Chapter 11

Thermal Properties of Matter

Solutions

SECTION - A

Objective Type Questions

(Temperature and Heat)

1. Temperature is a measure of

(1) Hotness or coldness
(2) Heat possessed by a body
(3) Potential energy
(4) Thermal energy

Sol. Answer (1)

Temperature is the measure of hotness and coldness.

2. If in winter season the surface temperature of lake is 1°C, the temperature at the bottom of lake will be

(1) 1°C
(2) 0°C
(3) 4°C
(4) All values less than 1°C are possible

Sol. Answer (3)

Temperature of the surface is the lowest and it should increase as we go down to the bottom.

Temperature > 1°C

(Measurement of Temperature)

3. The readings of a bath on Celsius and Fahrenheit thermometers are in the ratio 2 : 5. The temperature of the bath is

(1) –26.66°C (2) 40°C (3) 45.71°C (4) 26.66°C

Sol. Answer (3)

$$\frac{T_C}{100} = \frac{T_F - 32}{180}$$

$$\left\{\begin{array}{l} \text{where} \\ T_C \longrightarrow \text{temperature in Celcius} \\ T_F \longrightarrow \text{temperature in Fahrenheit} \end{array}\right\}$$

$T_C : T_F$ given as 2 : 5

Let $T_C = 2x,\ T_F = 5x$

$$\frac{2x}{10} = \frac{5x-32}{18} \Rightarrow x = \frac{160}{7}$$

So, $2x = \frac{320}{7} \sim 45.7°C$

4. The pressure of a gas filled in the bulb of a constant volume gas thermometer at temperatures 0°C and 100°C are 27.50 cm and 37.50 cm of Hg respectively. At an unknown temperature the pressure is 32.45 cm of Hg. Unknown temperature is

(1) 30°C (2) 39°C

(3) 49.5°C (4) 29.6°C

Sol. Answer (3)

$$\frac{P-P_0}{P_{100}-P_0}=\frac{x-x_0}{x_{100}-x_0}=\frac{T-T_0}{T_{100}-T_0}$$

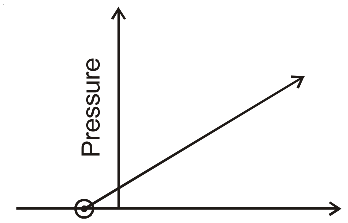
$$\frac{32.45-27.50}{37.50-27.50}=\frac{T-0}{100-0}$$

T = 49.5°C

5. A graph is plotted by taking pressure along y-axis and centigrade temperature along x-axis for an ideal gas at constant volume. x intercept of the graph is

(1) –273.15ºC (2) –273.15 K (3) –273ºC (4) –273 K

Sol. Answer (1)



(Thermal Expansion)

6. A hole is drilled in a copper sheet. The diameter of hole is 4.24 cm at 27.0°C. Diameter of the hole when it is heated to 35°C is

(1) Less than 4.24 cm (2) Equal to 4.24 cm

(3) More than 4.24 cm (4) Data insufficient

Sol. Answer (3)

Thermal expansion in this case can be imagined as a photographic enlargement, hence the diameter of hole will also increase.

7. On heating a uniform metallic cylinder length increases by 3%. The area of cross-section of its base will increase by

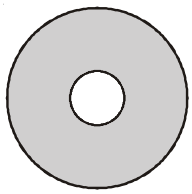
(1) 1.5% (2) 3% (3) 9% (4) 6%

Sol. Answer (4)

$\beta = 2\alpha$

$\therefore$ Area of crossection increases by 2 × 3 = 6%

8. A circular metallic disc of radius R has a small circular cavity of radius r as shown in figure. On heating the system



(1) R increases and r decreases
(2) R decreases and r increases
(3) Both R and r increases
(4) Both R and r decreases

Sol. Answer (3)

Both R and r will increase, superficial expansion is always outwards.

9. A uniform copper rod of length 50 cm and diameter 3.0 mm is kept on a frictionless horizontal surface at 20°C. The coefficient of linear expansion of copper is 2.0×10^{-5} K^{-1} and Young's modulus is 1.2×10^{11} N/m^2. The copper rod is heated to 100°C, then the tension developed in the copper rod is

(1) 12×10^3 N
(2) 36×10^3 N
(3) 18×10^3 N
(4) Zero

Sol. Answer (4)

Since the rod is not bounded, No compressive stress

hence no tensions

10. A seconds pendulum clock has a steel wire. The clock shows correct time at 25°C. How much time does the clock lose or gain, in one week, when the temperature is increased to 35°C?

($\alpha_{steel} = 1.2 \times 10^{-5}$ / °C)

(1) 321.5 s
(2) 3.828 s
(3) 82.35 s
(4) 36.28 s

Sol. Answer (4)

$$\frac{\Delta T}{T} = \frac{1}{2}\alpha\,\theta$$

$$= \frac{1}{2} \times 1.2 \times 10^{-5} \times 10$$

$$\frac{\Delta T}{T} = 6.0 \times 10^{-5}$$

Hence time lost in 1 week = $6.0 \times 10^{-5} \times T$

$= 6.0 \times 10^{-5} \times 7 \times 24 \times 3600$

$= 36.28$ s

11. The apparent coefficient of expansion of a liquid when heated in a brass vessel is X and when heated in a tin vessel is Y. If α is the coefficient of linear expansion for brass, the coefficient of linear expansion of tin is

(1) $\dfrac{X+Y+3\alpha}{3}$
(2) $\dfrac{X+3\alpha-Y}{3}$
(3) $\dfrac{X+Y-2\alpha}{3}$
(4) $\dfrac{(X+Y-2\alpha)}{2}$

Sol. Answer (2)

Coefficient of expansion of liquid = [Apparent coefficient of expansion + Coefficient of expansion of vessel]

Let coefficient of expansion of liquid be = x

Then

$x = X + 3\,\alpha_{brass}$

$x = Y + 3\,\alpha_{tin}$

$X + 3\,\alpha_{brass} = Y + 3\,\alpha_{tin}$

$$\alpha_{tin} = \frac{3\alpha_{brass} - Y + X}{3} = \frac{3\alpha - Y + X}{3}$$

12. The coefficient of volume expansion of glycerin is 49 × 10^{-5} K^{-1}. The fractional change in the density on a 30°C rise in temperature is

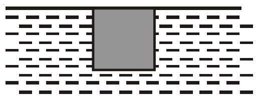
(1) 1.47 × 10^{-2} (2) 1.47 × 10^{-3} (3) 1.47 × 10^{-1} (4) 1.47 × 10^{-4}

Sol. Answer (1)

$\rho_2 = \rho_1(1 - \gamma\Delta T)$

$$\frac{-\rho_2 + \rho_1}{\rho_1} = 49\times10^{-5}\times30 \Rightarrow \frac{\Delta\rho}{\rho_1} = 1.47\times10^{-2} \qquad [\because\ \Delta\rho = \rho_1 - \rho_2]$$

13. A solid cube is first floating in a liquid. The coefficient of linear expansion of cube is α and the coefficient of volume expansion of liquid is γ. On increasing the temperature of (liquid + cube) system, the cube will sink if



(1) $\gamma = 3\alpha$ (2) $\gamma > 3\alpha$ (3) $\gamma < 3\alpha$ (4) $\gamma = 2\alpha$

Sol. Answer (2)

Cube will sink if expansion in liquid upon heating is more than that of cube

or $3\,\alpha < \gamma$

14. A steel tape is calibrated at 20°C. On a cold day when the temperature is –15°C, percentage error in the tape will be [$\alpha_{steel} = 1.2 \times 10^{-5}\,°C^{-1}$]

(1) –0.035% (2) –0.042% (3) 0.012% (4) –0.018%

Sol. Answer (2)

$$\%\ \text{error} = \frac{\Delta L}{L}\times100$$

$$= \frac{L\,\alpha\,\Delta T}{L}\times100$$

$$= 1.2\times10^{-5}\times(-35)\times100 = -\,0.042\%$$

(Specific Heat Capacity)

15. The water equivalent of 20 g of aluminium (specific heat 0.2 cal g^{-1} $°C^{-1}$), is

(1) 40 g (2) 4 g (3) 8 g (4) 160 g

Sol. Answer (2)

0.2 × 20 = 4 [Thermal Capacity]

Water equivalent numerically equal to thermal capacity

So W = 4 g

16. 100 g of ice (latent heat 80 cal g^{-1}, at 0°C) is mixed with 100 g of water (specific heat 1 cal g^{-1} °C^{-1}) at 80°C. The final temperature of the mixture will be

(1) 0°C (2) 40°C (3) 80°C (4) < 0°C

Sol. Answer (1)

100 g ice 0°C + 100 g water 80°C

$Q_{required} = mL$ if $\Delta T = 80$ [Q_f becomes = 0°]

$= 100 \times 80$ $Q_{available} = mC\Delta T$

$= 8000$ cal $= 100 \times 1 \times 80 = 8000$ cal

[Required to melt whole ice]

Since $Q_{required} = Q_{available}$

$\therefore$ Whole system will be water at equillibrium and temperature would be 0°C

17. 200 g of ice at –20°C is mixed with 500 g of water at 20°C in an insulating vessel. Final mass of water in vessel is (specific heat of ice = 0.5 cal g^{-1}°C^{-1})

(1) 700 g (2) 600 g

(3) 400 g (4) 200 g

Sol. Answer (2)

Maximum heat supplied by water

$\Delta Q_1 = 500 \times 1 \times (20 - 0)$

$= 10{,}000$ cal

Heat required to raise the temperature of ice upto 0°C

$\Delta Q_2 = 200 \times 0.5 \times 20$

$= 2000$ cal

$\Delta Q_1 - \Delta Q_2 = 8000$ cal

Melts the ice

$8000 = m \times 80$

$m = 100$ g

So, mass of water is 500 + 100 = 600 g.

18. Which of the following material is most suitable for cooking utensil?

(1) Low conductivity and low specific heat (2) High conductivity and low specific heat

(3) Low conductivity and high specific heat (4) High conductivity and high specific heat

Sol. Answer (2)

For cooking high conductivity and low specific heat because we do not want to waste heat energy in heating up the vessel it self also we want the vessel to absorb as much as heat is available.

(Calorimetry)

19. Which of the following material is used to make calorimeter?

(1) Glass (2) Ebonite

(3) Metal (4) Superconductor

Sol. Answer (3)

Metal is used (copper)

20. The thermal capacity of 100 g of aluminum (specific heat = 0.2 cal/g°C) is

(1) 0.002 cal/°C (2) 20 cal/°C (3) 200 cal/°C (4) 100 cal/°C

Sol. Answer (2)

Thermal capacity = m.C

= 100 × 0.2 = 20 cal/°C

(Change of State)

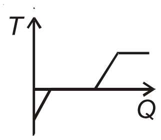
21. The density of water is maximum at

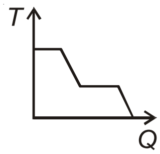
(1) 39.2°F (2) 4°F (3) 0°C (4) 273 K

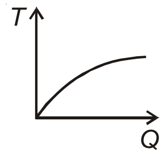
Sol. Answer (1)

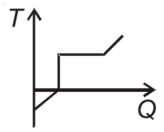
Density of water is maximum at 4°C or 39.2°F.

22. A block of ice at –12°C is slowly heated and converted into steam at 100°C. Which of the following curves best represents the event?

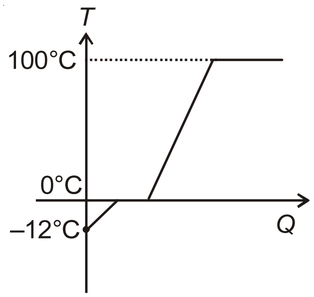
(1) 

(2) 

(3) 

(4) 

Sol. Answer (1)



(Heat Transfer)

23. In engines water is used as coolant, because

(1) It's good conductor of heat energy (2) It has low density

(3) It has high specific heat (4) It's bad conductor of heat energy

Sol. Answer (3)

Because it absorbs and gives off heat readily or it has high specific heat.

24. Select correct statement related to heat

(1) Heat is possessed by a body

(2) Hot water contains more heat as compared to cold water

(3) Heat is a energy which flows due to temperature difference

(4) All of these

Sol. Answer (3)

Heat is a energy which flows due to temperatures difference.

25. Which of the following factors affect the thermal conductivity of a rod?

(1) Area of cross-section (2) Length of rod

(3) Material of rod (4) All of these

Sol. Answer (3)

Thermal conductivity is material property.

26. What is the dimensional formula for thermal resistance?

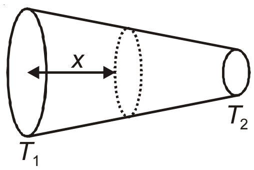
(1) $[M^{-1} L^{-2} T^{-1} K]$ (2) $[ML^2 T^{-2} K^{-1}]$ (3) $[ML^{-3} T^2 K^{-1}]$ (4) $[M^{-1} L^{-2} T^3 K]$

Sol. Answer (4)

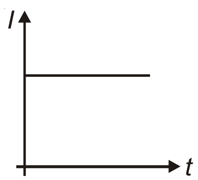
$$R = \frac{L}{KA}$$

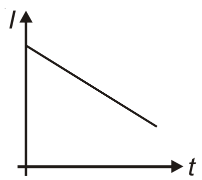
$[R] = [M^{-1} L^{-2} T^3 K]$

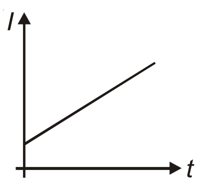
27. Two ends of a rod of non uniform area of cross-section are maintained at temperature T_1 and T_2 ($T_1 > T_2$) as shown in the figure

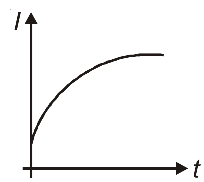


If I is heat current through the cross-section of conductor at distance x from its left face, then the variation of I with x is best represented by

(1) 

(2) 

(3) 

(4) 

Sol. Answer (1)

In steady state rate of heat transfer is constant so heat current through any cross-section remains same with time.

28. Four rods of same material with different radii r and length l are used to connect two reservoirs of heat at different temperatures. Which one will conduct maximum heat?

(1) r = 1 cm, l = 1 m (2) r = 2 cm, l = 2 m

(3) r = 1 cm, l = 1/2 m (4) r = 2 cm, l = 1/2 m

Sol. Answer (4)

$$H = \frac{K\pi r^2}{L}(T_2 - T_1)$$

$$H \propto r^2 \text{ and } H \propto \frac{1}{L}$$

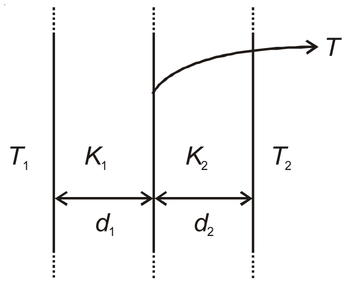
So the rod with maximum $\frac{r^2}{L}$ ratio will conduct maximum heat.

29. Two walls of thickness d_1 and d_2, 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 will be

(1) $\dfrac{K_1T_1+K_2T_2}{d_1+d_2}$ (2) $\dfrac{K_1T_1d_2+K_2T_2d_1}{K_1d_2+K_2d_1}$ (3) $\dfrac{(K_1d_1+K_2d_2)T_1T_2}{T_1+T_2}$ (4) $\dfrac{K_1d_1T_1+K_2d_2T_2}{K_1d_1+K_2d_2}$

Sol. Answer (2)

Heat flow across both the walls will be same.



$$\frac{K_1A}{d_1}(T-T_1)=\frac{K_2A}{d_2}(T_2-T)$$

$$K_1Td_2-K_1T_1d_2=K_2T_2d_1-K_2Td_1$$

$$T=\frac{K_1T_1d_2+K_2T_2d_1}{K_1d_2+K_2d_1}$$

30. A cylinder of radius R made of a material of thermal conductivity K_1 is surrounded by a cylindrical shell of inner radius R and outer radius $2R$ made of a material of thermal conductivity K_2. The two ends of the combined system are maintained at two different temperatures. There is no loss of heat across the cylindrical surface and the system is in steady state. The effective thermal conductivity of the system is

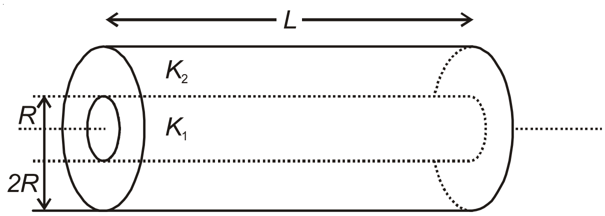
(1) K_1+K_2 (2) $\dfrac{K_1+3K_2}{4}$ (3) $\dfrac{K_1K_2}{K_1+K_2}$ (4) $\dfrac{3K_1+K_2}{4}$

Sol. Answer (2)

$$R=\frac{L}{KA}$$ [R is thermal resistance]

These two cylinders are like two resistances in a parallel connection.

$$\therefore \quad \frac{1}{R_{\text{eff}}}=\frac{1}{R_1}+\frac{1}{R_2}$$

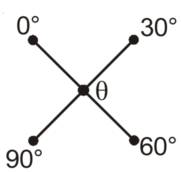


$$\frac{K_{eff}\times\pi(2R)^2}{L}=\frac{K_1\times\pi R^2}{L}+\frac{K_2\times\pi\left(4R^2-R^2\right)}{L}$$

Solving for K_{eff} we get

$$K=\frac{K_1+3K_2}{4}$$

31. Four rods of same material and having the same cross section and length have been joined, as shown. The temperature of the junction of four rods will be



(1) 20°C (2) 30°C (3) 45°C (4) 60°C

Sol. Answer (3)

Incoming heat = outgoing heat

$(90° - \theta) + (60° - \theta) = \theta - 30° + \theta - 0°$

$180° = 4\theta$

$45°C = \theta$

32. Why it is more hotter for same distance over the top of a candle than it in the side of its flame?

(1) Conduction of heat in air is upward

(2) Heat is maximum radiated in upward direction

(3) Radiation and conduction both contribute in transferring heat upwards

(4) Convection takes more heat in upward direction

Sol. Answer (4)

On the sides heating is only due to Radiation but over the top heating is due to Radiation as well as convection.

33. In gravity free space heat transfer is not possible by

(1) Conduction (2) Convection (3) Radiation (4) Both (1) & (3)

Sol. Answer (2)

For heat transfer through convention presence of gravity is a must requirement.

34. Which factor does not affect convection?

(1) Temperature difference (2) The rate of movement of carrying medium

(3) The volumetric specific heat of carrying medium (4) The thermal conductivity of carrying medium

Sol. Answer (4)

The thermal conductivity of carrying medium does not affects convection process.

35. A polished plate with rough black spot is heated to a high temperature and then taken to a dark room, then

(1) Spot will appear brighter than the plate

(2) Spot will appear darker than the plate

(3) Both will appear equally brighter

(4) Both will not be visible

Sol. Answer (1)

Rough black spot will act like a black body so radiations absorbed as well as emitted by the spot would be more than the other parts of the plate.

36. Select the incorrect statement

(1) A body radiates at all temperatures except 0 K

(2) A good reflector is a bad radiator

(3) A colder body can radiate heat to the hotter surroundings

(4) A body does not radiate when its temperature is below 0ºC

Sol. Answer (4)

0°C is 273 K so a body will radiate.

37. "A good absorber is a good emitter" is explained by

(1) Stefan's law (2) Wien's law

(3) Newton's law of cooling (4) Kirchhoff's law

Sol. Answer (4)

Kirchhoff's Law states that "A good absorber is a good emitter".

38. The rate of radiation of energy from a hot object is maximum, if its surface is

(1) White and smooth (2) Black and rough (3) Black and smooth (4) White and rough

Sol. Answer (2)

Black and rough surfaces absorb maximum amount of radiation and than radiate the same amount of radiations.

39. Two balls of same material and same surface finish have their diameters in the ratio 1 : 2. They are heated to the same temperature and are left in a room to cool by radiation, then the initial rate of loss of heat

(1) Will be same for the balls

(2) For larger ball is half that of other ball

(3) For larger ball is twice that of other ball

(4) For larger ball is four times that of the other ball

Sol. Answer (4)

By Stefan-Boltzmann's law

$$H = \sigma eA\left(T^4 - T_0^4\right)$$

$$H \propto A \propto r^2$$

$\therefore$ *f* or larger ball is $(2)^2$ that of the smaller ball.

40. A black body, which is at a high temperature *T* K, thermal radiation emitted at the rate of *E* W/m^2. If the temperature falls to *T*/4 K, the thermal radiation emitted in W/m^2 will be

(1) *E* (2) *E*/4

(3) *E*/64 (4) *E*/256

Sol. Answer (4)

Radiation $\propto T^4$

$$\frac{E_1}{E_2} = \frac{T_1^4}{T_2^4}$$

$$\frac{E}{E_2} = \frac{T^4 \times (4)^4}{T^4}$$

$$\Rightarrow \quad E_2 = \frac{E}{256}$$

41. A sphere, a cube and a thin circular plate, all made of the same mass and finish are heated to a temperature of 200°C. Which of these objects will cool slowest, when left in air at room temperature?

(1) The sphere (2) The cube

(3) The circular plate (4) All will cool at same rate

Sol. Answer (1)

Objects with more surface area cool faster [Stefan Boltzmann law].

42. Two metal spheres have radii r and $2r$ and they emit thermal radiation with maximum intensities at wavelengths λ and 2λ respectively. The respective ratio of the radiant energy emitted by them per second will be

(1) 4 : 1 (2) 1 : 4 (3) 16 : 1 (4) 8 : 1

Sol. Answer (1)

$T \propto \frac{1}{\lambda}$ [wien's displacement law]

So, $\frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1} = \frac{2\lambda}{\lambda} = 2$

and $H = eA\sigma T^4 \Rightarrow H \propto AT^4$

$$\frac{H_1}{H_2} = \frac{4\pi r^2}{4\pi(2r)^2} \times \frac{T_1^4}{T_2^4} = \frac{1}{4} \times (2)^4 = 4$$

$\therefore$ $H_1 : H_2 :: 4 : 1$

43. If temperature of sun is decreased by 1 % then the value of solar constant will change by

(1) 2% (2) –4% (3) –2% (4) 4%

Sol. Answer (2)

Solar constant $\propto T^4$ $\left[\because S = \left[\frac{R}{r}\right]^2 \sigma T^4\right]$

$$\frac{\Delta S}{S} = \frac{4\Delta T}{T}$$

and $\frac{\Delta T}{T} = -1\%$ [given]

So $\frac{\Delta S}{S} = -4\%$

44. The value of solar constant is

(1) 2 kcal m^{-2} $minute^{-1}$ (2) 20 kcal m^{-2} $minute^{-1}$

(3) 2 kWm^{-2} (4) 200 Wm^{-2}

Sol. Answer (2)

Value of solar constant $= \left[\frac{R}{r}\right]^2 \sigma T^4$

Where,

R = Radius of sun

r = Distance of earth from sun

σ = Stefan's constant

T = Temperature of sun

$\frac{R}{r} = 4.65 \times 10^{-3}$ radians

$\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$

T = 5800 K

So substituting values we get

$S = (4.65 \times 10^{-3})^2 \times 5.67 \times 10^{-8} \times (5800)^4$

$\simeq 1360\ \text{Wm}^{-2}$

$\sim 21\ \text{Kcal m}^{-2}\ \text{min}^{-1}$

(Newton's Law of Cooling)

45. A body cools down from 80°C to 60°C in 10 minutes when the temperature of surroundings is 30°C. The temperature of the body after next 10 minutes will be

(1) 30°C (2) 48°C (3) 50°C (4) 52°C

Sol. Answer (2)

Apply newton's law of cooling

$$\ln\left(\frac{T_1 - T_0}{T_2 - T_0}\right) = Kt$$

$$\ln\left(\frac{80-30}{60-30}\right) = K \times 10 \qquad \ldots(1)$$

Let temperature of body after next 10 minutes = T

So,

$$\ln\left(\frac{60-30}{T-30}\right) = K \times 10 \qquad \ldots(2)$$

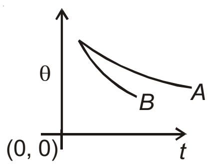
Using equation 1 and 2

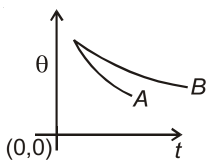
$$\ln\frac{5}{3} = \ln\frac{30}{T-30}$$

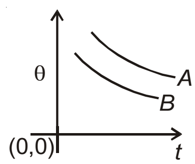
$30 \times 3 = 5T - 5 \times 30$

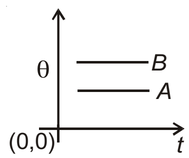
$\Rightarrow$ T = 48°C

46. Two bodies A and B of same mass, area and surface finish with specific heats S_A and S_B ($S_A > S_B$) are allowed to cool for given temperature range. Temperature varies with time as

(1) 

(2) 

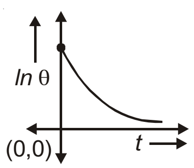
(3) 

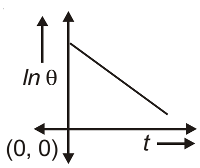
(4) 

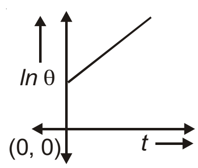
Sol. Answer (1)

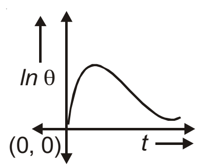
Body with more specific heat takes time to cool if initial temperature is same.

47. Instantaneous temperature difference between cooling body and the surroundings obeying Newton's law of cooling is θ. Which of the following represents the variation of $ln\ \theta$ with time t?

(1) 

(2) 

(3) 

(4) 

Sol. Answer (2)

$$\ln\left(\frac{T_f - T_0}{T - T_0}\right) = Kt$$

If θ is the instantaneous temperature than

$$\ln\left(\frac{\theta_i - \theta_0}{\theta - \theta_0}\right) = Kt$$

$$\begin{Bmatrix} \theta_i \longrightarrow \text{initial temperature} \\ \theta_0 \longrightarrow \text{temperature of surrounding} \end{Bmatrix}$$

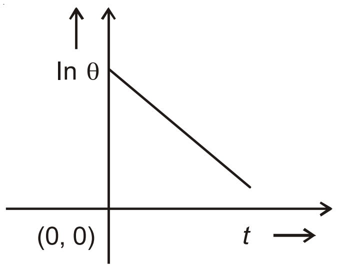
$\ln(\theta_i - \theta_0) - \ln(\theta - \theta_0) = KT$

$\ln(\theta - \theta_0) = -Kt + \ln(\theta_i - \theta_0)$

Comparing to

$y = mx + C$

We get a negative slope, so graph will be a straight line with decreasing slope.



SECTION - B

Objective Type Questions

(Measurement of Temperature)

1. A uniform thermometre scale is at steady state with its 0 cm mark at 20°C and 100 cm mark at 100°C. Temperature of the 60 cm mark is

(1) 48°C (2) 68°C

(3) 52°C (4) 58°C

Sol. Answer (2)

$$\frac{T-20}{100-20} = \frac{60-0}{100-0}$$

$$\frac{T-20}{80} = \frac{60}{100}$$

$T = 48 + 20 = 68°C$

2. If C_p and C_v denote the specific heats (per unit mass) of an ideal gas of molecular weight M, where R is the molar gas constant

(1) $C_p - C_v = R/M^2$ (2) $C_p - C_v = R$

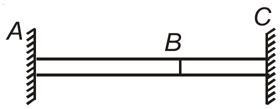
(3) $C_p - C_v = R/M$ (4) $C_p - C_v = MR$

Sol. Answer (3)

$C_p - C_v = \dfrac{R}{M}$ because C_p and C_v are given per unit mass.

(Thermal Expansion)

3. Two uniform rods *AB* and *BC* have Young's modulii 1.2 × 10^{11} N/m² and 1.5 × 10^{11} N/m² respectively. If coefficient of linear expansion of *AB* is 1.5 × 10^{-5}/°C and both have equal area of cross section, then coefficient of linear expansion of *BC*, for which there is no shift of the junction at all temperatures, is



(1) 1.5 × 10^{-5}/°C (2) 1.2 × 10^{-5}/°C (3) 0.6 × 10^{-5}/°C (4) 0.75 × 10^{-5}/°C

Sol. Answer (2)

Y_{AB} = 1.2 × 10^{11} N/m², Y_{BC} = 1.5 × 10^{11} N/m²

No shift of the junction at all

$$\therefore \quad \alpha L\Delta\theta = \frac{FL}{AY}$$

$$\Rightarrow \quad \alpha \propto \frac{1}{Y}$$

So, $\dfrac{\alpha_1}{\alpha_2} = \dfrac{Y_2}{Y_1}$

Substituting values, $\dfrac{1.5\times10^{-5}}{\alpha_2} = \dfrac{1.5\times10^{11}}{1.2\times10^{11}} \Rightarrow \alpha_2$ = 1.2 × 10^{-5}/°C

4. Coefficient of linear expansion of a vessel completely filled with Hg is 1 × 10^{-5}/°C. If there is no overflow of Hg on heating the vessel, then coefficient of cubical expansion of Hg is

(1) 4 × 10^{-5}/°C (2) > 3 × 10^{-5}/°C (3) ≤ 3 × 10^{-5}/°C (4) Data is insufficient

Sol. Answer (3)

Expansion in Hg volume ≤ expansion in container.

⇒ Volume coefficient of Hg ≤ 3 × Linear coefficient of expansion of vessel

≤ 3 × 1 × 10^{-5}/°C

$\gamma_{Hg} \le 3 \times 10^{-5}$/°C

5. A metallic tape gives correct value at 25ºC. A piece of wood is being measured by this metallic tape at 10ºC. The reading is 30 cm on the tape, the real length of wooden piece must be

(1) 30 cm (2) > 30 cm

(3) < 30 cm (4) Data is not sufficient

Sol. Answer (3)

At lesser temperature tape will decrease in length so the reading 30 cm on the tape is lesser than 30 cm in real.

6. In a thermostat two metal strips are used, which have different

(1) Length (2) Area of cross-section

(3) Mass (4) Coefficient of linear expansion

Sol. Answer (4)

Coefficient of linear expansion should be different.

7. The coefficient of linear expansion of a crystalline substance in one direction is $2 \times 10^{-4}/°C$ and in every direction perpendicular to it is $3 \times 10^{-4}/°C$. The coefficient of cubical expansion of crystal is equal to

(1) $5 \times 10^{-4}/°C$ (2) $4 \times 10^{-4}/°C$ (3) $8 \times 10^{-4}/°C$ (4) $7 \times 10^{-4}/°C$

Sol. Answer (3)

$\alpha_1 + \alpha_2 + \alpha_3 = \alpha$

$2 \times 10^{-4} + 3 \times 10^{-4} + 3 \times 10^{-4} = \alpha \Rightarrow 8 \times 10^{-4}/°C = \alpha$

(Specific Heat Capacity)

8. The molar specific heat at constant pressure of an ideal gas is $(7/2)R$. The ratio of specific heat at constant pressure to that at constant volume is

(1) $\frac{9}{7}$ (2) $\frac{7}{5}$ (3) $\frac{8}{7}$ (4) $\frac{5}{7}$

Sol. Answer (2)

$$C_p = \frac{7}{2}R$$

$$C_v = C_p - R = \frac{5}{2}R$$

$$\therefore \quad \frac{C_p}{C_v} = \frac{7}{5}$$

9. 50 g ice at 0°C is dropped into a calorimeter containing 100 g water at 30°C. If thermal capacity of calorimeter is zero then amount of ice left in the mixture at equilibrium is

(1) 12.5 g (2) 25 g (3) 20 g (4) 10 g

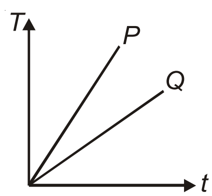
Sol. Answer (1)

Heat required to bring 100 g of water from 30°C to 0°C will be $Q = 100 \times 1 \times 30 = 3000$ cal

$\therefore$ Amount of ice that get melted = $\frac{3000}{80} = 37.5$ g

So amount left = 12.5 g

10. Heat energy at constant rate is given to two substances P and Q. If variation of temperature (T) of substances with time (t) is as shown in figure, then select the correct statement.



(1) Specific heat of P is greater than Q (2) Specific heat of Q is greater than P

(3) Both have same specific heat (4) Data is insufficient to predict it

Sol. Answer (2)

$\frac{dT}{dt}$ (slope) less means more specific heat.

(Change of State)

11. A bullet of mass 10 g moving with a speed of 20 m/s hits an ice block of mass 990 g kept on a frictionless floor and gets stuck in it. How much ice will melt if 50% of the lost KE goes to ice? (initial temperature of the ice block and bullet = 0°C)

(1) 0.001 g (2) 0.002 g (3) 0.003 g (4) 0.004 g

Sol. Answer (3)

50% of lost KE goes to melt ice

$$\Rightarrow \quad \frac{1}{2}\times\frac{1}{2}\times\frac{10\times20\times20}{1000}=1\,\text{J}$$

Amount of ice that melts $=\dfrac{1}{80\times4.2}=0.003$ g

12. Heat is being supplied at a constant rate to the sphere of ice which is melting at the rate of 0.1 gm/s. It melts completely in 100 s. The rate of rise of temperature thereafter will be

(1) 0.4°C/s (2) 2.1°C/s (3) 3.2°C/s (4) 0.8°C/s

Sol. Answer (4)

$$\frac{dQ}{dt}=\frac{dm}{dt}\times L \qquad [\because Q=mL]$$

$$\frac{dQ}{dt}=0.1\times80=8\text{ cal/gs}$$ also, $Q = ms\Delta t$

So $\dfrac{dQ}{dt}=ms\dfrac{dT}{dt}$

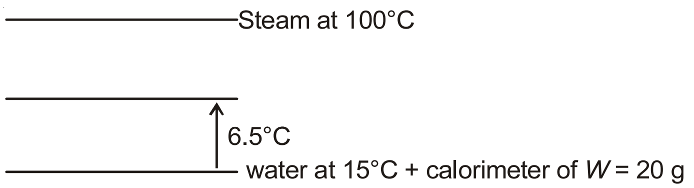
$$8=10\times1\times\frac{dT}{dt}$$ [$\because$ It melts in 100 s so total mass of sphere = 0.1 × 100 = 10 g]

$$8°\text{C/s}=\frac{dT}{dt}$$

13. In a calorimeter of water equivalent 20 g, water of mass 1.1 kg is taken at 288 K temperature. If steam at temperature 373 K is passed through it and temperature of water increases by 6.5°C then the mass of steam condensed is

(1) 17.5 g (2) 11.7 g (3) 15.7 g (4) 18.2 g

Sol. Answer (2)



Let mass of steam that gets condenced while the temperature of water is raised by 6.5°C = x g

So, heat released by steam = 540x cal + x × 1 × 78.5 [$Q = mL + ms\Delta T$]

This heat goes to the water + calorimeter system

Q required by water = 1100 × 1 × 6.5 = 7150 cal

Q required by calorimeter = 20 × 1 × 6.5 = 130 cal

$Q_{\text{released}} = Q_{\text{required}}$

$78.5\,x + 540\,x = 7150 + 130 \Rightarrow x \simeq 11.7$ g

(Heat Transfer)

14. 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? (σ stands for Stefan's constant.)

(1) $\left(\dfrac{4\pi R^2 Q}{\sigma}\right)^{1/4}$ (2) $\left(\dfrac{Q}{4\pi R^2\sigma}\right)^{1/4}$ (3) $\dfrac{Q}{4\pi R^2\sigma}$ (4) $\left(\dfrac{Q}{4\pi R^2\sigma}\right)^{-1/2}$

Sol. Answer (2)

$H = \sigma (4\pi R^2)T^4$ [$H = \sigma eAT^4$] for black body $e = 1$

$$\Rightarrow T = \left[\frac{Q}{\sigma 4\pi r^2}\right]^{1/4}$$

15. Gravitational force is required for

(1) Stirring of liquid (2) Convection (3) Conduction (4) Radiation

Sol. Answer (2)

Gravity is required for convection.

16. Which of the following processes is reversible?

(1) Transfer of heat by conduction (2) Transfer of heat by radiation

(3) Isothermal compression (4) Electrical heating of a nichrome wire

Sol. Answer (3)

In isothermal compression

Work done = Q (heat supplied)

$\therefore$ Isothermal compression is reversible

17. Solar constant (S) depends upon the temperature of the Sun (T) as

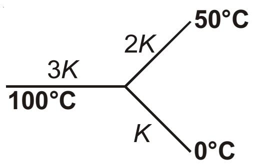
(1) $S \propto T$ (2) $S \propto T^2$ (3) $S \propto T^3$ (4) $S \propto T^4$

Sol. Answer (4)

$$S = \left[\frac{R}{r}\right]^2 \sigma T^4$$

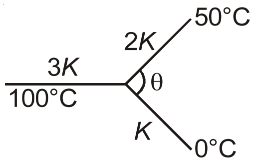
$S \propto T^4$

18. Three rods of same dimensions have thermal conductivities $3K$, $2K$ and K. They are arranged as shown, with their ends at 100°C, 50°C and 0°C. The temperature of their junction is



(1) 75°C (2) $\dfrac{200}{3}$ °C (3) 40°C (4) $\dfrac{100}{3}$ °C

Sol. Answer (2)



$3K(100 - \theta) + 2K(50 - \theta) = K\theta$

$300K - 3K\theta + 100K - 2K\theta = K\theta$

$400 = 6\theta$

$$\frac{400}{6} = \theta$$

$$\frac{200}{3} = \theta$$

19. If wavelength of maximum intensity of radiation emitted by Sun and Moon are 0.5×10^{-6} m and 10^{-4} m respectively, then the ratio of their temperature is

(1) $\frac{1}{10}$ (2) $\frac{1}{50}$ (3) 100 (4) 200

Sol. Answer (4)

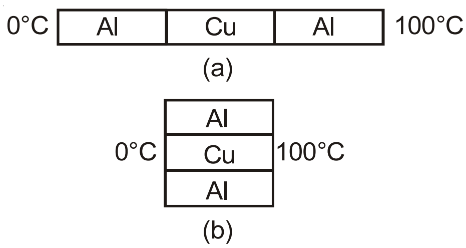
$\lambda_m T_1$ = Constant [Wien's law]

$\Rightarrow \lambda_1 T_1 = \lambda_2 T_2$

$0.5 \times 10^{-6} \times T_1 = 10^{-4} \times T_2$

$$\frac{T_1}{T_2} = 200$$

20. The three rods shown in figure have identical dimensions. Heat flows from the hot end at a rate of 40 W in the arrangement (a). Find the rates of heat flow when the rods are joined as in arrangement (b). (Assume K_{Al} = 200 W/m °C and K_{Cu} = 400 W/m °C)



(1) 75 W (2) 200 W (3) 400 W (4) 4 W

Sol. Answer (3)

(a) 

$\because$ The rods have identical dimensions.

Let their area of crossection be = A

and length be = L

So each rod would have heat resistance of

$$R = \frac{L}{KA}$$

$$R_{eff} = R_1 + R_2 + R_3$$

$$= \frac{L}{K_{Al}A} + \frac{L}{K_{Cu}A} + \frac{L}{K_{Al}A}$$

$$R_{eff} = \frac{L}{A} \times \frac{5}{400} \qquad [\because K_{Al} = 200,\ K_{Cu} = 400]$$

$$H_1 = \frac{\Delta T}{R_{eff}} = \frac{100}{\frac{L}{A} \times \frac{5}{400}} \qquad \ldots(1)$$

(b) When rods are connected in parallel

$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$R_{eff} = \frac{L}{A} \times 800$$

$$H_2 = \frac{100}{\frac{L}{A} \times 800} \qquad \ldots(2)$$

Dividng (2) by (1)

$$\frac{40}{H_2} = \frac{400}{800 \times 5} \Rightarrow H_2 = 400 \text{ W}$$

21. Two spheres of same material and radius r and $2r$ are heated to same temperature and are kept in identical surroundings, ratio of their rate of loss of heat is

(1) 1 : 2
(2) 1 : 4
(3) 1 : 6
(4) 1 : 8

Sol. Answer (2)

Heat loss $\propto$ Area $\propto$ (Radius)^2

$$\text{So } \frac{H_1}{H_2} = \left[\frac{r_1}{r_2}\right]^2 = \left[\frac{r}{2r}\right]^2 = \frac{1}{4}$$

22. If a graph is plotted by taking spectral emissive power along y-axis and wavelength along x-axis then the area below the graph above wavelength axis is

(1) Emissivity
(2) Total intensity of radiation
(3) Diffusivity
(4) Solar constant

Sol. Answer (2)

$$\int_0^\infty e_\lambda \, d\lambda = \text{ area under the graph of } e_\lambda \text{ and } \lambda$$

also it gives total radiated average power per unit surface area which is called total intensity of radiation.

23. A spherical black body with radius 12 cm radiates 450 W power at 500 K. If the radius is halved and temperature is doubled, the power radiated in watt would be

(1) 225 (2) 450 (3) 900 (4) 1800

Sol. Answer (4)

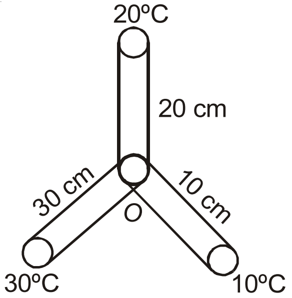
Power radiated $\propto r^2 T^4$

$$\frac{P_1}{P_2} = \left[\frac{r_1}{r_2}\right]^2 \left[\frac{T_1}{T_2}\right]^4$$

$$\frac{450}{P_2} = \left[\frac{r}{r/2}\right]^2 \left[\frac{T}{2T}\right]^4 = 1$$

$\Rightarrow$ P_2 = 1800 W

24. Three rods of same material, same area of cross-section but different lengths 10 cm, 20 cm and 30 cm are connected at a point as shown. What is temperature of junction *O*?



(1) 19.2°C (2) 16.4°C (3) 11.5°C (4) 22°C

Sol. Answer (2)

Let temperature of junction be = θ

Heat flowing to junction = heat out flowing

$$\frac{KA}{30}(30-\theta) = \frac{KA}{20}(\theta-20) + \frac{KA}{10}(\theta-10)$$

$$\frac{(30-\theta)}{3} = \frac{(\theta-20)}{2} + \frac{(\theta-10)}{1}$$

$$\frac{(30-\theta)}{3} = \frac{\theta-20+2\theta-20}{2}$$

$60 - 2\theta = 9\theta - 120$

$$\frac{180}{11} = \theta$$

16.36°C = θ

25. If transmission power of a surface is $\frac{1}{9}$, reflective power is $\frac{1}{6}$, then what is its absorptive power?

(1) $\frac{18}{13}$ (2) $\frac{13}{18}$ (3) $\frac{3}{15}$ (4) $\frac{15}{3}$

Sol. Answer (2)

$t + r + a = 1$

$a = 1 - (t + r)$

$$= 1 - \left(\frac{1}{9} + \frac{1}{6}\right)$$

$$a = \frac{13}{18}$$

26. A solid cylinder of length L and radius r is heat upto same temperature as that of a cube of edge length a. If both have same material, volume and allowed to cool under similar conditions, then ratio of amount of radiations radiated will be (Neglect radiation emitted from flat surfaces of the cylinder)

(1) $\frac{a}{3r}$ (2) $\frac{2a}{rL}$ (3) $\frac{a^2}{rL}$ (4) $\frac{\pi a^2}{2rL}$

Sol. Answer (1)

$\because$ Both have same volume

$\therefore$ $a^3 = \pi r^2 L$ ...(1)

Amount of radiation $\propto$ Surface area [$\because$ Temperature, material are same for both]

$$\frac{\text{Radiation cylinder}}{\text{Radiation cube}} = \frac{2\pi rL}{6a^2} = \frac{2\pi rL \,.\, a}{6a^3}$$

Using equation (1)

We get

$$\frac{R_{\text{cylinder}}}{R_{\text{cube}}} = \frac{a}{3r}$$

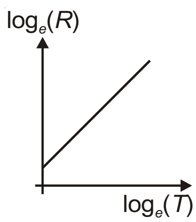
27. A very thin metallic shell of radius r is heated to temperature T and then allowed to cool. The rate of cooling of shell is proportional to

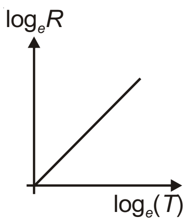
(1) rT (2) $\frac{1}{r}$ (3) r^2 (4) r^0

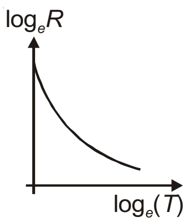
Sol. Answer (4)

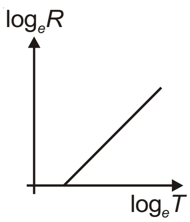
Rate of cooling depends on temperature of body, surrounding temperature, not on radius.

28. If an object at absolute temperature (T) radiates energy at rate R, then select correct graph showing the variation of $\log_e R$ with $\log_e(T)$.

(1) 

(2) 

(3) 

(4) 

Sol. Answer (1)

$R = eA\sigma T^4$

$\log_e R = eA\sigma \times 4 \log_e T$

directly proportional.

29. Two diagonally opposite corners of a square made of a four thin rods of same material, same dimensions are at temperature 40°C and 10°C. If only heat conduction takes place, then the temperature difference between other two corners will be

(1) 0°C (2) 10°C (3) 25°C (4) 15°C

Sol. Answer (1)

Arrangement is like resistances in wheat stone bridge

$\therefore$ No temperature difference between two outer corners.

30. Bottom of a lake is at 0°C and atmospheric temperature is –20°C. If 1 cm ice is formed on the surface in 24 h, then time taken to form next 1 cm of ice is

(1) 24 h (2) 72 h (3) 48 h (4) 96 h

Sol. Answer (2)

Time intervals to change thickness from 0 to x from x to $2x$ are in ratio of 1 : 3 : 5 : 7 ……

$\therefore$ $t_1 : t_2 = 1 : 3$

$= 24 : 24 \times 3$

$\Rightarrow$ $t_2 = 72$ hours

31. The power received at distance d from a small metallic sphere of radius $r(<<d)$ and at absolute temperature T is P. If temperature is doubled and distance reduced to half of initial value, then the power received at that point will be

(1) $4p$ (2) $8p$ (3) $32p$ (4) $64p$

Sol. Answer (4)

Solar constant $\propto \frac{T^4}{r^2}$

Solar constant equivalent to power received so

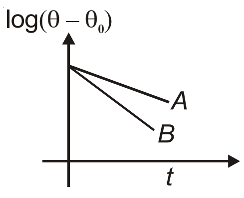
$$\frac{P_1}{P_2} = \frac{T_1^4}{r_1^2} \times \frac{r_2^2}{T_2^4}$$

$$\frac{P}{P_2} = \frac{T^4}{r^2} \times \frac{(r/2)^2}{(2T)^4}$$

$P_2 = 64p$

(Newton's Law of Cooling)

32. Two bodies A and B of equal masses, area and emissivity cooling under Newton's law of cooling from same temperature are represented by the graph. If θ is the instantaneous temperature of the body and θ_0 is the temperature of surroundings, then relationship between their specific heats is



(1) $S_A = S_B$ (2) $S_A > S_B$ (3) $S_A < S_B$ (4) None of these

Sol. Answer (2)

Body loosing its temperature soon means low specific heat $\Rightarrow S_A > S_B$

33. Assume that Solar constant is 1.4 kW/m^2, radius of sun is 7 × 10^5 km and the distance of earth from centre of sun is 1.5 × 10^8 km. Stefan's constant is 5.67 × 10^{-8} Wm^{-2} K^{-4}, find the approximate temperature of sun

(1) 5800 K (2) 16000 K (3) 15500 K (4) 8000 K

Sol. Answer (1)

$$S = \left[\frac{R}{r}\right]^2 \sigma T^4$$

$$1.4\times 10^3 = \left[\frac{7\times 10^5}{1.5\times 10^8}\right]^2 \times 5.67\times 10^{-8}\times T^4 \Rightarrow T = 5800 \text{ K}$$

SECTION - C

Previous Years Questions

1. The power radiated by a black body is P and it radiates maximum energy at wavelength, λ_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 **[NEET-2018]**

(1) $\frac{3}{4}$ (2) $\frac{4}{3}$

(3) $\frac{81}{256}$ (4) $\frac{256}{81}$

Sol. Answer (4)

We know, $\lambda_{max}T = \text{constant}$ (Wien's law)

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

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

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

$$\text{So, } \frac{P_2}{P_1} = \left(\frac{T'}{T}\right)^4 = \left(\frac{4}{3}\right)^4 = \frac{256}{81}$$

2. 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 **[NEET-2017]**

(1) 225 (2) 450 (3) 1000 (4) 1800

Sol. Answer (4)

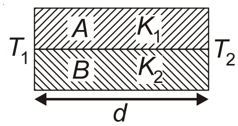
Rate of power loss, $r \propto R^2T^4$

$$\frac{r_1}{r_2} = \frac{R_1^2T_1^4}{R_2^2T_2^4} = 4\times\frac{1}{16}$$

$$\frac{450}{r_2} = \frac{1}{4} \Rightarrow r_2 = 1800 \text{ watt}$$

3. 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

[NEET-2017]



(1) $\frac{K_1+K_2}{2}$ (2) $\frac{3(K_1+K_2)}{2}$ (3) $K_1 + K_2$ (4) $2(K_1 + K_2)$

Sol. Answer (1)

Thermal current

$$H = H_1 + H_2 = \frac{K_1A(T_1-T_2)}{d}+\frac{K_2A(T_1-T_2)}{d}$$

$$\frac{K_{EQ}2A(T_1-T_2)}{d}=\frac{A(T_1-T_2)}{d}[K_1+K_2]$$

$$K_{EQ}=\left[\frac{K_1+K_2}{2}\right]$$

4. 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 **[NEET (Phase-2)-2016]**

(1) 50°C (2) More than 50°C

(3) Less than 50°C but greater than 0°C (4) 0°C

Sol. Answer (2)

Loss of heat by hot body = Gain of heat by cold body

$$T_{c_1}\Delta\theta_1 = T_{c_2}\Delta\theta_2$$

$$T_{c_1} > T_{c_2} \quad \Rightarrow \quad \Delta\theta_1 < \Delta\theta_2$$

5. 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

[NEET (Phase-2)-2016]

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

Sol. Answer (2)

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

$$\frac{3T-2T}{10}=K(2.5T-T)$$

$$\Rightarrow \frac{T}{10}=K(1.5)T$$

$$K=\frac{1}{15}$$

Now, $\frac{T-x}{10} = K\left(\frac{T+x}{2} - T\right)$

Solving $x = \frac{3T}{2}$

6. Coefficient of linear expansion of brass and steel rods are α_1 and α_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? **[NEET-2016]**

(1) $\alpha_1 l_1 = \alpha_2 l_2$ (2) $\alpha_1 l_2 = \alpha_2 l_1$ (3) $\alpha_1 l_2^2 = \alpha_2 l_1^2$ (4) $\alpha_1^2 l_2 = \alpha_2^2 l_1$

Sol. Answer (1)

$l_2' - l_1' = l_2 - l_1$

$\Rightarrow$ $l_2(1 + \alpha_2 \Delta t) - l_1(1 + \alpha_1 \Delta t) = l_2 - l_1$

$l_2 \alpha_2 = l_1 \alpha_1$

7. 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 3.4×10^5 J/kg and $g = 10$ N/kg] **[NEET-2016]**

(1) 68 km (2) 34 km (3) 544 km (4) 136 km

Sol. Answer (4)

$\frac{mgh}{4} = mL_f$

$\Rightarrow$ $h = \frac{4L_f}{g} = \frac{4 \times 3.4 \times 10^5}{10} = 136$ km

8. 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, $b = 2.88 \times 10^6$ nmK. Which of the following is **correct**? **[NEET-2016]**

(1) $U_2 > U_1$ (2) $U_1 = 0$ (3) $U_3 = 0$ (4) $U_1 > U_2$

Sol. Answer (1)

$T_1 = 5760$ K , $\lambda_m T = 2.88 \times 10^6$ nmK

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

λ_m = Wavelength corresponding to maximum energy $U_2 > U_1$

9. The value of coefficient of volume expansion of glycerin is 5×10^{-4} K^{-1}. The fractional change in the density of glycerin for a rise of 40°C in its temperature is **[Re-AIPMT-2015]**

(1) 0.010 (2) 0.015 (3) 0.020 (4) 0.025

Sol. Answer (3)

10. 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 **[AIPMT-2015]**

(1) 4.0 J/s (2) 44.0 J/s (3) 16.8 J/s (4) 8.0 J/s

Sol. Answer (1)

11. On observing light from three different stars P, Q and R , it was found that intensity of violet colour is maximum in the spectrum of P, the intensity of green colour is maximum in the spectrum of R and the intensity of red colour is maximum in the spectrum of Q. If T_P, T_Q and T_R are the respective absolute temperatures of P, Q and R then it can be concluded from the above observations that **[AIPMT-2015]**

(1) $T_P < T_Q < T_R$ (2) $T_P > T_Q > T_R$

(3) $T_P > T_R > T_Q$ (4) $T_P < T_R < T_Q$

Sol. Answer (3)

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}] **[AIPMT-2014]**

(1) 24 g (2) 31.5 g (3) 42.5 g (4) 22.5 g

Sol. Answer (4)

13. 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 **[AIPMT-2014]**

(1) 45°C (2) 20°C (3) 42°C (4) 10°C

Sol. Answer (1)

14. 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 **[NEET-2013]**

(1) Wien's displacement law (2) Kirchoff's law

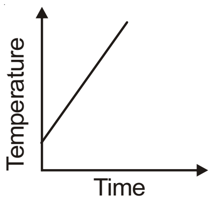
(3) Newton's law of cooling (4) Stefan's law

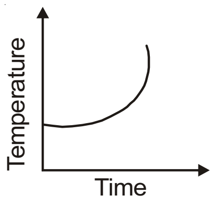
Sol. Answer (1)

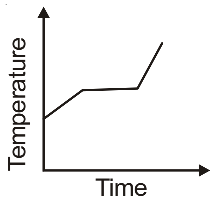
According to Wien's displacement Law, if temperature rises than λ decreases.

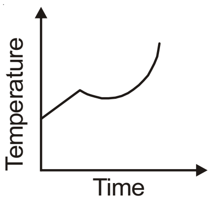
Which explains change of colour.

15. 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? **[AIPMT (Prelims)-2012]**

(1) 

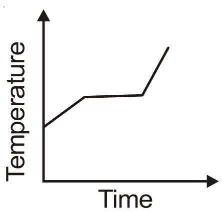
(2) 

(3) 

(4) 

Sol. Answer (3)

Liquid oxygen when heated will observe a rise in temperature as well as change in state one time which can be represented as



16. 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? **[AIPMT (Prelims)-2012]**

(1) $\left(\dfrac{4\pi R^2 Q}{\sigma}\right)^{1/4}$ (2) $\left(\dfrac{Q}{4\pi R^2\sigma}\right)^{1/4}$ (3) $\dfrac{Q}{4\pi R^2\sigma}$ (4) $\left(\dfrac{Q}{4\pi R^2\sigma}\right)^{-1/2}$

(σ stands for Stefan's constant)

Sol. Answer (2)

$Q = e\sigma AT^4$

For black body, $e = 1$

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

17. 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 = 3.36×10^5 J kg^{-1}) **[AIPMT (Mains)-2012]**

(1) 1.24 J/m/s/°C (2) 1.29 J/m/s/°C

(3) 2.05 J/m/s/°C (4) 1.02 J/m/s/°C

Sol. Answer (1)

In 1 hour, 4.8 kg ice melts

$\Rightarrow$ Heat supplied = $3.36 \times 10^5 \times 4.8$ J {$Q = L\,m$}

Heat supplied per second $= \dfrac{KA}{L} \times \Delta T$

$$\frac{3.36\times 10^5 \times 4.8}{1\times 3600} = \frac{K\times 0.36}{0.1}\times 100 \Rightarrow K = 1.24 \text{ J/m/s/°C}$$

18. When 1 kg of ice at 0°C melts to water at 0°C, the resulting change in its entropy, taking latent heat of ice to be 80 cal/°C, is **[AIPMT (Prelims)-2011]**

(1) 293 cal/K (2) 273 cal/K

(3) 8×10^4 cal/K (4) 80 cal/K

Sol. Answer (1)

Change in entropy, $\Delta S = \dfrac{\text{Heat absorbed}}{\text{Temperature at that instant}}$

$\Delta S = \dfrac{Q}{T}$ [$Q = mL_1$]

$\Delta S = \dfrac{1000\times 80}{273} \Rightarrow \Delta S = 293$ cal/K

19. 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? **[AIPMT (Prelims)-2010]**

(1) $\dfrac{Q}{4}$ (2) $\dfrac{Q}{16}$ (3) $2Q$ (4) $\dfrac{Q}{2}$

Sol. Answer (2)

Original volume $\propto r^2h$

New volume also same as the original volume

But new radius = $r/2$

Let new height be = h'

So $r^2h = \left(\frac{r}{2}\right)^2 h'$

$4h = h'$

$Q \propto \frac{KR^2}{L}$

$Q_2 \propto \frac{KR^2}{4 \times 4 \times L} = \frac{Q}{16}$

20. 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 (where σ is Stefan's constant) **[AIPMT (Prelims)-2010]**

(1) $\frac{\sigma r^2 T^4}{R^2}$ (2) $\frac{\sigma r^2 T^4}{4\pi r^2}$ (3) $\frac{\sigma r^4 T^4}{r^4}$ (4) $\frac{4\pi\sigma r^2 T^4}{R^2}$

Sol. Answer (1)

$P = \frac{Q}{4\pi R^2}$, $Q = \sigma \cdot 4\pi r^2 \cdot T^4$ $\Rightarrow$ $P = \frac{\sigma r^2 T^4}{R^2}$

21. 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

[AIPMT (Prelims)-2009]

(1) $\frac{dQ}{dt} = \frac{k(T_1 - T_2)}{LA}$ (2) $\frac{dQ}{dt} = kLA(T_1 - T_2)$ (3) $\frac{dQ}{dt} = \frac{kA(T_1 - T_2)}{L}$ (4) $\frac{dQ}{dt} = \frac{kL(T_1 - T_2)}{A}$

Sol. Answer (3)

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

22. 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 **[AIPMT (Prelims)-2009]**

(1) 50 (2) 112 (3) 80 (4) 60

Sol. Answer (2)

Radiation $\propto T^4$

So $\frac{R_1}{R_2} = \left(\frac{T_1}{T_2}\right)^4$

$\frac{7}{x} = \left(\frac{500}{1000}\right)^4$

x = 112 cal/cm^{2}s

23. 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? **[AIPMT (Prelims)-2008]**

(1) 139° W (2) 78° W (3) 117° W (4) 200° W

Sol. Answer (3)

$$\frac{39-0}{100-0}=\frac{T-39}{239-39}$$

117°W = T

24. 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 (where σ is the Stefan's constant) **[AIPMT (Prelims)-2007]**

(1) $\frac{r^2\sigma(t+273)^4}{R^2}$ (2) $\frac{4\pi r^2\sigma t^4}{R^2}$ (3) $\frac{r^2\sigma(t+273)^4}{4\pi R^2}$ (4) $\frac{16\pi^2 r^2\sigma t^4}{R^2}$

Sol. Answer (1)

$$P=\frac{Q}{4\pi R^2},\ Q=\sigma 4\pi r^2(t+273)^4$$

$$\Rightarrow\ P=\frac{r^2\sigma(t+273)^4}{R^2}$$

25. A black body is at 727°C. It emits energy at a rate which is proportional to **[AIPMT (Prelims)-2007]**

(1) $(727)^4$ (2) $(727)^2$ (3) $(1000)^4$ (4) $(1000)^2$

Sol. Answer (3)

$E \propto T^4$

So $E \propto (727 + 273)^4$

$\propto (1000)^4$

26. 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 : **[AIPMT (Prelims)-2006]**

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

Sol. Answer (4)

Wien's law $\left[\lambda \propto \frac{1}{T}\right]$

$$\Rightarrow\ \frac{T_1}{T_2}=\frac{\lambda_2}{\lambda_1}$$

$$\frac{1500\text{ K}}{2500\text{ K}}=\frac{\lambda}{5000\text{ Å}}\ \Rightarrow\ 3000\text{ Å}=\lambda$$

27. Which of the following circular 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 ? **[AIPMT (Prelims)-2005]**

(1) $r = 2r_0;\ l = 2l_0$ (2) $r = 2r_0;\ l = l_0$ (3) $r = r_0;\ l = l_0$ (4) $r = r_0;\ l = 2l_0$

Sol. Answer (2)

Rod with more $\frac{A}{L}$ ratio or $\frac{r^2}{L}$ ratio will conduct more heat $\left\{\because H \propto \frac{A}{L}\right\}$

28. The coefficients of linear expansion of brass and steel are α_1 and α_2 respectively. When we take a brass rod of length l_1 and steel rod of length l_2 at 0°C, then difference in their lengths ($l_2 - l_1$) will remain the same at all temperatures, if

(1) $\alpha_1^2 l_1 = \alpha_2^2 l_2$ (2) $\alpha_1 l_2 = \alpha_2 l_1$ (3) $\alpha_1 l_1 = \alpha_2 l_2$ (4) $\alpha_1 l_2^2 = \alpha_2 l_1^2$

Sol. Answer (3)

Let the temperature difference be = t

$l_1' = l_1 + l_1\alpha_1 t$

$l_2' = l_2 + l_2\alpha_2 t$ {Where l_2' and l_2 are increased lengths}

$l_2' - l_1' = l_2 - l_1$ {$\because$ difference of length is same at all temperature}

$l_2 + l_2\alpha_2 t - l_1 - l_1\alpha_1 t = l_2 - l_1$

$l_2\alpha_2 = l_1\alpha_1$

29. The density of water at 20°C is 998 kg/m³ and at 40°C 992 kg/m³. The coefficient of volume expansion of water is

(1) 10^{-4}/°C (2) 3×10^{-4}/°C (3) 2×10^{-4}/°C (4) 6×10^{-4}/°C

Sol. Answer (2)

$\rho_2 = \rho_1 (1 - \gamma\Delta T)$

$992 = 998 (1 - \gamma \times 20) \Rightarrow \gamma \simeq 3 \times 10^{-4}$/°C

30. If 1 g of steam at 100°C steam is mixed with 1 g of ice at 0°C, then resultant temperature of the mixture is

(1) 100°C (2) 230°C (3) 270°C (4) 50°C

Sol. Answer (1)

Heat required to convert phase of ice = 80 cal

Heat required to bring water at 0°C to water at 100°C = 100 cal

Total heat required = 180 cal

Heat available = 540 cal [L_u of 1 g steam]

$\therefore$ Final mixture will have steam + water

and when steam is present in mixture temperature has to be 100°C

31. 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

(1) 2 : 1 (2) 8 : 1 (3) 1 : 1 (4) 1 : 8

Sol. Answer (4)

$H \propto \frac{d^2}{L}$ $\left[H = \frac{KA}{L}(\Delta T)\right]$

So $\frac{H_1}{H_2} = \left[\frac{d_1}{d_2}\right]^2 \left[\frac{L_2}{L_1}\right] = \left[\frac{1}{2}\right]^2 \times \frac{1}{2} = \frac{1}{8}$

$\frac{H_1}{H_2} = \frac{1}{8}$

32. A cylindrical rod has temperatures T_1 and T_2 at its ends. The rate of flow of heat is Q (cal/s). If all the linear dimensions are doubled keeping temperatures constant, then rate of flow of heat Q_2 will be

(1) $4Q_1$ (2) $2Q_1$ (3) $\frac{Q_1}{4}$ (4) $\frac{Q_1}{2}$

Sol. Answer (2)

$$Q_1 = \frac{KA}{L}(T_2 - T_1) = \frac{K \cdot \pi r^2}{L}(T_2 - T_1) \quad \text{and} \quad Q_2 = \frac{K \cdot \pi(2r^2)}{(2L)}(T_2 - T_1) = \frac{2K \cdot \pi r^2}{L}(T_2 - T_1) = 2Q_1$$

33. 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

(1) $K_1A_1 = K_2A_2$ (2) $K_1A_1 = 4K_2A_2$ (3) $K_1A_1 = 2K_2A_2$ (4) $4K_1A_1 = K_2A_2$

Sol. Answer (2)

$\because$ ΔT is same for both the rods and lengths are also same $\Rightarrow \frac{H}{KA} = \text{constant}$

So $\frac{H_1}{K_1A_1} = \frac{H_2}{K_2A_2}$

$$\frac{H_1}{H_2} = \frac{K_1A_1}{K_2A_2} \qquad \left[\because \frac{H_1}{H_2} = 4\right]$$

$\Rightarrow 4K_2A_2 = K_1A_1$

34. Consider two rods of same lengths 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 flow of heat due to conduction is equal, then

(1) $K_1A_1 = K_2A_2$ (2) $\frac{K_1A_1}{S_1} = \frac{K_2A_2}{S_2}$ (3) $K_2A_1 = K_1A_2$ (4) $\frac{K_2A_1}{S_2} = \frac{K_1A_2}{S_1}$

Sol. Answer (1)

$$\frac{K_1A_1}{L}(T_2 - T_1) = \frac{K_2A_2}{L}(T_2 - T_1)$$

$\Rightarrow K_1A_1 = K_2A_2$

35. Unit of Stefan's constant is

(1) watt-m^2-K^4 (2) watt-m^2/K^4 (3) watt/m^2-K (4) watt/m^{2}K^4

Sol. Answer (4)

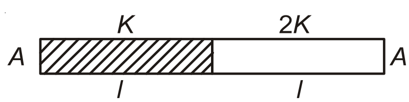
Unit of Stefan's constant is watt/m^{2}K^4

36. Consider a compound slab consisting of two pieces of same length and different materials having equal thicknesses and thermal conductivities K and 2 K, respectively. The equivalent thermal conductivity of the slab is

(1) 2/3 K (2) $\sqrt{2}$ K (3) 3K (4) 4/3 K

Sol. Answer (4)

Connected series way so,



$R = R_1 + R_2$ [For series]

$\frac{2l}{K'A} = \frac{l}{KA} + \frac{l}{2KA} \Rightarrow K' = 4/3\ K.$

37. Gravitational force is required for

(1) Stirring of liquid (2) Convection

(3) Conduction (4) Radiation

Sol. Answer (2)

Gravity is the necessary requirement for convection.

38. A black body is at a temperature of 500 K. It emits energy at a rate which is proportional to

(1) $(500)^3$ (2) $(500)^4$ (3) 500 (4) $(500)^2$

Sol. Answer (2)

$E \propto T^4$

So, $E \propto (500)^4$

39. Which of the following is closest to an ideal black body?

(1) Black lamp (2) Cavity maintained at constant temperature

(3) Platinum black (4) A lamp of charcoal heated to high temperature

Sol. Answer (2)

Cavity maintained at constant temperature is closest to black body.

40. For a black body at temperature 727°C, its rate of energy loss is 20 watt and temperature of surrounding is 227°C. If temperature of black body is changed to 1227°C then its rate of energy loss will be

(1) 304 W (2) $\frac{320}{3}$ W (3) 240 W (4) 120 W

Sol. Answer (2)

According to Stefan - Boltzmann's Law

$$\frac{dH}{dt} \propto T^4 - T_0^4$$

$$\frac{20}{x} = \frac{1000^4 - 5^4}{1500^4 - 5^4}$$

$$\Rightarrow \quad x = \frac{320}{3} \text{ W}$$

41. 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

(1) $t_1 < t_2 < t_3$ (2) $t_1 > t_2 > t_3$ (3) $t_1 = t_2 = t_3$ (4) $t_1 < t_2 = t_3$

Sol. Answer (1)

$$80°C \xrightarrow[t_1]{} 75°C \xrightarrow[t_2]{} 70°C \xrightarrow[t_3]{} 65°C$$

According to newton's law of cooling

$$\ln \frac{T_1 - T_0}{T_2 - T_0} = kt$$

Where T_0 is temperature of surroundings and T_1 and T_2 are initial and final temperature so more difference between T_1, T_2 and T_0 less is the time taken to reach T_2 from T_1

$\Rightarrow \quad t_3 > t_2 > t_1$

42. The Wien's displacement law expresses the relation between

(1) Wavelength corresponding to maximum intensity and temperature

(2) Radiation energy and wavelength

(3) Temperature and wavelength

(4) Colour of light and temperature

Sol. Answer (1)

$\lambda_{\text{Maximum}} \cdot$ Temperature = b(constant)

43. We consider the radiation emitted by the human body. Which one of the following statements is correct?

(1) The radiation emitted is in the infra-red region

(2) The radiation is emitted only during the day

(3) The radiation is emitted during the summers and absorbed during the winters

(4) The radiation emitted lies in the ultraviolet region and hence is not visible

Sol. Answer (1)

Wavelength lies in infra-red region as temperature of human body is very low.

44. If λ_m denotes the wavelength at which the radiative emission from a black body at a temperature T K is maximum, then

(1) $\lambda_m \propto T^4$

(2) λ_m is independent of T

(3) $\lambda_m \propto T$

(4) $\lambda_m \propto T^{-1}$

Sol. Answer (4)

Wien's displacement Law

$\lambda_m \cdot T = b$

So $\lambda_m \propto \dfrac{1}{T}$

45. A black body has wavelength corresponding to maximum intensity λ_m at 2000 K. Its corresponding wavelength at 3000 K will be

(1) $\dfrac{3}{2}\lambda_m$

(2) $\dfrac{2}{3}\lambda_m$

(3) $\dfrac{16}{81}\lambda_m$

(4) $\dfrac{81}{16}\lambda_m$

Sol. Answer (2)

$\lambda \propto \dfrac{1}{T}$ [Wien's Law]

So $\dfrac{\lambda_1}{\lambda_2} = \dfrac{T_2}{T_1}$

$\dfrac{\lambda_m}{\lambda} = \dfrac{3000}{2000}$

$\dfrac{2}{3}\lambda_m = \lambda$

46. 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?

(1) 320 kcal/m^2 min (2) 40 kcal/m^2 min (3) 160 kcal/m^2 min (4) 80 kcal/m^2 min

Sol. Answer (1)

$E \propto T^4$

$$\frac{20}{E} = \left(\frac{T}{2T}\right)^4$$

E = 320 kcal/m^2 minute

SECTION - D

Assertion - Reason Type Questions

1. A : Density of water is maximum at 4°C.

R : Water has both positive and negative temperature coefficients of volumetric expansions depending on the temperature range.

Sol. Answer (2)

A : is true

R : is true

But the correct explanation is that due to structural changes in moleculer of water we observe this anomalous behaviour.

2. A : A solid and a hollow sphere of same diameter and same material when heated for the same temperature rise, will expand by the same amount.

R : The change in volume is independent of the original mass but depends on original volume.

Sol. Answer (1)

A : is true

R : is true and correct explanation of Assertion.

3. A : Fahrenheit is the smallest unit for measuring temperature.

R : Fahrenheit was the first temperature scale used for measuring temperature.

Sol. Answer (2)

A : is true

R : is true

But correct explanation is Fahrenheit has 180 divisions where as other scales have 100 divisions.

4. A : Material used for making cooking utensils is the one having high specific heat and high conductivity.

R : Low conductivity means high specific heat.

Sol. Answer (4)

A : is false, material used for making cooking utensils is the one having low specific heat and high conductivity.

R : is false.

5. A : The value of the absorptive power and the emissivity has the same value for a single body at a particular temperature.

   R : Value of absorptive power is 1 for a black body.

Sol. Answer (2)

A : is true

R : is true

But the correct reason is black body radiate as much as it absorbs.

6. A : The reflectance of a black body is zero.

   R : Black body absorbs all radiations incident on it.

Sol. Answer (1)

A : is true

R : is true and correct explanation.

7. A : Evaporation of water is fast on the surface of moon as compared to earth.

   R : On the surface of moon temperature is much greater than the surface of earth.

Sol. Answer (3)

A : is true

R : is false, temperature of surface of moon is much less than that of earth's surface.

8. A : The internal energy of a solid substance increases during melting.

   R : Latent heat is required to melt a solid substance.

Sol. Answer (1)

A : is true

R : is true and correct explanation.

9. A : Transmission cables are not tightly fixed on the poles.

   R : During winters the length of cables decreases due to decrease in temperature, which can damage poles.

Sol. Answer (1)

A : True

R : True and correct explanation.

10. A : The thermal conductivity of a body depends on its material and dimensions.

    R : Thermal conductivity is proportional to length and inversely proportional to area cross-section of body.

Sol. Answer (4)

A : False, Thermal conductivity depends only on material

R : False, Thermal conductivity is constant for a given material

11. A : Eskimos make double wall houses of ice blocks.

    R : The air trapped between double walls prevents the conduction of heat energy from inside the house to outside it.

Sol. Answer (1)

A : True

R : True and correct explanation

12. A : The rate of growth of ice on the surface of a lake decreases with increase in thickness of ice layer.

R : Ice is poor conductor of heat energy.

Sol. Answer (1)

A : True

R : True and correct explanation.

13. A : Natural convection is not possible in an orbiting satellite.

R : Natural convection is not possible in gravity free space.

Sol. Answer (1)

A : True

R : True and correct explanation.

❑ ❑ ❑