SOLVED EXAMPLES

Example 1. 10 g of ice at 0°C is added in 40 g of water at 15ºC. The temperature of the mixture is

(1) 0 (2) 3ºC (3) 12ºC (4) 8ºC

solution : As the temperature of ice is at 0°C (Melting point) So,

Total Heat required to melt the ice = mL = 10 × 80 = 800 cal.

Maximum heat which can be supplied by hot water

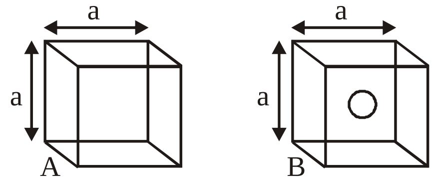
$= mc_w\Delta T = 40 \times 1 \times 15 = 600$ cal.

As heat supplied < heat required to melt ice,

$\therefore$ Temperature of mixture the will be 0ºC

(as whole of the ice will not melt), So answer is (1)

Example 2. A and B are made up of an isotropic medium. Both A and B are of equal volume.Body B has cavity as shown in figure. Which of the following statement is true



(a) (b)

(1) Expansion in volume of A > expansion in B

(2) Expansion in volume of B > expansion in A

(3) Expansion in A = expansion in B

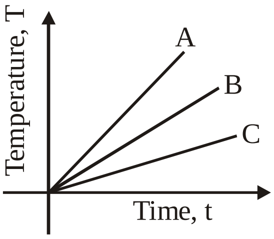
(4) None of these

Solution : Answer will be (3) as cavity also expands at same rate as the surrounding substance. Thermal expansion of isotropic bodies is independent of shape, size and availability of hole/cavity.

Example 3. Which of the substances A, B or C has the highest specific heat ? The temperature vs time graph is shown.

(1) A (2) B

(3) C (4) All have equal specific heat.



Solution : Substances having more specific heat take longer time to get heated to a higher temperature and longer time to get cooled. So, Answer will be (3)

Example 4.

A block of ice at –10ºC is slowly heated and converted to steam at 100ºC. Which of the following curves represents the phenomenon qualitatively ?

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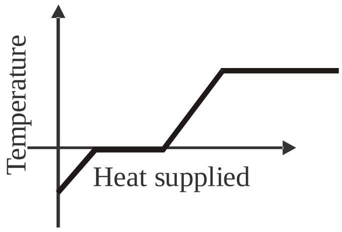
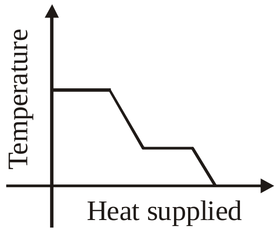


(2)


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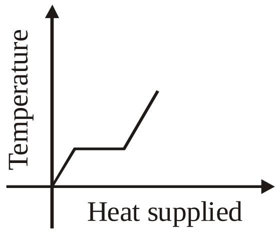

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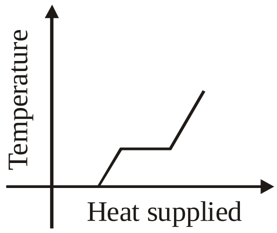


Solution :

Initially, on heating temperature rises from –10ºC to 0ºC. Then ice melts and temperature does not rise. when whole ice melts, temperature begins to rise until it teaches 100ºC. Then it becomes constant. At boiling point temperature will not rise until 100°C. So, answer is (1)

Example 5.

2 kg of ice at –20ºC is mixed with 5 kg of H_2O at 20ºC in an insulating vessel having negligible heat capacity. Calculate the final mass of water left in the container. Given specific heats of water and ice are 1 kcal kg^{-1}ºC^{-1} and 0.5 kcal kg^{-1}ºC^{-1} and latent heat of fusion of ice is 80 k cal kg^{-1}.

(1) 7 kg (2) 6 kg (3) 4 kg (4) 2 kg.

Solution :

Heat required to melt all ice.

$= m_{ice}c_{ice}\Delta T + m_{ice}L = 2 \times 0.5 \times 20 + 2 \times 80 = 180$ kcal

Maximum heat available from water = $m_w c_w \Delta T$ = 5 × 1 × 20 = 100 kcal

$\because$ 100 kcal < 180 kcal, So, all ice will not melt. Let x kg ice will melt then,

Heat gain = Heat loss

$x \times L + m_{ice} \times 0.5 \times 20 = 100$

$xL + 20 = 100$

$x = 1$kg

Hence, total amount of water = 5 kg + 1 kg = 6 kg

So, the correct option is (2)

Example 6.

A bimetallic strip is formed out of two identical strips, one of Cu and the other of brass. The coefficients of linear expansion of two metals are α_c and α_B. If on heating the temperature of the strip goes up by ΔT .and the strip bends to from an arc of radius R. Then R is

(1) Proportional to ΔT

(2) Inversely proportional to ΔT

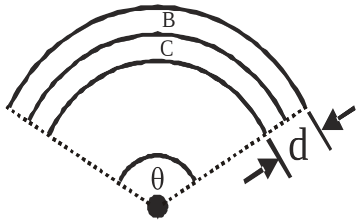
(3) Proportional to $|\alpha_B - \alpha_C|$

(4) Inversely proportional to $|\alpha_B - \alpha_C|$

Solution :

$\ell_B = \ell_0(1+\alpha_B\Delta T)$; $\ell_C = \ell_0(1+\alpha_C\Delta T)$

$\ell_C = R\theta$; $\ell_B = (R+d)\theta$



Thus $\frac{R+d}{R} = \frac{1+\alpha_B\Delta T}{1+\alpha_C\Delta T} = \frac{l_B}{l_C}$

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

(using binomial theorem)

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

$\therefore$ the correct choice are (2) and (4).

Example 7.

A copper cube of mass 200 g slides down on a rough inclined plane of inclination 37º at a constant speed. Assume mechanical energy goes into the copper block as thermal energy. Find the increase in temperature of the block as it slides down through 60 cm. Specific heat capacity of copper is 420 J kg^{-1} K^{-1}.

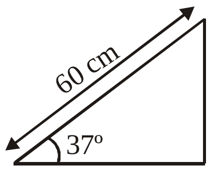
(1) 8.6×10^{-3} °C (2) 6.8×10^{-3} °C (3) 8.6×10^{3} °C (4) 6.8×10^{3} °C

Solution :

E = mgh = 0.2 × 10 × (0.36) = 0.72 J

E = $mc\Delta\theta$ = 0.72

$\Delta\theta = \frac{0.72}{0.2\times 420} = 8.6\times10^{-3}$°C



Hence (1) is the correct option

Example 8.

A mixture of 250 g of water and 200 g of ice at 0ºC is kept in a calorimeter which has water equivalent of 50 g. If 200 g of steam at 100ºC is passed through the mixture, calculate the final temperature and weight of content of the calorimeter. Given that specific heat of ice and water are 0.5 and 1 cal/g–ºC while latent heat 80 and 540 cal/g respectively. [Assume No heat loss from calorimeter]

(1) 100 °C, 450g (2) 50°C, 650 g

(3) 100 °C, 572.2g (4) 100°C, 650 g

Solution :

If 200 g of steam condenses, the heat released by it will be

Q_1 = 200 × 540 = 108 kcal

Now as heat required by ice and water to change into water at 100ºC.

Q_2 = 200 × 80 + (200 + 250 + 50) × 1 × (100 – 0) = 66 kcal

As $Q_2 < Q_1$, whole of steam will not condense. If m is the mass of steam condensed.

m × 540 = 66 kcal or m = 122.2 g

So, finally the system will contain :

250 + 200 + 122.2 = 572.2 g of water

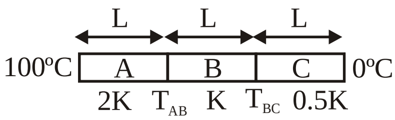
and 200 – 122.2 = 77.8 g of steam, all at 100ºC.

Hence (3) is the correct option

Example 9.

Three cylindrical rods A, B and C of equal lengths and equal diameters are joined in series as shown in figure. Their thermal conductivities are 2K, K and 0.5 K respectively. In steady state, if the free ends of rods A and C are at 100ºC and 0ºC respectively. What will be the equivalent thermal conductivity?

(1) $\frac{6}{7}K$ (2) $\frac{7}{6}K$ (3) $\frac{7}{2}K$ (4) $\frac{2}{7}K$



Solution :

$$K_{eq} = \frac{L_1 + L_2 + L_3}{\left(\frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3}\right)} = \frac{6}{7}K$$

Hence (1) is the correct option.

Example 10.

A 50 gm lead bullet (specific heat 0.02) is initially at 30ºC. It is fired vertically upwards with a speed to 840 m/s. On returning to the starting level it strikes a cake of ice of 0ºC. How much ice is melted nearly ? Assume that all energy is spent in melting only. Latent heat of ice = 80 cal/gm.

(1) 51g (2) 40g (3) 60g (4) 25g

Solution :

On returning to the starting level, the bullet will have the same velocity with which it was projected upwards. The bullet will therefore strike the cake of ice with a velocity of 840 m/s. On striking, the kinetic energy of the bullet is converted into heat. Thus the heat produced is given by

$$Q_1 = \frac{1}{2}mv^2 = \frac{1}{2}\times(50\times10^{-3}\,kg)\times(840\,m/s)^2 = 17640\,J = 4200\,cal$$

The heat given by the bullet in cooling upto the temperature of ice (= 0ºC) is

$$Q_2 = mc\Delta T = 50gm \times 0.02\frac{cal}{gm°C}\times 30°C = 30\ cal$$

Hence total heat given to the ice is $Q = Q_1 + Q_2 = 4200 + 30 = 4230$ cal

If M gm be the mass of ice melted, then ML = Q = 4230

or $M = \frac{4230}{L} = \frac{4230}{80} = 50.875\ gm$.

Hence (1) is the correct option

Example 11.

Estimate the temperature of the surface of the sun from the following data. Average radius of earth's orbit = 1.5×10^8 Km, average radius of the sun = 7.0×10^5 Km, solar radiant power on the earth at noon time = 1400 Wm^{-2}. Assume the sun to be a perfectly black body. ($\sigma = 5.67 \times 10^{-8}\ Wm^{-2}\ K^{-4}$).

(1) 2800K (2) 5802K (3) 2900K (4) 3902K

Solution :	$T = \text{Temperature of sun} = \left(\frac{S}{\sigma}\frac{R^2}{r^2}\right)^{1/4}$ $= \left(\frac{1400}{5.67\times10^{-8}}\right)^{1/4}\left(\frac{1.5\times10^{8}}{7\times10^{5}}\right)^{1/2} = 5802\text{ K}$ Hence (2) is the correction option.
Example 12.	A body cools in 7 minutes from 60°C to 40°C. The temperature after next 7 minutes will be ______. Given that the temperature of surroundings is 10°C. (1) 30°C (2) 20°C (3) 25°C (4) 28°C
Solution :	According to Newton's law of cooling $\left[\frac{\theta_1-\theta_2}{t}\right] = K\left[\left(\frac{\theta_1+\theta_2}{2}\right)-\theta_0\right]$ So that $\left[\frac{60-40}{7}\right] = K\left[\left(\frac{60+40}{2}\right)-10\right]$, i.e. $K = \frac{1}{14}$ Now if cooling from 40°C for 7 minute the temperature of the body becomes θ. according to Newton's law of cooling. $\left[\frac{40-\theta}{7}\right] = K\left[\left(\frac{40+\theta}{2}\right)-10\right]$ which in the light of Eqn. (1) i.e. K = (1/14) gives $\left[\frac{40-\theta}{7}\right] = \frac{1}{14}\left[\frac{20+\theta}{2}\right]$ i.e. $160-4\theta = 20+\theta$ or $\theta = 28^0\text{C}$ **Alternative Solution :** According to Newton's law of cooling, $-\frac{d\theta}{dt} = K(\theta-\theta_0)$ or $\int_0^t dt = \frac{1}{K}\int_{\theta_1}^{\theta_2} -\frac{d\theta}{(\theta-\theta_0)}$ or $t = \frac{1}{K}\log_e\left[\frac{\theta_1-\theta_0}{\theta_2-\theta_0}\right]$ So here $7 = \frac{1}{K}\log_e\left[\frac{60-10}{40-10}\right]$ and also $7 = \frac{1}{K}\log_e\left[\frac{40-10}{\theta-10}\right]$ $\therefore \log\left[\frac{50}{30}\right] = \log\left[\frac{30}{\theta-10}\right]$ or $\frac{5}{3} = \frac{30}{(\theta-10)}$ i.e. $5\theta-50 = 90$ or $\theta = 28^0\text{C}$ Hence (4) is the correct option.

Example 13.	Bodies A and B have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are same. The two bodies emit total radiant power at the same rate. Find the temperature of B. If the temperature of A is 5802 K. (1) 1934 K (2) 934 K (3) 2934 K (4) 5802 K
Solution :	Given $P = e_A \sigma A T_A^4 = e_B \sigma A T_B^4$ or $T_B = \left(\frac{e_A}{e_B}\right)^{1/4} T_A = \left(\frac{0.01}{0.81}\right)^{1/4} (5802)$ $T_B = \frac{5802}{3} = 1934\text{ K}$ Hence (1) is the correct option.
Example 14.	A liquid takes 5 minutes to cool from 80°C to 50°C. How much time will it take to cool from 60°C to 30°C? Temperature of the surrounding = 20°C. (1) 5 min (2) 10 min (3) 20 min (4) 15 min
Solution :	$-\frac{d\theta}{dt} = K(\theta - \theta_0)$ or $t = \frac{1}{K}\log\left[\frac{\theta_1 - \theta_0}{\theta_2 - \theta_0}\right]$ or, $t = \frac{1}{k}\log\left[\frac{60-20}{30-20}\right] = \frac{1}{k}\log 4$ $5 = \frac{1}{K}\log\left[\frac{80-20}{50-20}\right]$ or $\frac{5}{t} = \frac{\frac{1}{K}\log_e 2}{\frac{1}{K}\log 2^2}$ or t = 10 minutes Hence (2) is the correct option
Example 15.	A body cools from 50°C to 45°C in 5 min and 45°C to 40°C in another 8 min. Find the temperature of the surrounding. (1) 30°C (2) 25°C (3) 34°C (4) 43°C
Solution :	Using $t = \frac{1}{K}\log\left[\frac{\theta_1 - \theta_0}{\theta_2 - \theta_0}\right]$ $5 = \frac{1}{K}\log\left[\frac{50-\theta_0}{45-\theta_0}\right]$ also, $8 = \frac{1}{K}\log\left[\frac{45-\theta_0}{40-\theta_0}\right]$ or $\log\left\{\frac{50-\theta_0}{45-\theta_0}\right\}^{1/5} = \log\left\{\frac{45-\theta_0}{40-\theta_0}\right\}^{1/8}$ Solving for θ_0 we get $\theta_0 = 34^0\text{C}$ Hence (3) is the correct option.

b G b G b G b G b

MULTIPLE CHOICE QUESTIONS

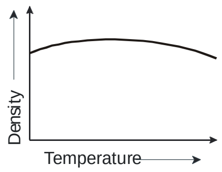
LEVEL - I

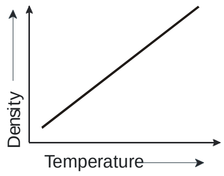
1. If 10 gram ice at –10ºC is added to 40 g of water at 15ºC, the temperature of the mixture is

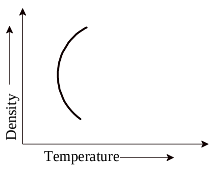
   (1) 3.75ºC (2) 0ºC

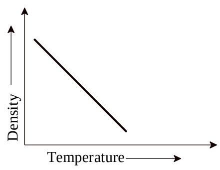
   (3) 3ºC (4) –2ºC.

2. The variation of density of water with temperature is represented by the

   (1) 

   (2) 

   (3) 

   (4) 

3. While measuring the thermal conductivity of a liquid, we keep the upper part hot and lower part cool, so that

   (1) Convection may be stopped

   (2) Radiation may be stopped

   (3) Heat conduction is easier downwards

   (4) It is easier and more convenient to do so

4. In which of the following process, convection does not take place primarily

   (1) Sea and land breeze

   (2) Boiling of water

   (3) Warming of glass of bulb due to filament

   (4) Heating air around a furnace

5. The temperature of sun is determined by

   (1) Stefan's law

   (2) Wein's displacement law

   (3) Kirchhoff's law

   (4) Ohm's law

6. If the temperature of a hot body is increased by 50% then the increase in the quantity of emitted heat radiation will be

   (1) 125% (2) 200%

   (3) 300% (4) 400%

7. A liquid cools down from 70°C to 60°C in 5 minutes. The time taken to cool it from 60°C to 50°C will be

   (1) 5 minutes

   (2) Less than 5 minutes

   (3) Greater than 5 minutes

   (4) Lesser or greater than 5 minutes depending upon the density of the liquid.

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

   (1) greater than its latent heat of fusion

   (2) greater than its latent heat of sublimation

   (3) equal to its latent heat of sublimation

   (4) less than is latent heat of fusion

9. If the emissive and absorptive powers of a body are E and A respectively at temperature T then the emissive power of a black body will be

   (1) E/A (2) EAT^4

   (3) EA/T (4) A/E

10. If the temperature of an iron rod is doubled then the amount of radiation emitted by it, as compared to its initial value, becomes

    (1) 1/2 (2) equal

    (3) 4 times (4) 16 times

11. 50 g ice at –5ºC is added to 200 g of water at 40ºC in a calorimeter. The water equivalent of calorimeter is 50 g. The temperature of the mixture finally is

    (1) 9.58ºC (2) 12.58ºC

    (3) 19.58ºC (4) 29.58ºC.

12. On heating a liquid of coefficient of cubical expansion γ in a container having coefficient of liner expansion $\gamma/3$, the level of liquid in the container will

    (1) Rise (2) Fall

    (3) Will remain almost stationary

    (4) It is difficult to say

13. If specific heat of a substance is infinite, it means

(1) Heat is given out (2) Heat is taken in

(3) No change in temperature takes place whether heat is taken or given

(4) All of the above

14. If two metallic plates of equal thicknesses and thermal conductivities K_1 and K_2 are put together face to face and a common plate is constructed, then the equivalent thermal conductivity of this plate will be

(1) $\frac{K_1K_2}{K_1+K_2}$ (2) $\frac{2K_1K_2}{K_1+K_2}$

(3) $\frac{(K_1^2+K_2^2)^{3/2}}{K_1K_2}$ (4) $\frac{(K_1^2+K_2^2)^{3/2}}{2K_1K_2}$

15. Two metal rods A and B of same size are arranged as shown in the figure. The extreme ends of the combination are maintained at the indicated temperatures. The arrangement is thermally insulated. The coefficients of thermal conductivity of A and B are 300 W/m°C and 200 W/m°C, respectively. After steady state is reached, the temperature of the interface will be

(1) 45°C (2) 90°C

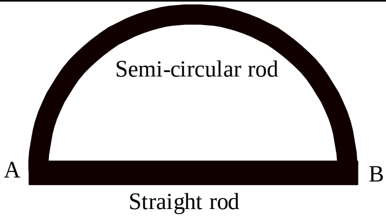
(3) 50°C (4) 60°C

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

(1) $T_1 = T_2 = T_3$ (2) $T_1 > T_2 > T_3$

(3) $T_1 < T_2 < T_3$ (4) $T_1 < T_2 < T_3$

17. Two rods (one semi-circular and other straight) of same material and of same cross section area are joined as shown in figure. The points A and B are maintained a different temperature. The ratio of the heat transferred through a cross-section of a semi-circular rod to the heat transferred through a cross-section of the straight rod in a given time is



(1) $2:\pi$ (2) 1:2

(3) $\pi:2$ (4) 3:2

18. The diameter of ball P is three times that of another ball Q of the same material. P and Q are heated to same temperature and allowed to cool up to same temperature. The relation between their rates of cooling will be

(1) $R_P = R_Q/3$ (2) $R_P = 3R_Q$

(3) $R_P = 9R_Q$ (4) $R_P = R_Q$

19. Two rods of the same material have diameter in the ratio of 1 : 2 and lengths in the ratio of 2 : 1. If the temperature difference between their ends is the same, the ratio of heats conduced by them in a given time will be

(1) 1 : 4 (2) 1 : 8

(3) 4 : 1 (4) 8 : 1

20. If a piece of metal is heated to an absolute temperature T and then put in an enclosure at absolute temperature t, then the heat generated in the atmosphere will be proportional to

(1) $(T - t)^4$ (2) $T^4 - t^4$

(3) $T^2 - t^2$ (4) $T^3 - t^3$

LEVEL - II

1. 10 g of steam at 100°C passes over a large ice block. What approximate amount of ice will melt ?

(1) 8 g (2) 18 g

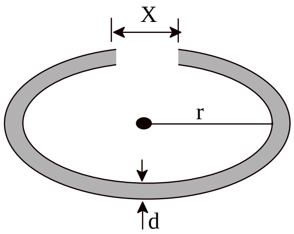
(3) 45 g (4) 80 g.

2. At what temperature the centigrade (Celsius) and Fahrenheit, readings are the same

(1) –40° (2) +40°

(3) 36.6° (4) –37°

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

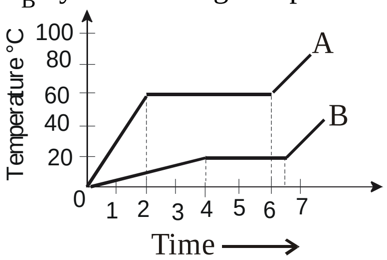


(1) x decreases, r and d increase
(2) x and r increase, d decrease
(3) x, r and d all increase
(4) Data insufficient to arrive at a conclusion

4. The thermal capacity of 40 gm of aluminium (specific heat = 0.2 cal/gm/°C) is
(1) 40 cal/°C (2) 160 cal/°C
(3) 200 cal/°C (4) 8 cal/°C

5. A metal ball immersed in alcohol weighs W_1 at 0°C and W_2 at 59°C. The coefficient of cubical expansion of the metal is less than that of alcohol. Assuming that the density of metal is large compared to that of alcohol, it can be shown that
(1) $W_1 > W_2$ (2) $W_1 = W_2$
(3) $W_1 < W_2$ (4) $W_2 = (W_1/2)$

6. Two substances A and B of equal mass m are heated at uniform rate of 6 cal s^{-1} under similar conditions. A graph between temperature and time is shown in figure. Ratio of heat absorbed H_A/H_B by them during complete fusion is



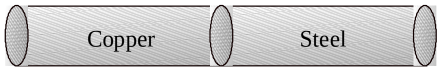
(1) $\frac{9}{4}$ (2) $\frac{4}{9}$
(3) $\frac{8}{5}$ (4) $\frac{5}{8}$

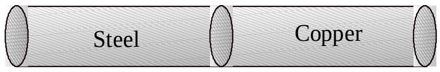
7. Two rods A and B are of equal lengths. Their ends are kept between the same temperature and their area of cross-sections are A_1 and A_2 and thermal conductivities K_1 and K_2. The rate of heat transmission in the two rods will be equal, if
(1) $K_1A_2 = K_2A_1$ (2) $K_1A_1 = K_2A_2$
(3) $K_1 = K_2$ (4) $K_1A_1^2 = K_2A_2^2$

8. Two walls of thicknesses d_1 and d_2 and thermal conductivities k_1 and k_2 are in contact. In the steady state, if the temperatures at the outer surfaces are T_1 and T_2, the temperature at the common wall is
(1) $\frac{k_1T_1d_2 + k_2T_2d_1}{k_1d_2 + k_2d_1}$ (2) $\frac{k_1T_1 + k_2d_2}{d_1 + d_2}$
(3) $\left(\frac{k_1d_1+k_2d_2}{T_1+T_2}\right)T_1T_2$ (4) $\frac{k_1d_1T_1 + k_2d_2T_2}{k_1d_1 + k_2d_2}$

9. Heat current is maximum in which of the following (rods are of identical dimension) combination if same temperature difference is applied.

(1) 

(2) 

(3) 

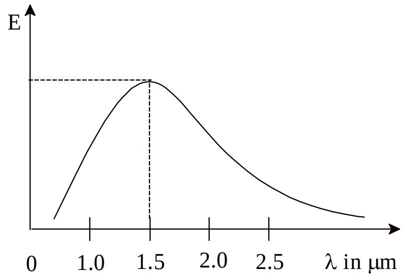
(4) 

10. If between wavelength λ and $\lambda + d\lambda$, e_λ and a_λ be the emissive and absorptive powers of a body and E_λ be the emissive power of a perfectly black body, then according to Kirchhoff's law, which is true
(1) $e_\lambda = a_\lambda = E_\lambda$ (2) $e_\lambda E_\lambda = a_\lambda$
(3) $e_\lambda = a_\lambda E_\lambda$ (4) $e_\lambda a_\lambda E_\lambda$ = constant

11. The rate of radiation of a black body at 0°C is EJ/sec. The rate of radiation of this black body at 273°C will be
(1) 16E (2) 8E
(3) 4E (4) E

12. A black body radiates energy at the rate of E W/m^2 at a high temperature TK. When the temperature is reduced to $\frac{1}{2}$K, the radiant energy will be
(1) $\frac{E}{16}$ (2) $\frac{E}{4}$
(3) 4E (4) 16E

13. In the figure, the distribution of energy density of the radiation emitted by a black body at a given temperature is shown. The possible temperature of the black body is
[wein's constant b = 2.89×10^{-3} m-K]



(1) 1500K
(2) 2000K
(3) 2500K
(4) 3000K

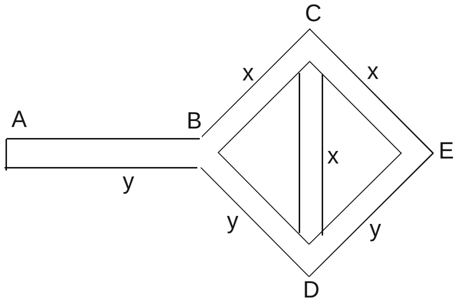
14. The difference between the length L_1 of a brass rod and length L_2 of a steel rod is contant at all temperature. The coefficient of linear expansion of brass and steel are α_1 and α_2 respectively. Then

(1) $L_1\alpha_1 = L_2\alpha_2$ (2) $L_1\alpha_2 = L_2\alpha_1$
(3) $L_1(1-\alpha_1) = L_2(1-\alpha_2)$
(4) $L_1(1-\alpha_2) = L_2(1-\alpha_1)$

15. A hot and a cold body are kept in vacuum separated from each other. Which of the following will cause decrease in temperature of the hot body?

(1) Radiation (2) Convection
(3) Conduction
(4) Temperature remains unchanged

16. Three rods of material x and three rods of material y are connected as shown in figure. All the rods are of identical length and cross-section. If the end A is maintained at 60°C and the junction E at 10°C, find effective Thermal Resistance. Given length of each rod = *l*, are of cross-section = A. conductivity of x = K and conductivity of y = 2K.

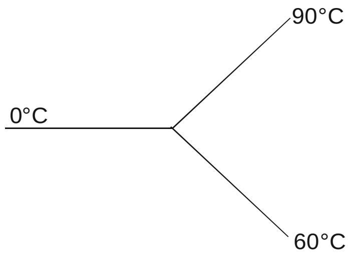


(1) $\frac{4\ell}{3KA}$ (2) $\frac{7\ell}{3KA}$
(3) $\frac{4KA}{3\ell}$ (4) $\frac{7KA}{3\ell}$

17. Two spheres of same material have radii 1 m and 4m and temperature 4000K and 2000K respectively. The ratio of energy radiated per second is

(1) 1 (2) 2
(3) 4 (4) none of these

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



(1) 45°C (2) 60°
(3) 30°C (4) 50°

19. Two rods are of same material and have same length and area. Heat ΔQ flows through them in 12 minutes, when they are joined side by side. If now both the rods are joined in parallel, then the same amount of heat ΔQ will flow in

(1) 24 min
(2) 3 min
(3) 12 min
(4) 6 min

20. A black body at 1227°C emits radiations with maximum intensity at a wavelength of 5000 Å. If the temeprature of the body is increased by 1000°C, the maximum intensity will be observed at a wavelength

(1) 4000 Å (2) 5000 Å
(3) 6000 Å (4) 3000 Å

LEVEL - III

1. Railway lines are laid with gaps to allow for expansion. If the gap between steel rails 33 m long be 1.80 cm at 10ºC, then at what temperature will the lines just touch ? Coefficient of linear expansion of steel (α) = 1.2×10^{-5}/ºC.

   (1) 55.5ºC (2) 54.5ºC
   (3) 52.5ºC (4) 53.5ºC

2. A brass disc at 20ºC has a diameter of 30 cm. A hole is cut on its surface and the hole is 10 cm in diameter. Calculate the diameter of the hole when the temperature of the disc is raised through 50ºC. Coefficient of linear expansion of brass = 1.8×10^{-5} per ºC.

   (1) 10.0054 cm
   (2) 12.0054 cm.
   (3) 11.0054 cm.
   (4) 13.0054 cm.

3. A brass rod at 30ºC is observed to be 1 metre long when measured by a steel scale which is correct at 0ºC. Find the correct length of the rod at 0ºC. Given : α for steel = 0.000012 per ºC and α for brass = 0.000019 per ºC.

   (1) 99.98 cm
   (2) 99.95 cm
   (3) 99.97 cm
   (4) 99.96 cm

4. A metal ball 0.1 m in radius is heated from 273 K to 348 K. Calculate the increase in surface area of the ball. Given : Coefficient of linear expansion of the metal is 0.000034/K.

   (1) 6.4×10^{-4} m^2 (2) 6.1×10^{-4} m^2
   (3) 6.3×10^{-4} m^2 (4) 6.2×10^{-4} m^2

5. The coefficient of volume expansion of glycerine is 46×10^{-5} ºC^{-1}. What is the fractional change in its density when there is a 30ºC rise in temperature ?

   (1) 0.0136 (2) 0.0139
   (3) 0.0137 (4) 0.0138

6. An iron ball of mass 100 gm is heated to 300ºC and dropped into a calorimeter, which contains 500 gm water at 20ºC. Water equivalent of the calorimeter is 100 gm and specific heat of iron is $0.1\frac{\text{Cal}}{\text{gm}^\circ\text{C}}$. The final temperature of the calorimeter + water + Iron ball is

   (1) 41.5°C (2) 41.0°C
   (3) 42.5°C (4) 42°C

7. A faulty thermometer reads the melting point and boiling point of water as –1°C and 104°C. The temperature of a body is measured as 20°C on that thermometre, find the true temperature of the body.

   (1) 30°C (2) 20°C
   (3) 25°C (4) 24°C

8. The temperature at which a perfect black body which radiates at the rate of 5.67 W cm^{-2}. Stefan's constant is 5.67×10^{-8} J s^{-1} m^{-2} K^{-4}.

   (1) 100 K (2) 1000 K
   (3) 10000 K (4) 10 K

9. Two bodies A and B have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are same. The two bodies emit total raditant power at the same rate. The wavelength λ_B correspondig to maximum spectral radiancy from B is shifted from the wavelength corresponding to maximum spectral radiancy in the radiation from A by 1.0 mm. If the temperature of A is 5802 K, wavelength λ_B is

   (1) 15 μm (2) 0.15 μm
   (3) 1.5 μm (4) 150 μm

10. Water in a bucket is placed in a room at 20ºC. The temperature of water in the bucket falls from 70.1 to 69.9ºC in 10 seconds. In what time its temperature will fall down 50.1ºC to 49.9ºC.

   (1) 7 sec (2) 10 sec
   (3) 17 sec (4) 1.7 sec

ANSWERS (HEAT AND THERMODYNAMICS - I)

LEVEL - I

1. (2)	5. (1)	9. (1)	13. (3)	17. (1)
2. (1)	6. (4)	10. (4)	14. (2)	18. (3)
3. (1)	7. (3)	11. (3)	15. (4)	19. (2)
4. (3)	8. (1)	12. (3)	16. (3)	20. (2)

LEVEL - II

1. (4)	5. (3)	9. (1)	13. (2)	17. (1)
2. (1)	6. (3)	10. (3)	14. (1)	18. (4)
3. (3)	7. (2)	11. (1)	15. (1)	19. (2)
4. (4)	8. (1)	12. (1)	16. (2)	20. (4)

LEVEL - III

1. (1)	3. (1)	5. (1)	7. (2)	9. (3)
2. (1)	4. (1)	6. (1)	8. (2)	10. (3)

SOLUTIONS (LEVEL - III)

1. $\Delta l = l_0 \alpha \Delta t$

   Here, Δl = 1.80 cm, l_0 = 33 m,

   α = 1.2 × 10^{-5}/ºC

   Then, $\Delta t = \dfrac{\Delta l}{l_0 \alpha} = \dfrac{.0180}{33 \times 1.2 \times 10^{-5}}$ = 45.5ºC.

   So, final temperature = 45.5 + 10 = 55.5ºC.

2. On heating, diameter of an empty space also increases just like any other length dimensions.

   $d_t = d_0(1 + \alpha t)$

   $\Rightarrow$ d_t = 10[1 + 1.8 × 10^{-5} × (50 – 20)]

   = 10.0054 cm.

3. The scale is correct at 0ºC. Therefore each division of scale is 1 cm at 0ºC. At 30ºC, each cm division increases in length and becomes (1 + 0.000012 × 30) cm, i.e., 1.00036 cm.

   True length of steel scale at 30ºC

   = 100 × 1.00036 cm = 100.036 cm

   Length of brass rod at 30ºC = 100.036 cm

   If L_0 is the length of the brass rod at 0ºC, then

   L_0 (1 + 0.000019 × 30) = 100.036

   $\therefore \quad L_0 = \dfrac{100.036}{1.00057} \text{cm} = 99.98 \text{cm}$

4. $\beta = 2\alpha = 2 \times .000034/\text{K}$ = .000068/K

   $A_0 = 4\pi r_0^2$ ..... (i)

   $\Delta A = A_0 . \beta . \Delta t$

   $= 4\pi r_0^2 \times \beta \Delta t$

   $= 4\pi \times (0.1)^2 \times .000068 \times (348 - 272)$

   = 6.4 × 10^{-4} m^2

5. $V' = V(1 + \gamma t)$

   or $V' = V(1 + 46 \times 10^{-5} \times 30)$

   or $V' = V(1 + 0.0138) = 1.0138\, V$

Initial density, $\rho = \frac{m}{V}$

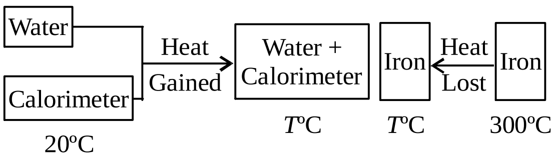
Final density,

$$\rho' = \frac{m}{V'} = \frac{m}{1.0138V} = \frac{1}{1.0138}\rho = 0.9864\rho$$

Fractional change in density,

$$= \frac{\rho - \rho'}{\rho} = \frac{\rho - 0.9864\rho}{\rho} = 0.0136$$

6.



Water and calorimeter are heated from 20ºC to *T*ºC. Iron ball is cooled from 300º to *T*ºC.

So, heat lost by (iron) = $mC\Delta t$

= 500 × 0.1 × (300 – *T*) = 50 (300 – *T*)

Heat gained (by Calorimeter + Water)

= (*m* + *W*) C Δ*t*

= (500 + 100) × 1 × (*T* – 20)

= 600 (*T*–20)

As heat gained = heat lost

So, 50(300 – *T*) = 600 (*T* – 20)

15000 – 50*T* = 600 *T* – 12000

27000 = 650 *T*

$$T = \frac{27000}{650} = 41.5°C$$

7.

$$\left(\frac{\text{t-LFP}}{\text{UP-LFP}}\right)_{\text{true}} = \left(\frac{\text{t-LFP}}{\text{VFP-LFP}}\right)_{\text{Faulty}}$$

$$\Rightarrow \frac{t-0}{100-0} = \frac{20+(1)}{104-(-1)}$$

$$\text{or,} \quad \frac{t}{100} = \frac{21}{105}$$

t = 20ºC

8. E = 5.67 W cm^{-2} = 5.67 × 10^4 W m^2 ;

σ = 5.67×10^{-8} J $s^{-1}m^{-2}$ K^{-4}, E = 1.0 (for black body)

Using, $E = \sigma T^4$;

$$\Rightarrow \quad T = \left(\frac{E}{\sigma}\right)^{\frac{1}{4}} = \left(\frac{5.67\times10^{+4}}{5.67\times10^{-8}}\right)^{\frac{1}{4}} = 1000 \text{ K}$$

9. $P_A = P_B$

$$\therefore \quad e_A\sigma A_A T_A^4 = e_B \sigma A_B T_B^4$$

$$\therefore \quad T_B = \left(\frac{e_A}{e_B}\right)T_A \quad (\text{as } A_A = A_B)$$

Substituting the values

$$T_B = \left(\frac{0.01}{0.81}\right)^{1/4} (5802) = 1934 \text{ K}$$

According to Wein's displacement law,

$$\lambda_A T_A = \lambda_B T_B$$

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

$$\text{or} \quad \lambda_B = 3\lambda_A$$

$$\text{Also,} \quad \lambda_B - \lambda_A = 1\mu m$$

$$\text{or} \quad \lambda_B - \left(\frac{1}{3}\right)\lambda_B = 1\mu m$$

$$\text{or} \quad \lambda_B = 1.5\mu m$$

10. Applying Newton's law of cooling

$$\frac{(\Delta T/\Delta t)_1}{(\Delta T/\Delta t)_2} = \frac{T_{1av} - T_0}{T_{2av} - T_0}$$

$$\frac{0.2/10}{0.2/t} = \frac{10-20}{50-20}$$

$$\text{Solving} \quad \frac{t}{10} = \frac{50}{30} \quad \Rightarrow t = \frac{50}{3} \approx 17\text{sec.}$$