \mathrm{mL} = \frac{5}{3} \times 80\mathrm{cal}/\ \mathrm{s}^{-1}$

$= \frac{5}{3} \times 80 \times 4.2\mathrm{Js}^{-1} = 560\mathrm{W}.$

40. Calculate the heat of combustion of coal, when 10 gm of coal, on burning raises the temperature of 2kg of water from 20°C to 55°C.

Ans. : $\mathrm{m} = 2\ \mathrm{kg}, \triangle\theta = 35^{\circ}\mathrm{C}$

Heat producted $= \mathrm{ms}\triangle\theta = \mathrm{ms}\theta = 2 \times 4086 \times 35 = 293020\mathrm{J}$

41. Calculate the temperature whose value is the same on the Celsius and Fahrenheit scale?

Ans. : Let the required temperature in both the scales be x.

i.e., $\mathrm{C} = \mathrm{F} = \mathrm{x}$

Now $\frac{\mathrm{C}}{100} = \frac{\mathrm{F}-32}{180}$

$\therefore \frac{\mathrm{x}}{100} = \frac{\mathrm{x}-32}{180}$

$180\mathrm{x} = 100\mathrm{x} - 3200$

$80\mathrm{x} = -3200$

$\Rightarrow \mathrm{x} = -40$

- 40ºC is equivalent to - 40ºF.

42. A cylinder of diameter exactly 1cm at 30°C is to be slid into a hole in a steel plate. The hole has a diameter of 0.99970cm at 30°C. To what temperature must the plate be heated? For steel $\alpha - 1.1 \times 10^{-5}(^{\circ}\mathrm{C}^{-1})$.

Ans. : The hole will expand in the same way as a circle of steel filling it would expand. The diameter of the hole needs to be changed by:

$\Delta\mathrm{l} = 1 - 0.99970 = 0.00030\mathrm{cm}$

But $\Delta\mathrm{l} = \alpha\mathrm{l}\ \Delta\mathrm{T}$

$\therefore \Delta\mathrm{T} = \frac{\Delta\mathrm{L}}{\alpha\mathrm{l}}$

$= \frac{0.00030}{1.1\times10^{-5}\times0.99970} = 27.3^{\circ}\mathrm{C}$

The plate must be raised to a temperature of 30 + 27.3 = 57.3°C.

43. A glass flask of volume $250cm^3$ is just filled with mercury at 20°C. How much mercury overflows when the temperature of the system is raised to 100°C? The coefficient of volume expansion of glass is 12 × $10^{-6}(°C)^{-1}$ and that of mercury is 18 × 10^{-5} $(°C)^{-1}$.

Ans. : The increase in the volume of the flask is,

$(\Delta\mathrm{V})_{\mathrm{f}} = \mathrm{V}\gamma\ \Delta\mathrm{t} = 250 \times 12 \times 10^{-6} \times 80$

$= 0.24cm^3$

The increase in the volume of mercury is,

$(\Delta V)_m = 250 \times 18 \times 10^{-5} \times 80$

$3.6cm^3$

Therefore, the volume of mercury overflowing is,

3.6 - 0.24 = 3.36cm^3

44. Two vessels made of two different metals are identical in all respects. They are completely filled with ice at 0°C. The ice in one is melted in 30 minutes and that in another in 10 minutes by heat coming from outside. Compare the thermal conductivities of metals.

Ans. : We know that, $Q = \frac{KA(T_1 - T_2)t}{l}$

For given problem, kt = constant or $k \propto \frac{1}{t}$.

$\therefore \frac{k_1}{k_2} = \frac{t_2}{t_1} = \frac{10}{30} = \frac{1}{3}$.

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

Ans. : Since the $\alpha_{Cu} > \alpha_{Fe}$ so length of iron rod should be greater than the length of copper rod.

Let the initial lengths of iron and copper rods be l_1 and l_2, then,

$l_1 - l_2$ = 10cm ...(i)

Also since the difference has to be constant at all the temperatures, so,

$\Delta l = l_1 \alpha_{Fe}\ \Delta T = l_2\ \alpha_{Cu}\ \Delta T$

$\frac{l_1}{l_2} = \frac{\alpha_{Cu}}{\alpha_{Fe}}$

Solving eqn. (i) and (i), we get

l_1 = 28.3cm and l_2 = 18.3cm.

46. A metallic wire has resistance of 20 ohm at 20°C and a resistance of 21.2 ohm at 40°C. Calculate the temperature coefficient of resistance.

Ans. : $R_{20^\circ C} = 20\Omega, R_{40^\circ C} = 21.2\Omega.$

$\Delta\theta = 40^\circ C - 20^\circ C = 20^\circ C$

Using $\alpha = \frac{R_{20^\circ C} - R_{20^\circ C}}{R_{20^\circ C} \times \Delta T}$, we get

$\alpha = \frac{21.2 - 20}{20 \times 20} = \frac{1.2}{400}$

$= 3.0 \times 10^{-3}\ ^\circ C^{-1}$

47. A steel scale measures the length of a copper rod as 80.00cm when both are at 20°C, the calibration temperature for the scale. What would the scale read for the length of the rod when both are at 40°C? α for steel = 11 × 10^{-6}(°C^{-1}) and α for copper = 17 × 10^{-6}(°C^{-1}).

Ans. : The length of 1cm division of the steel scale at 40°C is:

(1cm) × (1 + 11 × 10^{-6} × 20) = 1.00022cm, Length of the copper rod at 40ºC will be (80) × (1 + 17 × 10^{-6} × 20) = 80.0272cm. The number of cm read on the scale will be,

$\frac{80.0272}{1.00022}\mathrm{cm} = 80.0096\mathrm{cm}.$

48. Define triple point of water. Why is it unique?

Ans. : It is the temperature at which the three phases of water, namely, ice, liquid water and water vapours are equally stable and coexistent. The triple point is suitable because it is unique, i.e., it occurs at one single temperature = 273.16K and one single pressure of about 0.46cm of the Hg column.

49. Two vessels of different materials are identical in size and wall thickness. They are filled with equal quantities of ice at 0°C. If the ice melts completely in 10 and 25 min respectively, compare the coefficients of thermal conductivity of the materials of the vessels.

Ans. : Let K_1 and K_2 be the coefficients of thermal conductivity of the materials and t, and t, be the times in which ice melts in the two vessels.

As the same quantity of ice melts in the two vessels, the quantity of heat flowed into the vessels must be same.

$\because \mathrm{Q} = \frac{\mathrm{K_1 A(T_1 - T_2)t_1}}{\mathrm{x}} = \frac{\mathrm{K_2 A(T_1 - T_2)t_2}}{\mathrm{x}}$

$\Rightarrow \mathrm{K_1 t_1 = K_2 t_2}$

$\therefore \frac{\mathrm{K_1}}{\mathrm{K_2}} = \frac{\mathrm{t_2}}{\mathrm{t_1}} = \frac{25\mathrm{min}}{10\mathrm{min}} = 5:2$

50. These days people use steel utensils with copper bottom. This is supposed to be good for uniform heating of food. Explain this effect using the fact that copper is the better conductor.

Ans. : The copper bottom of the steel utensil gets heated quickly. Because of the reason that copper is a good conductor of heat as compared to steel. But steel does not conduct as quickly, thereby allowing food inside to get heated uniformly.

51. 2kg water at 80°C is mixed with 3kg water at 20°C. Assuming no heat losses, find the final temperature of the mixture.

Ans. : Heat lost = heat gain

$\mathrm{m_1(80 - t) = m_2(t - 20)}$

$2(80 - \mathrm{t}) = 3(\mathrm{t} - 20)$

$\Rightarrow \mathrm{t} = 44^\circ\mathrm{C}.$

52. Does a body at 20˚C radiate in a room, where the room temperature is 30˚C? If yes, why does its temperature not fall further?

Ans. : Yes, the body will radiate. However, its temperature will not fall down with time because as the temperature of the surroundings is greater than the temperature of the body.

So, its rate of absorption will be greater than its rate of emission.

53. Why is a white dress more comfortable than a dark dress in summer?

Ans. : A white colour dress reflects almost all the radiations falling on it. So, it does not absorb any heat from the sunlight and we feel more comfortable in it.

On the other hand, a dark colour dress absorbs maximum radiation falling on it. So, we feel hot in a dark coloured dress during summers.

*** Given Section consists of questions of 3 marks each. [42]**

54. State Wien's displacement law. Draw graph showing energy emitted versus wavelength for a blackbody at different temperature.

Ans. : According to Wien's law, the product of the wavelength corresponding to maximum intense radiation and the absolute temperature is a constant, i.e., and , are the temperatures of the body and the surroundings respectively.

or $\frac{d\theta}{(\theta-\theta)_\theta} = \text{-Kdt}$

Integrating, we have,

$$\int_{\theta_1}^{\theta_2} \frac{d\theta}{(\theta-\theta)}_0 = \int_0^t -\text{Kdt} \int_{\theta_1}^{\theta_2} \frac{d\theta}{\theta-\theta}_0 = \int^t -\text{Kdt}$$

or $\log e\left(\frac{\theta_2-\theta_0}{\theta_1-\theta_0}\right) = -\text{Kt}$

$$\log e\left(\frac{60-25}{50-25}\right) = -K \times 10 \times 60 \ \ldots \text{(i)}$$

$$\log e\left(\frac{50-25}{\text{T-25}}\right) = -K \times 10 \times 60 \ldots \text{(ii)}$$

From (i)and (ii),

$\frac{35}{25} = \frac{25}{\text{T-25}}$

$\therefore T = 42.9^0 C$

55. A liquid cools from 70°C to 60°C in 5 minutes. Calculate the time taken by the liquid to cool from 60°C to 50°C, if the temperature of the surrounding is constant at 30°C.

Ans. : In the first case,

$T_1 = 70^\circ C, T_2 = 60^\circ C, t = 5\text{min},$

$T_0 = 30^\circ C$

$t = \frac{2.3026}{k} \log_{10} \frac{70-30}{60-30}$

$= \frac{2.3026}{K} \log_{10} \frac{4}{3} \ \ldots (1)$

In the second case,

$T_1 = 60^\circ C, T_2 = 50^\circ C, T_0 = 30^\circ C$

$t = \frac{2.3026}{K} \log_{10} \frac{60-30}{50-30}$

$= \frac{2.3026}{K} \log_{10} \frac{3}{2}$

Dividing (2) by (1), we get,

$\frac{t}{5} = \frac{\log_{10} 1.5}{\log_{10} 1.3333} = \frac{0.1761}{0.1249} = 1.4$

$t = 1.4 \times 5\text{min} = 7\text{min}.$

56. A body cools from 80 °C to 50 °C in 5 minutes. Calculate the time it takes to cool from 60°C to 30 °C. The temprature of the surroundings is 20°C.

Ans. : According to Newton's law of cooling, we have

$$mc\frac{(T_1-T_2)}{t}=K\left[\frac{(T_1+T_2)}{2}-T_0\right]\ldots(1)$$

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

$$\frac{mc}{K}=\frac{\left[\frac{(80+50)}{2}-20\right]}{\left[\frac{(80-50)}{5}\right]}=\frac{45}{6}$$

Substituting T1 = 60 and T2 = 30 and T0 = 20 (all in °C) in Eq. (1), we get

$$mc\frac{(60-30)}{t}=K\left[\frac{(60-30)}{2}-20\right]$$

$$\frac{30mc}{t}=25K$$

$$t=\frac{30mc}{(25K)}$$

$$=\left(\frac{30}{25}\right)\times\left(\frac{45}{6}\right)$$

= 9min

The body takes 9 min to cool from 60°C to 30°C.

57. A 10kW drilling machine is used to drill a bore in a small aluminium block of mass 8.0kg. How much is the rise in temperature of the block in 2.5 minutes,assuming 50% of power is used up in heating the machine itself or lost to the surroundings. Specific heat of aluminium = 0.91J g^{-1} K^{-1}.

Ans. : Power of the drilling machine, P = 10kW = 10 × 10^3W

Mass of the aluminum block, m = 8.0kg = 8 × 10^3g

Time for which the machine is used, t = 2.5min = 2.5 × 60 = 150s

Specific heat of aluminium, c = 0.91J g^{-1} K^{-1}

Rise in the temperature of the block after drilling = δT

Total energy of the drilling machine = Pt

= 10 × 10^3 × 150

= 1.5 × 10^6J

It is given that only 50% of the power is useful. Useful energy,

$$\triangle Q=\left(\frac{50}{100}\right)\times 1.5\times 10^6=7.5\times 10^5 J$$

But $\triangle Q=mc\triangle T$

$$\therefore \triangle T=\frac{\triangle Q}{mc}$$

$$=\frac{(7.5\times 10^5)}{(8\times 10^3\times 0.91)}$$

$$=103^\circ C$$

Therefore, in 2.5 minutes of drilling, the rise in the temperature of the block is 103°C.

58. A sphere of $0.047kg$ aluminium is placed for sufficient time in a vessel containing boiling water, so that the sphere is at $100^\circ C$. It is then immediately transfered to $0.14kg$ copper calorimeter containing $0.25kg$ water at $20^\circ C$. The

temperature of water rises and attains a steady state at $23^{\circ}C$. Calculate the specific heat capacity of aluminium.

Ans. : In solving this example, we shall use the fact that at a steady state, heat given by an aluminium sphere will be equal to the heat absorbed by the water and calorimeter.

Mass of aluminium sphere $(m_1) = 0.047kg$

Initial temperature of aluminium sphere $= 100^{\circ}C$

Final temperature $= 23^{\circ}C$

Change in temperature $(\Delta T) = (100^{\circ}C - 23^{\circ}C) = 77^{\circ}C$

Let specific heat capacity of aluminium be s_{Al}.

The amount of heat lost by the aluminium sphere

$= m_1 s_{Al} \Delta T = 0.047kg \times s_{Al} \times 77^{\circ}C$

Mass of water $(m_2) = 0.25kg$

Mass of calorimeter $(m_3) = 0.14kg$

Initial temperature of water and calorimeter $= 20^{\circ}C$

Final temperature of the mixture $= 23^{\circ}C$

Change in temperature $(\Delta T_2) = 23^{\circ}C - 20^{\circ}C = 3^{\circ}C$

Specific heat capacity of water (s_w)

$= 4.18 \times 10^3 Jkg^{-1}K^{-1}$

Specific heat capacity of copper calorimeter

$= 0.386 \times 10^3 Jkg^{-1}K^{-1}$

The amount of heat gained by water and

$\text{calorimeter } = m_2 S_w \Delta T_2 + m_3 S_{cu} \Delta T_2$

$= (m_2 S_w + m_3 S_{cu})(\Delta T_2)$

$= (0.25kg \times 4.18 \times 10^3 Jkg^{-1}K^{-1} + 0.14kg \times$

$0.386 \times 10^3 Jkg^{-1}K^{-1})(23^{\circ}C - 20^{\circ}C)$

In the steady state heat lost by the aluminium sphere $=$ heat gained by water + heat gained by calorimeter.

$\text{So, } 0.047kg \times s_{Al} \times 77^{\circ}C$

$= (0.25kg \times 4.18 \times 10^3 Jkg^{-1}K^{-1} + 0.14kg \times$

$0.386 \times 10^3 Jkg^{-1}K^{-1})(3^{\circ}C)$

$s_{Al} = 0.911kJkg^{-1}K^{-1}$

59. Calculate the heat required to convert $3kg$ of ice at $-12^{\circ}C$ kept in a calorimeter to steam at $100^{\circ}C$ at atmospheric pressure. Given specific heat capacity of ice $= 2100Jkg^{-1}K^{-1}$, specific heat capacity of water $= 4186J^{-1}Kg^{-1}$, latent heat of fusion of ice $= 3.35 \times 10^5 Jkg^{-1}$ and latent heat of steam $= 2.256 \times 10^6 Jkg^{-1}$.

Ans. :

We have

Mass of the ice, $m = 3$ kg

specific heat capacity of ice, s_{ice}

$= 2100 \text{ J kg}^{-1} \text{ K}^{-1}$

specific heat capacity of water, s_{water}

$= 4186 \text{ J kg}^{-1} \text{ K}^{-1}$

latent heat of fusion of ice, $L_{f\,ice}$

$= 3.35 \times 10^5 \text{ J kg}^{-1}$

latent heat of steam, L_{steam}

$= 2.256 \times 10^6 \text{ J kg}^{-1}$

Now,

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

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

$= m\, s_{ice}\, \Delta T_1 = (3 \text{ kg})\ (2100 \text{ J kg}^{-1} \text{ K}^{-1})\ [0-(-12)]°\text{C} = 75600 \text{ J}$

Q_2 = heat required to melt ice at 0 °C to water at 0 °C

$= m\, L_{f\,ice} = (3 \text{ kg})\ (3.35 \times 10^5 \text{ J kg}^{-1})$

$= 1005000 \text{ J}$

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

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

$= 1255800 \text{ J}$

Q_4 = heat required to convert water at 100 °C to steam at 100 °C.

$= m\ L_{steam} = (3 \text{ kg})\ (2.256 \times 10^6 \text{ J kg}^{-1})$

$= 6768000 \text{ J}$

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

$= 75600\text{J} + 1005000 \text{ J} + 1255800 \text{ J} + 6768000 \text{ J}$

$= 9.1 \times 10^6 \text{ J}$

60. 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? Co-efficient of linear expansion of brass = 2.0 × 10^{-5} K^{-1}; Young's modulus of brass = 0.91 × 1011Pa.

Ans. :

Initial Temperature = 27°C

Length of the brass wire at T_1, l = 1.8m

Final temperature, T_2 = –39°C

Diameter of the wire, d = 2.0mm = 2 × 10^{-3}m

Tension developed in the wire = F

Coefficient of linear expansion of brass, $\alpha = 2.0 \times 10^{-5} \mathrm{K}^{-1}$

Young's modulus of brass, Y = 0.91 × 10^{11} Pa

Young's modulus is given by the relation:

$$\mathrm{y} = \frac{(\text{stress})}{(\text{strain})}$$

$$= \frac{\left(\frac{\mathrm{F}}{\mathrm{A}}\right)}{\left(\frac{\triangle \mathrm{L}}{\mathrm{L}}\right)}$$

$$\triangle \mathrm{L} = \frac{(\mathrm{F} \times \mathrm{L})}{(\mathrm{A} \times \mathrm{Y})}$$

Where,

F = Tension developed in the wire

A = Area of cross-section of the wire.

$\triangle \mathrm{L} =$ Change in the length, given by the relation:

$$\triangle \mathrm{L} = \alpha \mathrm{L}(\mathrm{T}_2 - \mathrm{T}_1) \ldots (2)$$

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

$$\alpha \mathrm{L}(\mathrm{T}_2 - \mathrm{T}_1) = \frac{(\mathrm{FL})}{\left(\pi \left(\frac{\mathrm{d}}{2}\right)^2 \times \mathrm{Y}\right)}$$

$$\mathrm{F} = \alpha(\mathrm{T}_2 - \mathrm{T}_2)\mathrm{Y}\pi\left(\frac{\mathrm{d}}{2}\right)^2$$

$$\mathrm{F} = 2 \times 10^{-5} \times (-39 \times -27) \times 3.14 \times 0.91 \times 10^{11} \times \left(\frac{(2 \times 10^3)}{(2)^2}\right)$$

$$= -3.8 \times 10^2 \mathrm{N}$$

(The negative sign indicates that the tension is directed inward.) Hence, the tension developed in the wire is 3.8 ×10^2 N.

61. The coefficient of volume expansion of glycerine is 49 × 10^{-5} K^{-1}. What is the fractional change in its density for a 30°C rise in temperature?

Ans. : Coefficient of volume expansion of glycerin, $\alpha_{\mathrm{v}} = 49 \times 10^{-5} \mathrm{K}^{-1}$

Rise in temperature, $\triangle \mathrm{T} = 30^{\circ}$

Fractional change in its volume $= \frac{\triangle \mathrm{V}}{\mathrm{V}}$

This change is related with the change in temperature as:

$$\frac{\triangle \mathrm{V}}{\mathrm{V}} = \alpha_{\mathrm{v}} \triangle \mathrm{T}$$

$$\mathrm{V}_{\mathrm{T2}} - \mathrm{V}_{\mathrm{T}_1} = \mathrm{V}_{\mathrm{T}_1} \alpha_{\mathrm{v}} \triangle \mathrm{T}$$

$$\left(\frac{\mathrm{m}}{\rho_{\mathrm{T}_2}}\right) = \left(\frac{\mathrm{m}}{\rho_{\mathrm{T}_1}}\right) \alpha_{\mathrm{v}} \triangle \mathrm{T}$$

Where,

m = Mass of glycerine

$\rho_{\mathrm{T}_1} =$ Initial density at T_1

ρ_{T_2} = Initial density at T_2

$\frac{(\rho_{T_1} - \rho_{T_2})}{\rho_{T_2}} = \text{Fractional change in density}$

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

62. A hole is drilled in a copper sheet. The diameter of the hole is 4.24cm at 27.0 °C. What is the change in the diameter of the hole when the sheet is heated to 227°C? Coefficient of linear expansion of copper = 1.70 × 10–5 K^{-1}.

Ans. : Given:

Initial temperature, T_1 = 27.0°C

Diameter of the hole at T_1 , d_1 = 4.00cm

At T area of the hole, $A_1 = \pi\left(\frac{d_1^2}{4}\right)$

Final temperature, T_2 = 227°C

Let, the diameter of the hole at T_2 be d_2

At T area of the hole, $A_2 = \pi\left(\frac{d_2^2}{4}\right)$

Co-efficient of linear expansion of copper, $\alpha = 1.70 \times 10^{-5} K^{-1}$

We know, co-efficient of superficial expansion $\beta = 2\alpha = 3.1 \times 10^{-5}$

Also, increase in area $= A_2 - A_1 = \beta\alpha\triangle T$

or $A_2 = \beta\alpha \triangle T + A_1$

$\frac{\pi d_2^2}{4} = \frac{\pi}{4}(4)^2[1 + 3.4 \times 10^{-5}(228 - 27)]$

$d_2^2 = 4^2 \times 1.0068$

$\Rightarrow d_2 = 4.0136$

63. 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: asteel = 1.20×10^{-5} K^{-1}.

Ans. : The given temperature, T = 27°C can be written in Kelvin as: 27 + 273 = 300K

Outer diameter of the steel shaft at T, d_1 = 8.70cm

Diameter of the central hole in the wheel at T, d_2 = 8.69cm

Coefficient of linear expansion of steel, $\alpha_{\text{steel}} = 1.20 \times 10^{-5} K^{-1}$

After the shaft is cooled using 'dry ice', its temperature becomes T_1.

The wheel will slip on the shaft, if the change in diameter, $\triangle d = 8.69 - 8.70$

Temperature T_1, can be calculated from the relation:

$\triangle d = d_1 \alpha_{\text{steel}}(T_1 - T)$

$0.01 = 8.70 \times 1.20 \times 10^{-5} (T_1 - 300)$

$(T_1 - 300) = 95.78$

$\therefore T_1 = 204.21K$

= 204.21 – 273.16

= –68.95°C

Therefore, the wheel will slip on the shaft when the temperature of the shaft is –69°C.

64. A body cools from 80 °C to 50 °C in 5 minutes. Calculate the time it takes to cool from 60°C to 30 °C. The temprature of the surroundings is 20°C.

Ans. : According to Newton's law of cooling, we have

$$\mathrm{mc}\frac{(\mathrm{T_1}-\mathrm{T_2})}{\mathrm{t}} = \mathrm{K}\left[\frac{(\mathrm{T_1}+\mathrm{T_2})}{2} - \mathrm{T_0}\right] \ldots (1)$$

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

$$\frac{\mathrm{mc}}{\mathrm{K}} = \frac{\left[\frac{(80+50)}{2} - 20\right]}{\left[\frac{(80-50)}{5}\right]} = \frac{45}{6}$$

Substituting T1 = 60 and T2 = 30 and T0 = 20 (all in °C) in Eq. (1), we get

$$\mathrm{mc}\frac{(60-30)}{\mathrm{t}} = \mathrm{K}\left[\frac{(60-30)}{2} - 20\right]$$

$$\frac{30\mathrm{mc}}{\mathrm{t}} = 25\mathrm{K}$$

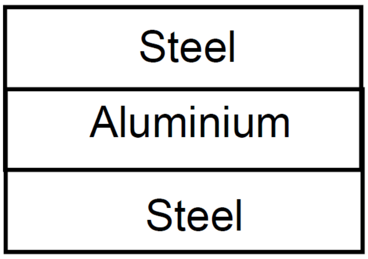
$$\mathrm{t} = \frac{30\mathrm{mc}}{(25\mathrm{K})}$$

$$= \left(\frac{30}{25}\right) \times \left(\frac{45}{6}\right)$$

= 9min

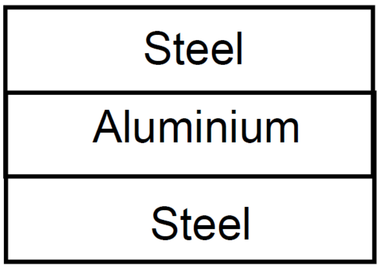
The body takes 9 min to cool from 60°C to 30°C.

65. Two steel rods and an aluminium rod of equal length l_0 and equal cross section are joined rigidly at their ends as shown in the figure below. All the rods are in a state of zero tension at 0°C. Find the length of the system when the temperature is raised to θ. Coefficient of linear expanaion of aluminium and steel are α_{a} and α_{s} respectively.



Young's modulus of aluminium is Y_a and of steel is Y_s.

Ans. :



Let the final length of the system at system of temp. $0^{\circ}\mathrm{C} = \ell_0$

Initial length of the system $= \ell_0$

When temp. changes by θ.

Strain of the system $= \ell_1 - \frac{\ell_0}{\ell_\theta}$

But the total strain of the system $\frac{\text{total stress of system}}{\text{total young's modulus of system}}$

Now, total stress = Stress due to two steel rod + Stress due to Aluminium

$= \gamma_s \alpha_s \theta + \gamma_s \text{ ds } \theta + \gamma_{al} \text{ at } \theta = 2\% \ \alpha_s \ \theta + \gamma 2 A \ell \theta$

Now young' modulus of system $= \gamma_s + \gamma_s + \gamma_{al} = 2\gamma_s + \gamma_{al}$

$\therefore$ Strain of system $= \frac{2\gamma_s \alpha_s \theta + \gamma_s \alpha_{al} \theta}{2\gamma_s + \gamma_{al}}$

$\Rightarrow \frac{\ell_\theta - \ell_0}{\ell_0}$

$= \frac{2\gamma_s \alpha_s \theta + \gamma_s \alpha_{al} \theta}{2\gamma_s + \gamma_{al}}$

$\Rightarrow \ell_\theta = \ell_0 \left[\frac{1 + \alpha_{al} \gamma_{al} + 2\alpha_s \gamma_s \theta}{\gamma_{al} + 2\gamma_s} \right]$

66. A pendulum clock gives correct time at 20˚C at a place where g = 9.800m s^{-2}. The pendulum consists of a light steel rod connected to a heavy ball. It is taken to a different place where g = 9.788m s^{-2}. At what temperature will it give correct time ? Coefficient of linear expansion of steel = 12 × 10^{-6} °C^{-1}.

Ans. : $g_1 = 9.8 \text{m/s}^2$,

$T_1 = 2\pi \frac{\sqrt{l_1}}{g_1}$

$g_2 = 9.788 \text{m/s}^2$

$T_2 = 2\pi \frac{\sqrt{l_1}}{g_2} = 2\pi \frac{\sqrt{l_1(1+\Delta T)}}{g}$

$\alpha_{steel} = 12 \times 10^{-6} /^\circ C$

$T_1 = 20^\circ C$

$T_2 = ?$

$T_1 = T_2$

$\Rightarrow 2\pi \frac{\sqrt{l_1}}{g_1}$

$= 2\pi \frac{\sqrt{l_1(1+\Delta T)}}{g_2}$

$\Rightarrow \frac{l_1}{g_1} = \frac{l_1(1+\Delta T)}{g_2}$

$\Rightarrow \frac{1}{9.8} = \frac{1 + 12 \times 10^{-6} \times \Delta T}{9.788}$

$\Rightarrow \frac{9.788}{9.8} = 1 + 12 \times 10^{-6} \times \Delta T$

$\Rightarrow \frac{9.788}{9.8} - 1 = 12 \times 10^{-6} \times \Delta T$

$\Rightarrow \Delta T = \frac{-0.00122}{12 \times 10^{-6}}$

$\Rightarrow T_2 - 20 = -101.6$

$\Rightarrow T_2 = -101.6 + 20 = -81.6 \approx -82^\circ C$

67. A resistance thermometer reads R = 20.0Ω, 27.5Ω, and 50.0Ω at the ice point (0˚C), the steam point (100˚C) and the zinc point (420˚C) respectively. Assuming that the resistance varies with temperature as $R_\theta = R_0(1 + \alpha\theta + \beta\theta^2)$, find the values of R_0, α and β. Here θ represents the temperature on Celsius scale.

Ans. : R at ice point $(R_0) = 20\Omega$

R at steam point $(R_{100}) = 27.5\Omega$

R at Zinc point $\left(\mathrm{R}_{420}\right)=50 \Omega$

$\mathrm{R}_\theta=\mathrm{R}_0\left(1+\alpha \theta+\beta \theta^2\right)$

$\Rightarrow \mathrm{R}_{100}=\mathrm{R}_0+\mathrm{R}_0 \alpha \theta+\mathrm{R}_0 \beta \theta^2$

$\Rightarrow \frac{\mathrm{R}_{100}-\mathrm{R}_0}{\mathrm{R}_0}=\alpha \theta+\beta \theta^2$

$\Rightarrow \frac{27.5-20}{20}=\alpha \times 100+\beta \times 10000$

$\Rightarrow \frac{7.5}{20}=100 \alpha+10000 \beta$

$\mathrm{R}_{420}=\mathrm{R}_0\left(1+\alpha \theta+\beta \theta^2\right)$

$\Rightarrow \frac{50-\mathrm{R}_0}{\mathrm{R}_0}=\alpha \theta+\beta \theta^2$

$\Rightarrow \frac{50-20}{20}=420 \times \alpha+176400 \times \beta$

$\Rightarrow \frac{3}{2}=420 \alpha+176400 \beta$

$\Rightarrow \frac{7.5}{20}=100 \alpha+10000 \beta$

$\Rightarrow \frac{3}{2}=420 \alpha+176400 \beta$

Solving (i) and (ii), we get

$\alpha=3.8 \times 10^{-3 \circ} \mathrm{C}^{-1}$

$\beta=-5.6 \times 10^{-7 \circ} \mathrm{C}^{-1}$

Therefore, resistance R_0 is 20Ω and the value of α is $3.8 \times 10^{-3 \circ} \mathrm{C}^{-1}$ and that of β is $-5.6 \times 10^{-7 \circ} \mathrm{C}^{-1}$

68. The volume of a glass vessel is 1000 cc at 20 °C. What volume of mercury should be poured into it at this temperature so that the volume of the remaining space does not change with temperature? Coefficients of cubical expansion of mercury and glass are 1.8×10^{-4} °C and $9{\cdot}0 \times 10^{-6}$ °C^{-1} respectively.

Ans. : $\mathrm{V}_{\mathrm{g}}=1000 \mathrm{~CC}$,

$\mathrm{V}_{\mathrm{Hg}}=?$

$\mathrm{T}_1=20^{\circ} \mathrm{C}$

$\gamma_{\mathrm{Hg}}=1.8 \times 10^{-4}\ /{ }^{\circ} \mathrm{C}$

$\gamma_{\mathrm{g}}=9 \times 10^{-6}\ /{ }^{\circ} \mathrm{C}$

$\Delta \mathrm{T}$ remains constant

Volume of remaining space $=\mathrm{V}^{\prime} \mathrm{g}-\mathrm{V}_{\mathrm{Hg}}^{\prime}$

Now

$\mathrm{V}_{\mathrm{g}}^{\prime}=\mathrm{V}_{\mathrm{g}}\left(1+\gamma_{\mathrm{g}} \Delta \mathrm{T}\right) \ldots(1)$

$\mathrm{V}_{\mathrm{Hg}}^{\prime}=\mathrm{V}_{\mathrm{Hg}}\left(1+\gamma_{\mathrm{Hg}} \Delta \mathrm{T}\right) \ldots(2)$

Subtracting (2) from (1)

$\mathrm{V}_{\mathrm{g}}^{\prime}-\mathrm{V}_{\mathrm{Hg}}$

$=\mathrm{V}_{\mathrm{g}}-\mathrm{V}_{\mathrm{Hg}}+\mathrm{V}_{\mathrm{g} \gamma \mathrm{g}} \Delta \mathrm{T}-\mathrm{V}_{\mathrm{Hg} \gamma \mathrm{Hg}} \Delta \mathrm{T}$

$\Rightarrow \frac{\mathrm{V}_{\mathrm{g}}}{\mathrm{v}_{\mathrm{Hg}}}=\frac{\gamma_{\mathrm{Hg}}}{\gamma_{\mathrm{g}}}$

$\Rightarrow \frac{1000}{V_g} = \frac{1.8\times10^{-4}}{9\times10^{-6}}$

$\Rightarrow V_{Hg} = \frac{9\times10^{-3}}{1.8\times10^{-4}}$

$= 500\ CC$

69. A glass window is to be fit in an aluminium frame. The temperature on the working day is 40°C and the glass window measures exactly 20cm × 30cm. What should be the size of the aluminium frame so that there is no stress on the glass in winter even if the temperature drops to 0°C ? Coefficients of linear expansion for glass and aluminium are $9.0 \times 10^{-6}\ {}^\circ C^{-1}$ and $24 \times 10^{-6}\ {}^\circ C^{-1}$ respectively.

Ans. : The final length of aluminium should be equal to final length of glass.

Let the initial length o faluminium = l

$l(1 - \alpha_{Al}\Delta T) = 20(1 - \alpha_0 \Delta\theta)$

$\Rightarrow l(1 - 24 \times 10^{-6} \times 40)$

$= 20(1 - 9 \times 10^{-6} \times 40)$

$\Rightarrow l(1\text{-}0.00096) = 20(1 - 0.00036)$

$\Rightarrow l = \frac{20\times0.99964}{0.99904} = 20.012cm$

Let initial breadth of aluminium = b

$b(1 - \alpha_{Al}\Delta T) = 30(1 - \alpha_0 \Delta\theta)$

$\Rightarrow b = \frac{30\times(1-9\times10^{-6}\times40)}{(1-24\times10^{-6}\times40)}$

$= \frac{30\times0.99964}{0.99964} = 30.018cm$

70. The temperatures of equal masses of three different liquids A, B and C are 12°C, 19°C and 28°C respectively. The temperature when A and B are mixed is 16°C, and when B and C are mixed, it is 23°C. What will be the temperature when A and C are mixed?

Ans. : Given,

Temperature of A = 12°C

Temperature of B = 19°C

Temperature of C = 28°C

Temperature of mixture of A and B = 16°C

Temperature of mixture of B and C = 23°C

Let the mass of the mixtures be M and the specific heat capacities of the liquids A, B and C be C_A, C_B, and C_C, respectively.

According to the principle of calorimetry, when A and B are mixed, we get

Heat gained by Liquid A = Heat lost by liquid B

$\Rightarrow MC_A(16 - 12) = MC_B(19 - 16)$

$\Rightarrow 4MC_A = 3MC_B$

$\Rightarrow MC_A = \left(\frac{3}{4}\right)MC_B \ \ldots(1)$

When B and C are mixed,

Heat gained by liquid B = Heat lost by liquid C

$\Rightarrow MC_B(23 - 19) = MC_C(28 - 23)$

$\Rightarrow 4MC_B = 5MC_C$

$\Rightarrow \mathrm{MC_C} = \left(\frac{4}{5}\right)\mathrm{MC_B}\ \ldots(2)$

When A and C are mixed,

Let the temperature of the mixture be T. Then,

Heat gained by liquid A = Heat lost by liquid C

$\Rightarrow MC_A$ (T - 12) = MC_C (28 - T)

Using the values of MC_A and MC_C, we get

From eqs. (1) and (2),

$\Rightarrow \left(\frac{3}{4}\right)\mathrm{MC_B}(\mathrm{T}-12) = \left(\frac{4}{5}\right)\mathrm{MC_B}(28-\mathrm{T})$

$\Rightarrow \left(\frac{3}{4}\right)(\mathrm{T}-12) = \left(\frac{4}{5}\right)(28-\mathrm{T})$

$\Rightarrow (3\times5)(\mathrm{T}-12) = (4\times4)(28-\mathrm{T})$

$\Rightarrow 15\mathrm{T} - 180 = 448 - 16\mathrm{T}$

$\Rightarrow 31\mathrm{T} = 628$

$\Rightarrow \mathrm{T} = \frac{628}{31} = 20.253^\circ\mathrm{C}$

$\Rightarrow \mathrm{T} = 20.3^\circ\mathrm{C}$

71. An aluminium vessel of mass 0.5kg contains 0.2kg of water at 20°C. A block of iron of mass 0.2kg at 100°C is gently put into the water. Find the equilibrium temperature of the mixture. Specific heat capacities of aluminium, iron and water are 910$\mathrm{Jkg^{-1}\text{-}K^{-1}}$, 470$\mathrm{Jkg^{-1}\text{-}K^{-1}}$ and 4200$\mathrm{Jkg^{-1}\text{-}K^{-1}}$ respectively.

Ans. : Given,

Mass of aluminium = 0.5kg

Mass of water = 0.2kg

Mass of iron = 0.2kg

Specific heat of aluminium = 910$\mathrm{Jkg^{-1}\text{-}K^{-1}}$

Specific heat of iron = 470$\mathrm{Jkg^{-1}\ K^{-1}}$

Specific heat of water = 4200$\mathrm{J\ kg^{-1}\ K^{-1}}$

Let the equilibrium temperature of the mixture be T.

Temperature of aluminium and water = 20°C = 273 + 20 = 293K

Temperature of iron = 100°C = 273 + 100 = 373K

Heat lost by iron, H_1 = 0.2 × 470 × (373 - T)

Heat gained by water = 0.2 × 4200 × (T - 293)

Heat gained by iron = 0.5 × 910 × (T - 293)

Total heat gained by water and iron, H_2 = 0.5 × 910 (T - 293) + 0.2 × 4200 × (T - 293)

H_2 = (T - 293) [0.5 × 910 + 0.2 × 4200]

We know,

Heat gain = Heat lost

$\Rightarrow$ (T - 293)[0.5 × 910 + 0.2 × 4200] = 0.2 × 470 × (373 - T)

$\Rightarrow$ (T - 293)(455 + 840) = 94(373 - T)

$\Rightarrow (\mathrm{T}-293)\frac{1295}{94} = (373-\mathrm{T})$

⇒ (T - 293) × 14 = (373 - T)

⇒ 14T - 293 × 14 = 373 - T

⇒ 15T = 373 + 4102 = 4475

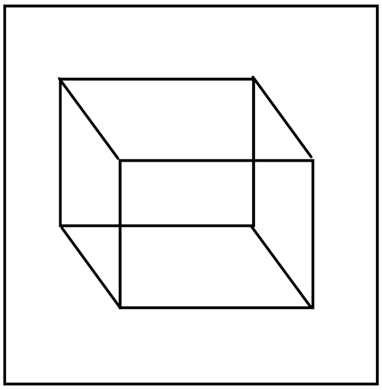
$\Rightarrow \mathrm{T} = \frac{4475}{15} = 298.33\mathrm{K} \approx 298\mathrm{K}$

∴ T = (298 - 273)°C = 25°C

∴ Final temperature = 25°C

72. A cubical block of mass 1.0kg and edge 5.0cm is heated to 227˚C. It is kept in an evacuated chamber maintained at 27˚C. Assuming that the block emits radiation like a blackbody, find the rate at which the temperature of the block will decrease. Specific heat capacity of the material of the block is 400Jkg^{-1}K^{-1}.

Ans. :



Since the Cube can be assumed as black body

$\mathrm{e} = \ell$

$\sigma = 6 \times 10^{-8} \mathrm{w/m^2\text{-}k^4}$

$\mathrm{A} = 6 \times 25 \times 10^{-4} \mathrm{m}^2$

$\mathrm{m} = 1\mathrm{kg}$

$\mathrm{s} = 400\mathrm{J/kg\text{-}^\circ K}$

$\mathrm{T_1} = 227^\circ\mathrm{C} = 500\mathrm{K}$

$\mathrm{T_2} = 27^\circ\mathrm{C} = 300\mathrm{K}$

$\Rightarrow \mathrm{ms}\frac{\mathrm{d}\theta}{\mathrm{dt}} = \mathrm{e}\sigma\mathrm{A}\left(\mathrm{T_1^4} - \mathrm{T_2^4}\right)$

$\Rightarrow \frac{\mathrm{d}\theta}{\mathrm{dt}} = \frac{\mathrm{e}\sigma\mathrm{A}\left(\mathrm{T_1^4} - \mathrm{T_2^4}\right)}{\mathrm{ms}}$

$= \frac{1 \times 6 \times 10^{-8} \times 6 \times 25 \times 10^{-4} \times \left[(500)^4 - (300)^4\right]}{1 \times 400}$

$= \frac{36 \times 25 \times 544}{}400 \times 10^{-4}$

$= 0.1224^\circ\mathrm{C/s} \approx 0.12^\circ\mathrm{C/s}.$

73. Two bodies of masses m_1 and m_2 and specific heat capacities s_1 and s_2 are connected by a rod of length l, cross-sectional area A, thermal conductivity K and negligible heat capacity. The whole system is thermally insulated. At time t = 0, the temperature of the first body is T_1 and the temperature of the second body is T_2 ($T_2 > T_1$). Find the temperature difference between the two bodies at time t.

Ans. : $\frac{\mathrm{Q}}{\mathrm{t}} = \frac{\mathrm{KA(T_1 - T_2)}}{\mathrm{L}}$

Rise in Temp. in $T_2 \Rightarrow \frac{KA(T_1 - T_2)}{Lm_1 s_1}$ Fall in Temp in $T_1 \Rightarrow \frac{KA(T_1 - T_2)}{Lm_2 s_2}$

Final Temp. $T_1 = T_1 - \frac{KA(T_1 - T_2)}{Lm_1 s_1}$ Final Temp. $T_2 = T_2 + \frac{KA(T_1 - T_2)}{Lm_1 s_1}$

$$\Rightarrow \frac{\triangle T}{dt} = T_1 - \frac{KA(T_1 - T_2)}{Lm_1 s_1} - T_2 - \frac{KA(T_1 - T_2)}{Lm_2 s_2}$$

$$= (T_1 - T_2) - \left[\frac{KA(T_1 - T_2)}{Lm_1 s_1} + \frac{KA(T_1 - T_2)}{Lm_2 s_2}\right]$$

$$\Rightarrow \frac{dT}{dt} = \frac{KA(T_1 - T_2)}{L}\left(\frac{1}{m_1 s_1} + \frac{1}{m_2 s_2}\right)$$

$$\Rightarrow \frac{dT}{(T_1 - T_2)} = \frac{KA}{L}\left(\frac{m_2 s_2 + m_1 s_2}{m_1 s_1 m_2 s_2}\right)dt$$

$$\Rightarrow \ln\triangle t = -\frac{KA}{L}\left(\frac{m_2 s_2 + m_1 s_2}{m_1 s_1 m_2 s_2}\right)t + C$$

At time $t = 0,\ T = T_0,\ \triangle T = \triangle T_0 \Rightarrow C = \ln\triangle T_0$

$$\Rightarrow \ln\frac{\triangle T}{\triangle T_0} = -\frac{KA}{L}\left(\frac{m_2 s_2 + m_1 s_2}{m_1 s_1 m_2 s_2}\right)t$$

$$\Rightarrow \frac{\triangle T}{\triangle T_0} = e^{\frac{KA}{L}\left(\frac{m_2 s_2 + m_1 s_2}{m_1 s_1 m_2 s_2}\right)t}$$

$$\Rightarrow \triangle T = \triangle T_0 e^{\frac{KA}{L}\left(\frac{m_2 s_2 + m_1 s_2}{m_1 s_1 m_2 s_2}\right)t}$$

$$= (T_2 - T_1)e^{\frac{KA}{L}\left(\frac{m_2 s_2 + m_1 s_2}{m_1 s_1 m_2 s_2}\right)t}$$

74. Why does blowing over a spoonful of hot tea cools it? Does evaporation play a role? Does radiation play a role?

Ans. : Here, major role is played by convection. When we blow air over a spoonful of hot tea, the air coming from our mouth has less temperature than the air above the tea. Since hot air has less density, it rises up and cool air goes down. In this way, the tea cools down.

We know that any hot body radiates.

So, the spoonful of tea will also radiate and as the temperature of the surrounding is less then the tea, the tea will cool down with time. Evaporation is also involved in this. On blowing over the hot tea, rate of evaporation increases and the cools down.

75. A spherical ball of surface area $20cm^2$ absorbs any radiation that falls on it. It is suspended in a closed box maintained at 57˚C.
   a. Find the amount of radiation falling on the ball per second.
   b. Find the net rate of heat flow to or from the ball at an instant when its temperature is 200˚C. Stefan constant = $6.0 \times 10^{-8} Wm^{-2}K^{-4}$.

Ans. :

a. $A = 20cm^2 = 20 \times 10^{-4} m^2$,

$T = 57^\circ C = 330K$

$E = A\sigma T^4$

$= 20 \times 10^{-4} \times 6 \times 10^{-8} \times (330)^4 \times 10^4$

$= 1.42J$

b. $\frac{E}{t} = A\sigma e\left(T_1^4 - T_2^4\right)$,

$A = 20cm^2 = 20 \times 10^{-4} m^2$

$\sigma = 6 \times 10^{-8}$,
$T_1 = 473K,\ T_2 = 330K$
$= 20 \times 10^{-4} \times 6 \times 10^{-8} \times 1\left[(473)^4 - (330)^4\right]$
$= 20 \times 6 \times \left[5.005 \times 10^{-10} - 1.185 \times 10^{10}\right]$
$= 20 \times 6 \times 3.82 \times 10^{-2}$
$= 4.58w$ From the ball.

76. A body cools down from 50°C to 45°C in 5 minutes and to 40°C in another 8 minutes. Find the temperature of the surrounding.

Ans. : $50^\circ C,\ 45^\circ C,\ 40^\circ C$

Let the surrounding temperature be 'T'°C

Avg. $t = \frac{50+45}{2} = 47.5$

Avg. temp. diff. from surrounding $T = 47.5 - T$

Rate of fall of temp $= \frac{50-45}{5} = 1^\circ C/mm$

From Newton's Law $1^\circ C/mm = bA \times t$

$\Rightarrow bA = \frac{1}{t}$

$= \frac{1}{47.5-T}\ \ldots(1)$

In second case,

Avg, temp $= \frac{40+45}{2} = 42.5$

Avg. temp. diff. from surrounding $t' = 42.5 - t$

Rate of fall of temp $= \frac{45-40}{8} = \frac{5}{8}\ ^\circ C/mm$

From Newton's Law $\frac{5}{B} = bAt'$

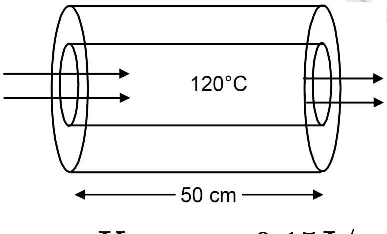
$\Rightarrow \frac{5}{8} = \frac{1}{(47.5-T)} \times (42.5 - T)$

By C & D [Componendo & Dividendo method]

We find, $T = 34.1^\circ C$

77. Steam at 120°C is continuously passed through a 50cm long rubber tube of inner and outer radii 1.0cm and 1.2cm. The room temperature is 30°C. Calculate the rate of heat flow through the walls of the tube. Thermal conductivity of rubber = 0.15Js^{-1}m^{-1}°C^{-1}.

Ans. :



Given, $K_{rubber} = 0.15 J/m\text{-}s\text{-}^\circ C,\ T_2 - T_1 = 90^\circ C$

We know for radial conduction in a Cylinder

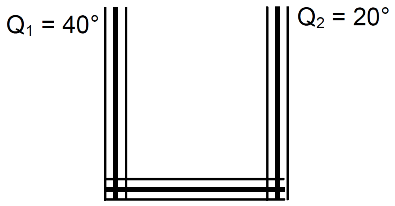
$$\frac{Q}{t} = \frac{2\pi Kl(T_2 - T_1)}{\ln\left(\frac{R_2}{R_1}\right)}$$

$= \frac{2 \times 3.14 \times 15 \times 10^{-2} \times 50 \times 10^{-1} \times 90}{\ln\left(\frac{1.2}{1}\right)}$

$= 232.5 \approx 233 \mathrm{J/s}.$

78. A steel frame $(\mathrm{K} = 45 \mathrm{Wm}^{-1\circ}\mathrm{C}^{-1})$ of total length 60cm and cross sectional area $0.20\mathrm{cm}^2$, forms three sides of a square. The free ends are maintained at 20˚C and 40˚C. Find the rate of heat flow through a cross section of the frame.

Ans. :



$\mathrm{K} = 45 \mathrm{w/m\text{-}^\circ C}$

$\ell = 60\mathrm{cm} = 60 \times 10^{-2}\mathrm{m}$

$\mathrm{A} = 0.2\mathrm{cm}^2 = 0.2 \times 10^{-4}\mathrm{m}^2$

Rate of heat flow,

$= \frac{\mathrm{KA}(\theta_1 - \theta_2)}{\ell}$

$= \frac{45 \times 0.2 \times 10^{-4} \times 20}{60 \times 10^{-2}}$

$= 30 \times 10^{-3} = 0.03\mathrm{w}$

79. A calorimeter contains 50g of water at 50˚C. The temperature falls to 45˚C in 10 minutes. When the calorimeter contains 100g of water·at 50˚0, it takes 18 minutes for the temperature to become 45˚C. Find the water equivalent of the calorimeter.

Ans. : Let the water eq. of calorimeter = m

$\frac{(\mathrm{m} + 50 \times 10^{-3}) \times 4200 \times 5}{10} =$ Rate of heat flow

$\frac{(\mathrm{m} + 50 \times 10^{-3}) \times 4200 \times 5}{18} =$ Rate of flow

$\Rightarrow \frac{(\mathrm{m} + 50 \times 10^{-3}) \times 4200 \times 5}{10} = \frac{(\mathrm{m} + 50 \times 10^{-3}) \times 4200 \times 5}{18}$

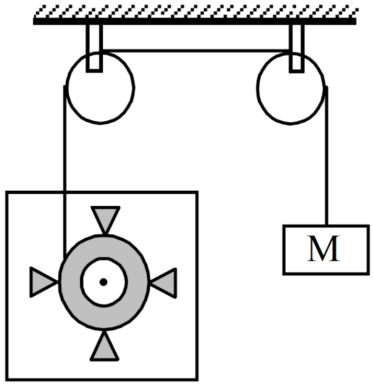
$\Rightarrow (\mathrm{m} + 50 \times 10^{-3})18 = 10\mathrm{m} + 1000 \times 10^{-3}$

$\Rightarrow 18\mathrm{m} + 18 \times 50 \times 10^{-3} = 10\mathrm{m} + 1000 \times 10^{-3}$

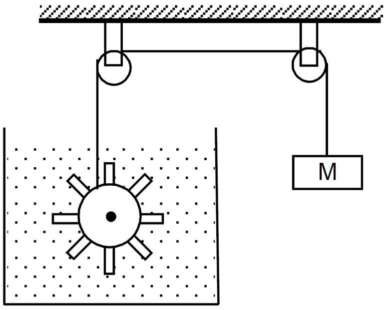
$\Rightarrow 8\mathrm{m} = 100 \times 10^{-3}\mathrm{kg}$

$\Rightarrow \mathrm{m} = 12.5 \times 10^{-3}\mathrm{kg} = 12.5\mathrm{g}$

80. Figure, shows water in a container having 2.0mm thick walls made of a material of thermal conductivity $0.50 \mathrm{Wm}^{-1\circ}\mathrm{C}^{-1}$. The container is kept in a melting-ice bath at 0˚C. The total surface area in contact with water is $0.05\mathrm{m}^2$. A wheel is clamped inside the water and is coupled to a block of mass M as shown in the figure. As the block goes down, the wheel rotates. It is found that after some time a steady state is reached in which the block goes down with a constant speed of $10\mathrm{cms}^{-1}$ and the temperature of the water remains constant at 1.0˚C. Find the mass M of the block. Assume that the heat flows out of the water only through the walls in contact. Take $g = 10\mathrm{ms}^{-2}$.



Ans. :



Given $\theta_1 = 1^\circ\mathrm{C},\ \theta_2 = 0^\circ\mathrm{C}$

$\mathrm{K} = 0.50\mathrm{w/m\text{-}^\circ C},\ \mathrm{d} = 2\mathrm{mm} = 2 \times 10^{-3}\mathrm{m}$

$\mathrm{A} = 5 \times 10^{-2}\mathrm{m}^2,\ \mathrm{v} = 10\mathrm{cm/s} = 0.1\mathrm{m/s}$

Power = Force × Velocity = Mg × v

Again Power $= \frac{\mathrm{dQ}}{\mathrm{dt}} = \frac{\mathrm{KA}(\theta_1 - \theta_2)}{\mathrm{d}}$

So, Mgv $= \frac{\mathrm{KA}(\theta_1 - \theta_2)}{\mathrm{d}}$

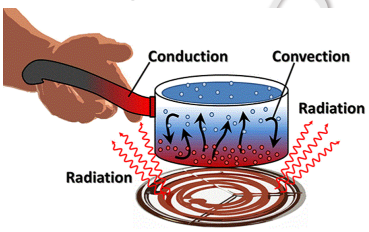
$\Rightarrow \mathrm{M} = \frac{\mathrm{KA}(\theta_1 - \theta_2)}{\mathrm{dvg}}$

$= \frac{5 \times 10^{-1} \times 5 \times^{-2} \times 1}{2 \times 10^{-3} \times 10^{-1} \times 10}$

$= 12.5\mathrm{kg}.$

* Case study based questions [32]

81. Read the passage given below and answer the following questions from (i) to (v). The figure shows the different modes of transfer of heat, heat transfer is defined as the movement of heat across the border of the system due to a difference in temperature between the system and its surroundings. The temperature difference exists between the two systems, heat will find a way to transfer from the higher to the lower system.



i. The sea breeze is caused by:
   a. conduction
   b. convection

c. radiation
d. none of these

ii. At what factor heat absorbed on radiation by the body depends on?
   a. distance between body
   b. source of heat
   c. its color
   d. all of the above

iii. When heat is transferred by molecular collision, it is referred to as heat transfer by:
   a. convection
   b. conduction
   c. radiation
   d. convection and radiation

iv. Thermal conductivity of air with rise in temperature:
   a. increase
   b. decrease
   c. constant
   d. none of these

v. Mass transfer does not take place in:
   a. conduction
   b. convection
   c. radiation
   d. none of these

Ans. :

i. (b) convection
ii. (d) all of the above
iii. (a) convection
iv. (a) increase
v. (c) radiation

82. Why do marine animals live deep inside a lake when the surface of the lake freezes?

Ans. : Water possesses an anomalous behaviour. The volume of a given amount of water decreases as it is cooled from room temperature, until its temperature reaches 4°C. Below 4°C, the volume increases, and therefore the density decreases.

When the temperature of the surface of lake falls in winter, the water at the surface becomes denser and sinks. As, the temperature reaches below 4°C, the density of the water at surface becomes less. Thus, it remains at surface and freezes. As, the ice is a bad conductor of heat, it traps the heat present in the lake's water beneath itself. Hence, no further cooling of water takes place once the top layer of the lake is completely covered by ice. Thus the life of the marine animals inside the lake is possible.

83. If an automobile engine is overheated, it is cooled by putting water on it. It is advised that the water should be put slowly with engine running. Explain the reason.

Ans. : In a hot engine the hot parts are expanded because of heat, if cold water is poured suddenly then there will be uneven thermal contraction in the parts. This will result in a stress to develop between the various parts of the engine and may let the engine to crack down.

84. Indian style of cooling drinking water is to keep it in a pitcher having porous walls. Water comes to the outer surface very slowly and evaporates. Most of energy needed for evaporation is taken from the water itself and the water is cooled down. Assume that a pitcher contains 10kg of water and 0.2g of water comes out per second. Assuming no backward heat transfer from the atmosphere to the water, calculate the time in which the temperature decrease by 5°C. Specific heat capacity of water = 4200J kg^{-1}°C^{-1} and latent heat of vaporization of water = 2.27×10^6 J kg^{-1}.

Ans. : Given,

Specific heat of water, S = 4200J kg^{-1} °C^{-1}

Latent heat of vapourisation of water, L = 2.27×10^6 J kg^{-1}

Mass, M = 0.2g = 0.0002kg

Let us first calculate the amount of energy required to decrease the temperature of 10kg of water by 5°C.

$U_1 = 10 \times 4200$J/kg° C × 5°C

$U_1 = 210{,}000 = 21 \times 10^4$ J

Let the time in which the temperature is decreased by 5°C be t.

Energy required per second for evaporation of water (at the rate of 0.2g/sec) is given by

$U_2 = ML$

$U_2 = (2 \times 10^{-4}) \times (2.27 \times 10^6) = 454$J

Total energy required to decrease the temperature of the water = 454 × t

= 21×10^4 J

Now,

$\mathrm{t} = \frac{21 \times 10^4}{454}$ seconds

The time taken in minutes is given by,

$\mathrm{t} = \frac{21 \times 10^4}{454 \times 60} = 7.7\ \mathrm{minute/s}$

∴ The time required to decrease the temperature by 5°C is 7.7 minutes.

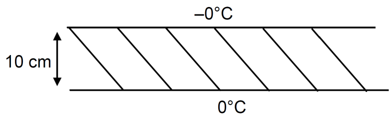
85. On a winter day when the atmospheric temperature drops to -10˚C, ice forms on the surface of a lake.

a. Calculate the rate of increase of thickness of the ice when 10cm of ice is already formed.

b. Calculate the total time taken in forming 10cm of ice. Assume that the temperature of the entire water reaches 0˚C before the ice starts forming. Density of water = 1000kgm^{-3}, latent heat of fusion of ice $= 3.36 \times 10^5 \mathrm{Jkg^{-1}}$ and thermal conductivity of ice $= 1.7 \mathrm{Wm^{-1\circ}C^{-1}}$. Neglect the expansion of water on freezing.

Ans. : $\mathrm{K} = 1.7 \mathrm{W/m\text{-}^\circ C},\ \mathrm{f_w} = 1000 \mathrm{Kg/m^3}$

$\mathrm{L_{ice}} = 3.36 \times 10^5 \mathrm{J/kg},\ \mathrm{T} = 10\mathrm{cm} \times 10^{-2}\mathrm{m}$



a. $\frac{Q}{t} = \frac{KA(\theta_1 - \theta_2)}{\ell}$

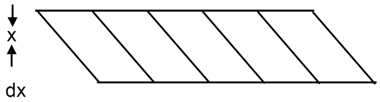
$\Rightarrow \frac{\ell}{t} = \frac{KA(\theta_1 - \theta_2)}{Q} = \frac{KA(\theta_1 - \theta_2)}{mL}$

$= \frac{KA(\theta_1 - \theta_2)}{Atf_w L} = \frac{1.7 \times \left[0 - (-10)\right]}{10 \times 10^{-2} \times 1000 \times 3.36 \times 10^5}$

$= \frac{17}{3.36} \times 10^{-7} = 5.059 \times 10^{-7}$

$= 5 \times 10^7 \mathrm{m/sec}$

b. Let us assume that x length of ice has become formed to form a small strip of ice of length dx, dt time is required.



$\frac{dQ}{dt} = \frac{KA(\triangle\theta)}{x}$

$\Rightarrow \frac{dmL}{dt} = \frac{KA(\triangle\theta)}{x}$

$\Rightarrow \frac{Adxf\omega L}{dt} = \frac{KA(\triangle\theta)}{x}$

$\Rightarrow \frac{dxf\omega L}{dt} = \frac{K(\triangle\theta)}{x}$

$\Rightarrow dt = \frac{xdxf\omega L}{K(\triangle\theta)}$

$\Rightarrow \int_0^t dt = \frac{f\omega L}{K(\triangle\theta)} \int_0^t xdx$

$\Rightarrow t = \frac{f\omega L}{K(\triangle\theta)} \left[\frac{x^2}{2}\right]_0^l = \frac{f\omega L}{K\triangle\theta} \frac{l^2}{2}$

Putting values:

$\Rightarrow t = \frac{1000 \times 3.36 \times 10^5 \times (10 \times 10^{-2})^2}{1.7 \times 10 \times 2}$

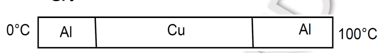
$= \frac{3.36}{2 \times 17} \times 10^6 \mathrm{sec}$

$= \frac{3.36 \times 10^6}{2 \times 17 \times 3600} \mathrm{hrs}$

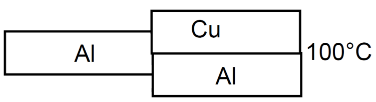
$= 27.45 \mathrm{hrs} \approx 27.5 \mathrm{hrs}.$

86. The three rods shown in figure, have identical geometrical dimensions. Heat flows from the hot end at a rate of 40 Win the arrangement (a) Find the rates of heat flow when the rods are joined as in arrangement (b) and in (c) Thermal conductivities of aluminium and copper are $200 Wm^{-1} {}^\circ C^{-1}$ and $400 Wm^{-1} {}^\circ C^{-1}$ respectively.

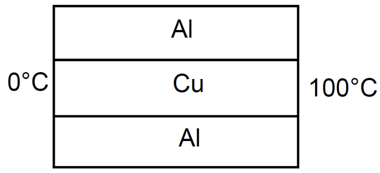
a.



b.



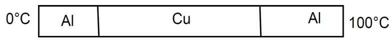
c.



Ans. : $\theta_1 - \theta_2 = 100$

$\frac{Q}{t} = \frac{\theta_1 - \theta_2}{R}$

a.



$$R = R_1 + R_2 + R3 = \frac{\ell}{aK_{Al}} + \frac{\ell}{aK_{Cu}} + \frac{\ell}{aK_{Al}}$$

$$= \frac{\ell}{a}\left(\frac{2}{200} + \frac{1}{400}\right)$$

$$= \frac{\ell}{a}\frac{1}{80}$$

$$\frac{Q}{t} = \frac{100}{\left(\frac{\ell}{a}\right)\left(\frac{1}{80}\right)}$$

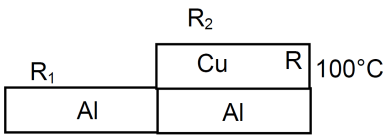
$$\Rightarrow 40 = 80 \times 100 \times \frac{a}{\ell}$$

$$\Rightarrow \frac{a}{\ell} = \frac{1}{200}$$

b. $R = R_1 + R_2 = R_1 + \frac{R_{cu}R_{Al}}{R_{Cu}+R_{Al}}$

$$= R_{Al} + \frac{R_{cu}R_{Al}}{R_{Cu}+R_{Al}}$$

$$= \frac{\frac{1}{AK_{Al}} + \frac{1}{AK_{Cu}} + \frac{1}{AK_{Al}}}{\frac{1}{A_{Cu}} + \frac{1}{A_{al}}}$$



$$= \frac{1}{AK_{Al}} + \frac{1}{A} + \frac{1}{K_{Cu}}$$

$$= \frac{1}{A}\left(\frac{1}{200} + \frac{1}{200+400}\right)$$

$$= \frac{1}{A} \times \frac{4}{600}$$

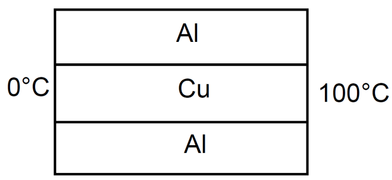
$$\frac{Q}{t} = \frac{\theta_1 - \theta_2}{R}$$

$$= \frac{100}{\left(\frac{1}{A}\right)\left(\frac{4}{600}\right)}$$

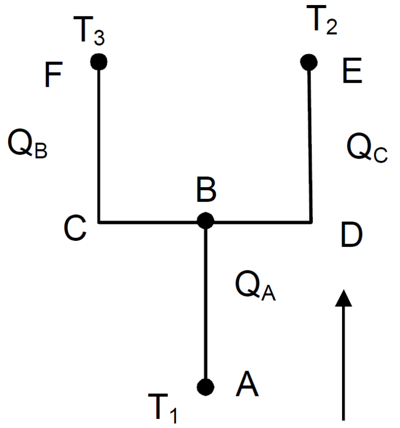
$$= \frac{100 \times 600}{4} \times \frac{1}{200}$$

$$= 75$$

c. $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{\frac{1}{aK_{Al}}} + \frac{1}{\frac{1}{aK_{Cu}}} + \frac{1}{\frac{1}{aK_{Al}}} +$

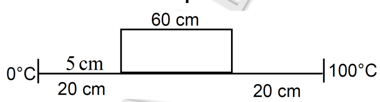


$$= \frac{a}{l}(K_{Al} + K_{Cu} + K_{Al})$$
$$= \frac{a}{l}(2 \times 200 + 400)$$
$$= \frac{a}{l}(800)$$
$$\Rightarrow R = \frac{l}{a} \times \frac{1}{800}$$



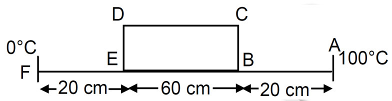
$$\Rightarrow \frac{Q}{t} = \frac{\theta_1 - \theta_2}{R}$$
$$= \frac{100 \times 800 \times a}{l}$$
$$= \frac{100 \times 800}{200}$$
$$= 400W$$

87. Consider the situation shown in figure. The frame is made of the same material and has a uniform cross-sectional area everywhere. Calculate the amount of heat flowing per second through a cross section of the bent part if the total heat taken out per second from the end at 100°C is 130J.



Ans. : $\left(\frac{Q}{t}\right)_{AB} = \left(\frac{Q}{t}\right)_{BE\ bent} + \left(\frac{Q}{t}\right)_{BE}$

$$\Rightarrow \left(\frac{Q}{t}\right)_{BE\ bent} = \frac{KA(\theta_1 - \theta_2)}{70}$$
$$\Rightarrow \left(\frac{Q}{t}\right)_{BE} = \frac{KA(\theta_1 - \theta_2)}{60}$$
$$\Rightarrow \frac{\left(\frac{Q}{t}\right)_{BE\ bent}}{\left(\frac{Q}{t}\right)_{BE}} = \frac{60}{70}$$
$$= \frac{6}{7}$$



$$\left(\frac{Q}{t}\right)_{BE\ bent} + \left(\frac{Q}{t}\right)_{BE} = 130$$
$$\Rightarrow \left(\frac{Q}{t}\right)_{BE\ bent} + \left(\frac{Q}{t}\right)_{BE} \times \frac{7}{6} = 130$$
$$\Rightarrow \left(\frac{7}{6} + 1\right)\left(\frac{Q}{t}\right)_{BE\ bent} = 130$$
$$\Rightarrow \left(\frac{Q}{t}\right)_{BE\ bent} = \frac{130 \times 6}{13}$$

$= 60$

88. Cloudy nights are warmer than the nights with clean sky. Explain.

Ans. : During night, the earth's surface radiates infrared radiation of larger wavelength. Gas molecules in the air absorb some of this energy and radiate energy of their own in all directions. Also, water molecules, like the vapour that makes the clouds, absorb more frequencies of infrared energy than clear air does.

Both these factors contribute to the fact that clouds radiate more heat in all directions (including the earth) than clear air does. In turn, this makes the overall temperature on the earth warmer when there is a cloud cover. The heat energy radiated by the earth is reflected back to earth. Due to this, cloudy nights are warmer than the nights with clean sky.

----- जब हौसला बना लिया ऊंची उड़ान का,फिर देखना फिजूल है कद आसमान का। -----