CHAPTER 11

# Thermal Properties of Matter

## 11.3 Measurement of Temperature

**1.** On a new scale of temperature (which is linear) and called the *W* scale, the freezing and boiling points of water are 39°W and 239°W respectively. What will be the temperature on the new scale, corresponding to a temperature of 39°C on the Celsius scale ?
(a) 200°W (b) 139°W
(c) 78°W (d) 117°W *(2008)*

**2.** Mercury thermometer can be used to measure temperature upto
(a) 260°C (b) 100°C
(c) 360°C (d) 500°C *(1992)*

**3.** A Centigrade and a Fahrenheit thermometer are dipped in boiling water. The water temperature is lowered until the Fahrenheit thermometer registers 140°F. What is the fall in temperature as registered by the centigrade thermometer?
(a) 80°C (b) 60°C
(c) 40°C (d) 30°C *(1990)*

## 11.5 Thermal Expansion

**4.** A copper rod of 88 cm and an aluminium rod of unknown length have their increase in length independent of increase in temperature. The length of aluminium rod is ($\alpha_{Cu} = 1.7 \times 10^{-5}\ K^{-1}$, $\alpha_{Al} = 2.2 \times 10^{-5}\ K^{-1}$)
(a) 68 cm (b) 6.8 cm
(c) 113.9 cm (d) 88 cm
*(NEET 2019)*

**5.** Coefficient of linear expansion of brass and steel rods are $\alpha_1$ and $\alpha_2$. Lengths of brass and steel rods are $l_1$ and $l_2$ respectively. If $(l_2 - l_1)$ is maintained same at all temperatures, which one of the following relations holds good?
(a) $\alpha_1^2 l_2 = \alpha_2^2 l_1$ (b) $\alpha_1 l_1 = \alpha_2 l_2$
(c) $\alpha_1 l_2 = \alpha_2 l_1$ (d) $\alpha_1 l_2^2 = \alpha_2 l_1^2$
*(NEET-I 2016, 1999)*

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

**7.** The density of water at 20°C is 998 kg/m$^3$ and at 40°C is 992 kg/m$^3$. The coefficient of volume expansion of water is
(a) $3 \times 10^{-4}$/°C (b) $2 \times 10^{-4}$/°C
(c) $6 \times 10^{-4}$/°C (d) $10^{-4}$/°C
*(Karnataka NEET 2013)*

## 11.6 Specific Heat Capacity

**8.** The quantities of heat required to raise the temperature of two solid copper spheres of radii $r_1$ and $r_2$ ($r_1 = 1.5r_2$) through 1 K are in the ratio
(a) $\frac{27}{8}$ (b) $\frac{9}{4}$
(c) $\frac{3}{2}$ (d) $\frac{5}{3}$ *(NEET 2020)*

**9.** Thermal capacity of 40 g of aluminium ($s = 0.2$ cal/g K) is
(a) 168 J/K (b) 672 J/K
(c) 840 J/K (d) 33.6 J/K *(1990)*

## 11.7 Calorimetry

**10.** Two identical bodies are made of a material for which the heat capacity increases with temperature. One of these is at 100°C, while the other one is at 0°C. If the two bodies are brought into contact, then, assuming no heat loss, the final common temperature is
(a) 50°C
(b) more than 50°C
(c) less than 50°C but greater than 0°C
(d) 0°C *(NEET-II 2016)*

## 11.8 Change of State

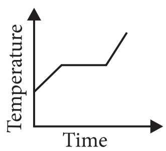
**11.** A piece of ice falls from a height $h$ so that it melts completely. Only one-quarter of the heat produced is absorbed by the ice and all energy of ice gets converted into heat during its fall. The value of $h$ is [Latent heat of ice is $3.4 \times 10^5$ J/ kg and $g = 10$ N/kg]

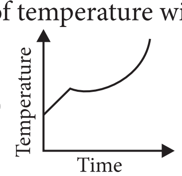
(a) 136 km (b) 68 km
(c) 34 km (d) 544 km *(NEET-I 2016)*

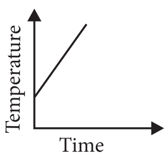
**12.** Steam at 100°C is passed into 20 g of water at 10°C. When water acquires a temperature of 80°C, the mass of water present will be [Take specific heat of water = 1 cal $g^{-1}$ °$C^{-1}$ and latent heat of steam = 540 cal $g^{-1}$]

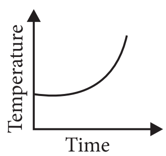
(a) 24 g (b) 31.5 g
(c) 42.5 g (d) 22.5 g *(2014)*

**13.** Liquid oxygen at 50 K is heated to 300 K at constant pressure of 1 atm. The rate of heating is constant. Which one of the following graphs represents the variation of temperature with time?

(a) 


(b) 


(c) 


(d) 


*(2012)*

**14.** If 1 g of steam is mixed with 1 g of ice, then resultant temperature of the mixture is

(a) 100°C (b) 230°C
(c) 270°C (d) 50°C *(1999)*

**15.** 10 gm of ice cubes at 0°C are released in a tumbler (water equivalent 55 g) at 40°C. Assuming that negligible heat is taken from the surroundings, the temperature of water in the tumbler becomes nearly ($L$ = 80 cal/g)

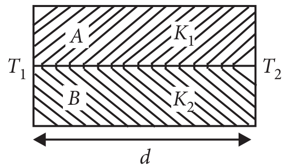
(a) 31°C (b) 22°C
(c) 19°C (d) 15°C *(1988)*

## 11.9 Heat Transfer

**16.** The power radiated by a black body is $P$ and it radiates maximum energy at wavelength, $\lambda_0$. If the temperature of the black body is now changed so that it radiates maximum energy at wavelength $\frac{3}{4}\lambda_0$, the power radiated by it becomes $nP$. The value of $n$ is

(a) $\frac{3}{4}$ (b) $\frac{4}{3}$ (c) $\frac{256}{81}$ (d) $\frac{81}{256}$ *(NEET 2018)*

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




(a) $\frac{3(K_1 + K_2)}{2}$ (b) $K_1 + K_2$
(c) $2(K_1 + K_2)$ (d) $\frac{K_1 + K_2}{2}$ *(NEET 2017)*

**18.** A spherical black body with a radius of 12 cm radiates 450 watt power at 500 K. If the radius were halved and the temperature doubled, the power radiated in watt would be

(a) 450 (b) 1000 (c) 1800 (d) 225 *(NEET 2017)*

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

(a) $U_1 > U_2$ (b) $U_2 > U_1$
(c) $U_1 = 0$ (d) $U_3 = 0$ *(NEET-I 2016)*

**20.** The two ends of a metal rod are maintained at temperatures 100°C and 110°C. The rate of heat flow in the rod is found to be 4.0 J/s. If the ends are maintained at temperatures 200°C and 210°C, the rate of heat flow will be

(a) 8.0 J/s (b) 4.0 J/s
(c) 44.0 J/s (d) 16.8 J/s *(2015 Cancelled)*

**21.** A piece of iron is heated in a flame. It first becomes dull red then becomes reddish yellow and finally turns to white hot. The correct explanation for the above observation is possible by using

(a) Kirchhoff's Law
(b) Newton's Law of cooling
(c) Stefan's Law
(d) Wien's displacement Law *(NEET 2013)*

**22.** Two metal rods 1 and 2 of same lengths have same temperature difference between their ends. Their thermal conductivities are $K_1$ and $K_2$ and cross sectional areas $A_1$ and $A_2$, respectively. If the rate of heat conduction in 1 is four times that in 2, then

(a) $K_1A_1 = 4K_2A_2$ (b) $K_1A_1 = 2K_2A_2$
(c) $4K_1A_1 = K_2A_2$ (d) $K_1A_1 = K_2A_2$ *(Karnataka NEET 2013)*

**23.** If the radius of a star is $R$ and it acts as a black body, what would be the temperature of the star, in which the rate of energy production is $Q$?

(a) $\frac{Q}{4\pi R^2\sigma}$ (b) $\left(\frac{Q}{4\pi R^2\sigma}\right)^{-1/2}$

(c) $\left(\frac{4\pi R^2 Q}{\sigma}\right)^{1/4}$ (d) $\left(\frac{Q}{4\pi R^2\sigma}\right)^{1/4}$

($\sigma$ stands for Stefan's constant) *(2012 )*

**24.** A slab of stone of area 0.36 $m^2$ and thickness 0.1 m is exposed on the lower surface to steam at 100°C. A block of ice at 0°C rests on the upper surface of the slab. In one hour 4.8 kg of ice is melted. The thermal conductivity of slab is
(Given latent heat of fusion of ice = $3.36 \times 10^5$ J $kg^{-1}$)

(a) 1.24 J/m/s/°C (b) 1.29 J/m/s/°C
(c) 2.05 J/m/s/°C (d) 1.02 J/m/s/°C *(Mains 2012)*

**25.** A cylindrical metallic rod in thermal contact with two reservoirs of heat at its two ends conducts an amount of heat $Q$ in time $t$. The metallic rod is melted and the material is formed into a rod of half the radius of the original rod. What is the amount of heat conducted by the new rod, when placed in thermal contact with the two reservoirs in time $t$?

(a) $\frac{Q}{4}$ (b) $\frac{Q}{16}$ (c) $2Q$ (d) $\frac{Q}{2}$ *(2010)*

**26.** The total radiant energy per unit area, normal to the direction of incidence, received at a distance $R$ from the centre of a star of radius $r$, whose outer surface radiates as a black body at a temperature $T$ K is given by

(a) $\frac{\sigma r^2 T^4}{R^2}$ (b) $\frac{\sigma r^2 T^4}{4\pi R^2}$

(c) $\frac{\sigma r^4 T^4}{R^4}$ (d) $\frac{4\pi\sigma r^2 T^4}{R^2}$

(where $\sigma$ is Stefan's constant) *(2010)*

**27.** Assuming the sun to have a spherical outer surface of radius $r$, radiating like a black body at temperature $t$°C, the power received by a unit surface, (normal to the incident rays) at a distance $R$ from the centre of the sun is

(a) $\frac{r^2\sigma(t+273)^4}{4\pi R^2}$ (b) $\frac{16\pi^2 r^2\sigma t^4}{R^2}$

(c) $\frac{r^2\sigma(t+273)^4}{R^2}$ (d) $\frac{4\pi r^2\sigma t^4}{R^2}$

(where $\sigma$ is the Stefan's constant.) *(2010, 2007)*

**28.** A black body at 227°C radiates heat at the rate of 7 cals/$cm^2$s. At a temperature of 727°C, the rate of heat radiated in the same units will be

(a) 50 (b) 112
(c) 80 (d) 60 *(2009)*

**29.** The two ends of a rod of length $L$ and a uniform cross-sectional area $A$ are kept at two temperatures $T_1$ and $T_2$ ($T_1 > T_2$). The rate of heat transfer, $\frac{dQ}{dt}$, through the rod in a steady state is given by

(a) $\frac{dQ}{dt} = \frac{k(T_1 - T_2)}{LA}$ (b) $\frac{dQ}{dt} = kLA(T_1 - T_2)$

(c) $\frac{dQ}{dt} = \frac{kA(T_1 - T_2)}{L}$ (d) $\frac{dQ}{dt} = \frac{kL(T_1 - T_2)}{A}$ *(2009)*

**30.** A black body is at 727°C. It emits energy at a rate which is proportional to

(a) $(1000)^4$ (b) $(1000)^2$
(c) $(727)^4$ (d) $(727)^2$ *(2007)*

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

(a) 3000 Å (b) 4000 Å
(c) 5000 Å (d) 6000 Å. *(2006)*

**32.** Which of the following rods, (given radius $r$ and length $l$) each made of the same material and whose ends are maintained at the same temperature will conduct most heat?

(a) $r = r_0, l = l_0$ (b) $r = 2r_0, l = l_0$
(c) $r = r_0, l = 2l_0$ (d) $r = 2r_0, l = 2l_0$. *(2005)*

**33.** If $\lambda_m$ denotes the wavelength at which the radiative emission from a black body at a temperature $T$ K is maximum, then

(a) $\lambda_m \propto T^4$
(b) $\lambda_m$ is independent of $T$
(c) $\lambda_m \propto T$ (d) $\lambda_m \propto T^{-1}$ *(2004)*

**34.** Consider a compound slab consisting of two different materials having equal thicknesses and thermal conductivities $K$ and $2K$, respectively. The equivalent thermal conductivity of the slab is

(a) $\frac{2}{3}K$ (b) $\sqrt{2}\,K$ (c) $3\,K$ (d) $\frac{4}{3}K$ *(2003)*

**35.** Unit of Stefan's constant is

(a) watt $m^2$ $K^4$ (b) watt $m^2/K^4$
(c) watt/$m^2$ K (d) watt/$m^2K^4$ *(2002)*

**36.** Consider two rods of same length and different specific heats ($S_1$, $S_2$), conductivities ($K_1$, $K_2$) and area of cross-sections ($A_1$, $A_2$) and both having temperatures $T_1$ and $T_2$ at their ends. If rate of loss of heat due to conduction is equal, then

(a) $K_1A_1 = K_2A_2$ (b) $\frac{K_1A_1}{S_1} = \frac{K_2A_2}{S_2}$

(c) $K_2A_1 = K_1A_2$ (d) $\frac{K_2A_1}{S_2} = \frac{K_1A_2}{S_1}$ *(2002)*

**37.** For a black body at temperature 727°C, its radiating power is 60 watt and temperature of surrounding is 227°C. If temperature of black body is changed to 1227°C then its radiating power will be
(a) 304 W (b) 320 W
(c) 240 W (d) 120 W *(2002)*

**38.** Which of the following is best close to an ideal black body?
(a) black lamp
(b) cavity maintained at constant temperature
(c) platinum black
(d) a lump of charcoal heated to high temperature. *(2002)*

**39.** The Wien's displacement law express relation between
(a) wavelength corresponding to maximum energy and temperature
(b) radiation energy and wavelength
(c) temperature and wavelength
(d) colour of light and temperature. *(2002)*

**40.** A cylindrical rod having temperature $T_1$ and $T_2$ at its end. The rate of flow of heat $Q_1$ cal/sec. If all the linear dimension are doubled keeping temperature constant, then rate of flow of heat $Q_2$ will be
(a) $4Q_1$ (b) $2Q_1$
(c) $Q_1/4$ (d) $Q_1/2$ *(2001)*

**41.** A black body has maximum wavelength $\lambda_m$ at 2000 K. Its corresponding wavelength at 3000 K will be
(a) $\frac{3}{2}\lambda_m$ (b) $\frac{2}{3}\lambda_m$
(c) $\frac{16}{81}\lambda_m$ (d) $\frac{81}{16}\lambda_m$ *(2000)*

**42.** The radiant energy from the sun, incident normally at the surface of earth is 20 kcal/m$^2$ min. What would have been the radiant energy, incident normally on the earth, if the sun had a temperature, twice of the present one?
(a) 320 kcal/m$^2$ min (b) 40 kcal/m$^2$ min
(c) 160 kcal/m$^2$ min (d) 80 kcal/m$^2$ min *(1998)*

**43.** A black body is at a temperature of 500 K. It emits energy at a rate which is proportional to
(a) $(500)^3$ (b) $(500)^4$
(c) 500 (d) $(500)^2$ *(1997)*

**44.** Heat is flowing through two cylindrical rods of the same material. The diameters of the rods are in the ratio 1 : 2 and the lengths in the ratio 2 : 1. If the temperature difference between the ends is same, then ratio of the rate of flow of heat through them will be
(a) 2 : 1 (b) 8 : 1 (c) 1 : 1 (d) 1 : 8 *(1995)*

**45.** If the temperature of the sun is doubled, the rate of energy recieved on earth will be increased by a factor of
(a) 2 (b) 4 (c) 8 (d) 16 *(1993)*

## 11.10 Newton's Law of Cooling

**46.** A body cools from a temperature $3T$ to $2T$ in 10 minutes. The room temperature is $T$. Assume that Newton's law of cooling is applicable. The temperature of the body at the end of next 10 minutes will be
(a) $\frac{7}{4}T$ (b) $\frac{3}{2}T$ (c) $\frac{4}{3}T$ (d) $T$ *(NEET-II 2016)*

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

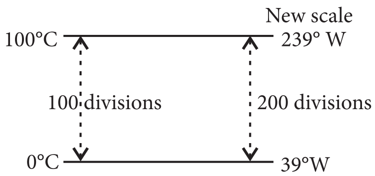
**48.** A beaker full of hot water is kept in a room. If it cools from 80°C to 75°C in $t_1$ minutes, from 75°C to 70°C in $t_2$ minutes and from 70°C to 65°C in $t_3$ minutes, then
(a) $t_1 < t_2 < t_3$ (b) $t_1 > t_2 > t_3$
(c) $t_1 = t_2 = t_3$ (d) $t_1 < t_2 = t_3$. *(1995)*

## ANSWER KEY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** (d) | **2.** (c) | **3.** (c) | **4.** (a) | **5.** (b) | **6.** (d) | **7.** (a) | **8.** (a) | **9.** (d) | **10.** (b) |
| **11.** (a) | **12.** (d) | **13.** (a) | **14.** (a) | **15.** (b) | **16.** (c) | **17.** (d) | **18.** (c) | **19.** (b) | **20.** (b) |
| **21.** (d) | **22.** (a) | **23.** (d) | **24.** (a) | **25.** (b) | **26.** (a) | **27.** (c) | **28.** (b) | **29.** (c) | **30.** (a) |
| **31.** (a) | **32.** (b) | **33.** (d) | **34.** (a) | **35.** (d) | **36.** (a) | **37.** (b) | **38.** (b) | **39.** (a) | **40.** (b) |
| **41.** (b) | **42.** (a) | **43.** (b) | **44.** (d) | **45.** (d) | **46.** (b) | **47.** (a) | **48.** (a) | | |

# Hints & Explanations

**1. (d) :**




$\therefore$ 39°C = 39 × 2 + 39 = (78 + 39)° W
= 117° W

**2. (c) :** Mercury thermometer is based on the principle of change of volume with rise of temperature and can measure temperatures ranging from –30°C to 357°C

**3. (c) :** Here, $F = 140°$

Using $\frac{F-32}{180} = \frac{C}{100}$, or, $\frac{140-32}{180} = \frac{C}{100}$ $\Rightarrow$ $C = 60°C$

we get, fall in temperature = 40°C

**4. (a) :** As per question, $\Delta l_{Cu} = \Delta l_{Al}$

or, $l_{Cu}\,\alpha_{Cu}\,\Delta T = l_{Al}\,\alpha_{Al}\,\Delta T$

$$l_{Al} = \frac{l_{Cu}\alpha_{Cu}}{\alpha_{Al}} = \frac{88\times1.7\times10^{-5}}{2.2\times10^{-5}} = 68 \text{ cm}$$

**5. (b) :** Linear expansion of brass = $\alpha_1$

Linear expansion of steel = $\alpha_2$

Length of brass rod = $l_1$, Length of steel rod = $l_2$

On increasing the temperature of the rods by $\Delta T$, new lengths would be

$$l_1' = l_1(1+\alpha_1\Delta T) \quad \text{... (i)}$$

$$l_2' = l_2(1+\alpha_2\Delta T) \quad \text{... (ii)}$$

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

$$l_2' - l_1' = (l_2 - l_1) + (l_2\alpha_2 - l_1\alpha_1)\Delta T$$

According to question,

$$l_2' - l_1' = l_2 - l_1 \quad \text{(for all temperatures)}$$

$\therefore$ $l_2\alpha_2 - l_1\alpha_1 = 0$ or $l_1\alpha_1 = l_2\alpha_2$

**6. (d) :** Let $\rho_0$ and $\rho_T$ be densities of glycerin at 0°C and $T$°C respectively. Then,

$$\rho_T = \rho_0(1 - \gamma\Delta T)$$

where $\gamma$ is the coefficient of volume expansion of glycerine and $\Delta T$ is rise in temperature.

$$\frac{\rho_T}{\rho_0} = 1 - \gamma\Delta T \quad \text{or} \quad \gamma\Delta T = 1 - \frac{\rho_T}{\rho_0}$$

Thus, $\frac{\rho_0 - \rho_T}{\rho_0} = \gamma\Delta T$

Here, $\gamma = 5 \times 10^{-4}\ K^{-1}$ and $\Delta T$ = 40°C = 40 K

$\therefore$ The fractional change in the density of glycerin

$$= \frac{\rho_0 - \rho_T}{\rho_0} = \gamma\Delta T = (5\times10^{-4}\,K^{-1})(40\text{ K}) = 0.020$$

**7. (a) :** As $\rho_{T_2} = \frac{\rho_{T_1}}{(1+\gamma\Delta T)} = \frac{\rho_{T_1}}{1+\gamma(T_2 - T_1)}$

Here, $T_1$ = 20°C, $T_2$ = 40°C

$\rho_{20} = 998$ kg/m$^3$, $\rho_{40} = 992$ kg/m$^3$

$$\therefore\ 992 = \frac{998}{1+\gamma(40-20)} \quad \text{or,}\ 992 = \frac{998}{1+20\gamma}$$

$$1+20\gamma = \frac{998}{992} \quad \text{or} \quad 20\gamma = \frac{998}{992} - 1 = \frac{6}{992}$$

$$\gamma = \frac{6}{992}\times\frac{1}{20} = 3\times10^{-4}/°C$$

**8. (a) :** Heat required, $\Delta Q = ms\Delta T$

$\Delta Q = (V \times \rho) \times s\,\Delta T$

$$= \frac{4}{3}\pi r^3\,\rho\cdot s\,\Delta T$$

$$\frac{\Delta Q_1}{\Delta Q_2} = \frac{r_1^3}{r_2^3} = \left(\frac{r_1}{r_2}\right)^3 = (1.5)^3 = \frac{27}{8}$$

**9. (d) :** Thermal capacity = $ms$ = 40 × 0.2
= 8 cal/K = 33.6 J/K.

**10. (b) :** Since, heat capacity of material increases with increase in temperature so, body at 100°C has more heat capacity than body at 0°C. Hence, final common temperature of the system will be closer to 100°C.

$\therefore$ $T_c > 50°C$

**11. (a) :** Gravitational potential energy of a piece of ice at a height ($h$) = $mgh$

Heat absorbed by the ice to melt completely

$$\Delta Q = \frac{1}{4}mgh \quad \text{...(i)}$$

Also, $\Delta Q = mL$ ...(ii)

From eqns. (i) and (ii), $mL = \frac{1}{4}mgh$ or, $h = \frac{4L}{g}$

Here $L = 3.4 \times 10^5$ J kg$^{-1}$, $g$ = 10 N kg$^{-1}$

$$\therefore\ h = \frac{4\times3.4\times10^5}{10} = 4\times34\times10^3 = 136 \text{ km}$$

**12. (d) :** Here,

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

Latent heat of steam, $L_s$ = 540 cal g$^{-1}$

Heat lost by $m$ g of steam at 100°C to change into water at 80°C is

$Q_1 = mL_s + ms_w\,\Delta T_w$
$= m \times 540 + m \times 1 \times (100 - 80)$
$= 540m + 20m = 560m$

Heat gained by 20 g of water to change its temperature from 10°C to 80°C is

$Q_2 = m_w\,s_w\,\Delta T_w$ = 20 × 1 × (80 – 10) = 1400

According to principle of calorimetry, $Q_1 = Q_2$

$\therefore$ $560m = 1400$ or $m$ = 2.5 g

Total mass of water present
= (20 + $m$) g = (20 + 2.5) g = 22.5 g

**13. (a) :** Temperature of liquid oxygen will first increase in the same phase. Then, the liquid oxygen will change to gaseous phase during which temperature will remain constant. After that temperature of oxygen in gaseous state will increase. Hence option (a) represents corresponding temperature-time graph.

**14. (a)**

**15. (b) :** Let the final temperature be $T$

Heat required by ice $= mL + m \times s \times (T - 0)$

$= 10 \times 80 + 10 \times 1 \times T$

Heat lost by tumbler $= 55 \times (40 - T)$

By using law of calorimetry,

heat gained = heat lost

$800 + 10T = 55 \times (40 - T)$

$\Rightarrow \quad T = 21.54°\text{C} = 22°\text{C}$

**16. (c) :** From Wien's law, $\lambda_{max}T = \text{constant}$

So, $\lambda_{max_1}T_1 = \lambda_{max_2}T_2$

$$\Rightarrow \lambda_0 T = \frac{3\lambda_0}{4}T' \Rightarrow \frac{T'}{T} = \frac{4}{3}$$

According to Stefan-Boltzmann law, energy emitted unit time by a black body is $Ae\sigma T^4$, *i.e.*, power radiated.

$\therefore \quad P \propto T^4$

$$\text{So, } \frac{P'}{P} = \left(\frac{T'}{T}\right)^4 \Rightarrow n = \left(\frac{4}{3}\right)^4 = \frac{256}{81}$$

**17. (d) :** Equivalent thermal conductivity of the composite rod in parallel combination will be,

$$K = \frac{K_1A_1 + K_2A_2}{A_1 + A_2} = \frac{K_1 + K_2}{2}$$

**18. (c) :** According to Stefan-Boltzman law, rate of energy radiated by a black body is given as

$E = \sigma AT^4 = \sigma 4pR^2T^4$

Given $E_1 = 450$ W, $T_1 = 500$ K, $R_1 = 12$ cm

$$R_2 = \frac{R_1}{2},\ T_2 = 2T_1,\ E_2 = ?$$

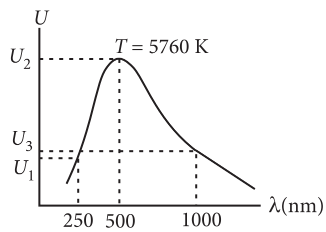
$$\frac{E_2}{E_1} = \frac{\sigma 4\pi R_2^2 T_2^4}{\sigma 4\pi R_1^2 T_1^4} = \left(\frac{R_2}{R_1}\right)^2\left(\frac{T_2}{T_1}\right)^4$$

$$\frac{E_2}{E_1} = \frac{1}{4} \times 16 = 4$$

$E_2 = E_1 \times 4 = 450 \times 4 = 1800$ W

**19. (b) :** According to Wein's displacement law

$$\lambda_m = \frac{b}{T} = \frac{2.88 \times 10^6 \text{ nm K}}{5760 \text{ K}} = 500 \text{ nm}$$




Clearly from graph $U_2 > U_3$ and $U_2 > U_1$

**20. (b)**

**21. (d) :** According to Wien's displacement law

$\lambda_m T = \text{constant}$

$$\lambda_m = \frac{\text{constant}}{T}$$

So when a piece of iron is heated, $\lambda_m$ decreases *i.e.* with rise in temperature the maximum intensity of radiation emitted gets shifted towards the shorter wavelengths. So the colour of the heated object will change that of longer wavelength (red) to that of shorter (reddish yellow) and when the temperature is sufficiently high and all wavelengths are emitted, the colour will become white.

**22. (a) :** Let $L$ be length of each rod.

Rate of heat flow in rod 1 for the temperature difference $\Delta T$ is

$$H_1 = \frac{K_1A_1\Delta T}{L}$$

Rate of heat flow in rod 2 for the same difference $\Delta T$ is

$$H_2 = \frac{K_2A_2\Delta T}{L}$$

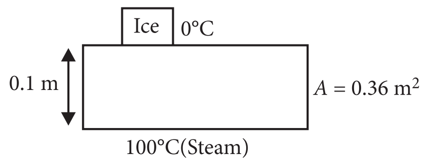
As per question, $H_1 = 4H_2$

$$\frac{K_1A_1\Delta T}{L} = 4\frac{K_2A_2\Delta T}{L};\ K_1A_1 = 4K_2A_2$$

**23. (d) :** According to Stefan's law, $Q = \sigma AT^4$

$$\text{or} \quad T = \left(\frac{Q}{\sigma A}\right)^{1/4} = \left(\frac{Q}{\sigma 4\pi R^2}\right)^{1/4}$$

**24. (a) :**




Heat flows through the slab in $t$ s is

$$Q = \frac{KA(T_1 - T_2)t}{L} = \frac{K \times 0.36 \times (100 - 0) \times 3600}{0.1}$$

$$= \frac{K \times 0.36 \times 100 \times 3600}{0.1} \quad \text{... (i)}$$

So ice melted by this heat is $m_{ice} = \dfrac{Q}{L_f}$ ... (ii)

or $\quad Q = m_{ice}L_f = 4.8 \times 3.36 \times 10^5$ J

From (i) and (ii), we get

$$\frac{K \times 0.36 \times 100 \times 3600}{0.1} = 4.8 \times 3.36 \times 10^5$$

$$K = \frac{4.8 \times 3.36 \times 10^5 \times 0.1}{0.36 \times 100 \times 3600} = 1.24 \text{ J/m/s/°C}$$

**25. (b) :** The amount of heat flows in time $t$ through a cylindrical metallic rod of length $L$ and uniform area of cross-section $A$ $(= \pi R^2)$ with its ends maintained at temperatures $T_1$ and $T_2$ $(T_1 > T_2)$ is given by

$$Q = \frac{KA(T_1 - T_2)t}{L} \quad \text{... (i)}$$

where $K$ is the thermal conductivity of the material of the rod.

Area of cross-section of new rod

$$A' = \pi\left(\frac{R}{2}\right)^2 = \frac{\pi R^2}{4} = \frac{A}{4}$$

As the volume of the rod remains unchanged

$\therefore \quad AL = A'L'$

where $L'$ is the length of the new rod

or $\quad L' = L\frac{A}{A'} = 4L$

Now, the amount of heat flows in same time $t$ in the new rod with its ends maintained at the same temperatures $T_1$ and $T_2$ is given by

$$Q' = \frac{KA'(T_1 - T_2)t}{L'}$$

Substituting the values of $A'$ and $L'$

$$Q' = \frac{K(A/4)(T_1 - T_2)t}{4L} = \frac{1}{16}\frac{KA(T_1 - T_2)t}{L} = \frac{1}{16}Q$$

(Using (i))

**26. (a) :** According to the Stefan Boltzmann law, the power radiated by the star whose outer surface radiates as a black body at temperature $T$ K is given by

$P = \sigma 4\pi r^2 T^4$

where, $r$ = radius of the star, $\sigma$ = Stefan's constant

The radiant power per unit area received at a distance $R$ from the centre of a star is

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

**27. (c)**

**28. (b) :** Rate of heat radiated at (227 + 273) K

= 7 cals/(cm$^2$s)

Let rate of heat radiated at (727 + 273) K

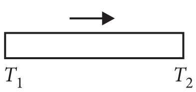
= $x$ cals/(cm$^2$s)

By Stefan's law, $7 \propto (500)^4$ and $x \propto (1000)^4$

$$\therefore \frac{x}{7} = 2^4 \Rightarrow x = 7 \times 2^4 = 112 \text{ cals/(cm}^2\text{ s)}$$

**29. (c) :** Similar to $I = V/R$

$$\frac{dQ}{dt} = \frac{kA}{L}(T_1 - T_2)$$




$k$ = conductivity of the rod.

**30. (a) :** According to Stefan's law, rate of energy radiated $E \propto T^4$

where $T$ is the absolute temperature of a black body.

$\therefore \quad E \propto (727 + 273)^4$ or $E \propto [1000]^4$.

**31. (a) :** According to Wein's displacement law,

$\lambda_{max} T$ = constant

$$\therefore \frac{\lambda_{max_1}}{\lambda_{max_2}} = \frac{T_2}{T_1}$$

or $$\lambda_{max_2} = \frac{\lambda_{max_1} \times T_1}{T_2} = \frac{5000 \times 1500}{2500} = 3000 \text{ Å}$$

**32. (b) :** Heat conducted

$$= \frac{KA(T_1 - T_2)t}{l} = \frac{K\pi r^2(T_1 - T_2)t}{l}$$

The rod with the maximum ratio of $r^2/l$ will conduct most. Here the rod with $r = 2r_0$ and $l = l_0$ will conduct most.

**33. (d) :** Wein's displacement law

$\lambda_m T$ = constant, $\lambda_m \propto T^{-1}$

**34. (a) :** The slabs are in series.

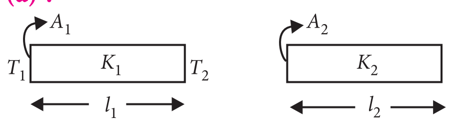
Total resistance $R = R_1 + R_2$

$$\Rightarrow \frac{l}{AK_{effective}} = \frac{l}{A.K} + \frac{l}{A2K}$$

$$\Rightarrow \frac{1}{K_{effective}} = \frac{1}{K} + \frac{1}{2K} = \frac{3}{2K} \quad \therefore K_{effective} = \frac{2K}{3}$$

**35. (d) :** Unit of Stefan's constant is watt/m$^2$K$^4$.

**36. (a) :**




$$\text{Rate of heat loss in rod 1} = Q_1 = \frac{K_1A_1(T_1 - T_2)}{l_1}$$

$$\text{Rate of heat loss in rod 2} = Q_2 = \frac{K_2A_2(T_1 - T_2)}{l_2}$$

By problem, $Q_1 = Q_2$.

$$\therefore \frac{K_1A_1(T_1 - T_2)}{l_1} = \frac{K_2A_2(T_1 - T_2)}{l_2}$$

$\therefore \quad K_1A_1 = K_2A_2 \quad [\because l_1 = l_2]$

**37. (b) :** Radiating power of a black body

$$E_0 = \sigma(T^4 - T_0^4)A$$

where $\sigma$ is known as the Stefan-Boltzmann constant, $A$ is the surface area of a black body, $T$ is the temperature of the black body and $T_0$ is the temperature of the surrounding.

$\therefore \quad 60 = \sigma(1000^4 - 500^4) \quad$ ...(i)

[$T$ = 727°C = 727 + 273 = 1000 K, $T_0$ = 227°C = 500 K]

In the second case, $T$ = 1227°C = 1500 K and let $E'$ be the radiating power.

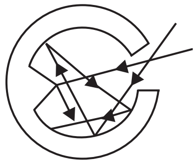
$\therefore \quad E' = \sigma(1500^4 - 500^4) \quad$ ...(ii)

From (i) and (ii) we have

$$\frac{E'}{60} = \frac{1500^4 - 500^4}{1000^4 - 500^4} = \frac{15^4 - 5^4}{10^4 - 5^4} = \frac{50000}{9375}$$

$$\therefore E' = \frac{50000}{9375} \times 60 = 320 \text{ W}$$

**38. (b) :** An ideal black body is one which absorbs all the incident radiation without reflecting or transmitting any part of it.



Black lamp absorbs approximately 96% of incident radiation.

An ideal black body can be realized in practice by a small hole in the wall of a hollow body (as shown in figure) which is at uniform temperature. Any radiation entering the hollow body through the holes suffers a number of reflections and ultimately gets completely absorbed. This can be facilitated by coating the interior surface with black so that about 96% of the radiation is absorbed at each reflection. The portion of the interior surface opposite to the hole is made conical to avoid the escape of the reflected ray after one reflection.

**39. (a) :** Wien's displacement law states that the product of absolute temperature and the wavelength at which the emissive power is maximum is constant *i.e.* $\lambda_{max} T$ = constant. Therefore it expresses relation between wavelength corresponding to maximum energy and temperature.

**40. (b) :** Heat flow rate $\frac{dQ}{dt} = \frac{KA(T_1 - T_2)}{L} = Q_1$

When linear dimensions are double.

$A_1 \propto r_1^2, L_1 = L$

$A_2 \propto 4r_1^2, L_2 = 2L$ so $Q_2 = 2Q_1$

**41. (b) :** According to Wein's law, $\lambda_m T$ = constant

$\therefore \quad \lambda' = (2/3)\lambda_m$

**42. (a) :** $E = \sigma T^4 = 20; \quad T' = 2T$

$\therefore \quad E' = \sigma(2T)^4 = 16\,\sigma T^4$

$= 16 \times 20 = 320$ kcal/m$^2$ min

**43. (b) :** Temperature of black body $T$ = 500 K Therefore total energy emitted by the black body

$E \propto T^4 \propto (500)^4$

**44. (d) :** Ratio of diameters of rod = 1 : 2 and ratio of their lengths 2 : 1.

The rate of flow of heat, $(Q) = \frac{KA\Delta T}{l} \propto \frac{A}{l}$.

Therefore, $\frac{Q_1}{Q_2} = \frac{A_1}{A_2} \times \frac{l_2}{l_1} = \left(\frac{1}{2}\right)^2 \times \frac{1}{2} = \frac{1}{8}$

or $Q_1 : Q_2 = 1 : 8$

**45. (d) :** Amount of energy radiated $\propto T^4$.

**46. (b) :** According to Newton's law of cooling,

$$\frac{dT}{dt} = K(T - T_s)$$

For two cases,

$$\frac{dT_1}{dt} = K(T_1 - T_s) \text{ and } \frac{dT_2}{dt} = K(T_2 - T_s)$$

Here, $T_s = T$, $T_1 = \frac{3T + 2T}{2} = 2.5\,T$

and $\frac{dT_1}{dt} = \frac{3T - 2T}{10} = \frac{T}{10}$

$$T_2 = \frac{2T + T'}{2} \text{ and } \frac{dT_2}{dt} = \frac{2T - T'}{10}$$

So, $\frac{T}{10} = K(2.5T - T)$ ...(i)

and $\frac{2T - T'}{10} = K\left(\frac{2T + T'}{2} - T\right)$ ...(ii)

Dividing eqn. (i) by eqn. (ii), we get

$$\frac{T}{2T - T'} = \frac{(2.5T - T)}{\left(\frac{2T + T'}{2} - T\right)} \text{ or, } \frac{2T + T'}{2} - T = (2T - T') \times \frac{3}{2}$$

$T' = 3(2T - T')$ or, $4T' = 6T$; $\therefore T' = \frac{3}{2}T$

**47. (a) :** Let $T_s$ be the temperature of the surroundings. According to Newton's law of cooling

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

For first 5 minutes,

$T_1 = 70°C$, $T_2 = 60°C$, $t = 5$ minutes

$\therefore \quad \frac{70 - 60}{5} = K\left(\frac{70 + 60}{2} - T_s\right) = K(65 - T_s)$ ... (i)

For next 5 minutes,

$T_1 = 60°C$, $T_2 = 54°C$, $t = 5$ minutes

$\therefore \quad \frac{60 - 54}{5} = K\left(\frac{60 + 54}{2} - T_s\right)$

$\frac{6}{5} = K(57 - T_s)$ ... (ii)

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

$$\frac{5}{3} = \frac{65 - T_s}{57 - T_s}$$

$285 - 5T_s = 195 - 3T_s$

$2T_s = 90$ or $T_s = 45°C$

**48. (a) :** The rate of cooling is directly proportional to the temperature difference of the body and the surroundings. So, cooling will be fastest in the first case and slowest in the third case.

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