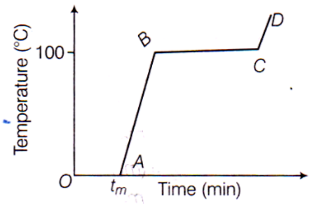
WEEKLY TEST MEDICAL PLUS - 03 TEST - 16 RAJPUR
SOLUTION Date 24-11-2019

[PHYSICS]

1. **(d)** A plot of temperature *versus* time showing the changes in the state of ice on heating (not to scale). (Also *refer solution no.*117.



$O \to A$: solid + liquid
$A \to B$: liquid
$B \to C$: liquid + gas
$C \to D$: gas

2. **(a)** The change of state from solid to liquid is called **melting** and from liquid to solid is called **fusion.** It is observed that the temperature remains constant until the entire amount of the solid substance melts. *e.g.*, Both the solid and liquid states of the substance coexist in thermal equilibrium during the change of states from solid to liquid. The temperature at which the solid and the liquid states of substance are in thermal equilibrium with each other is called its **melting point.**

3. -

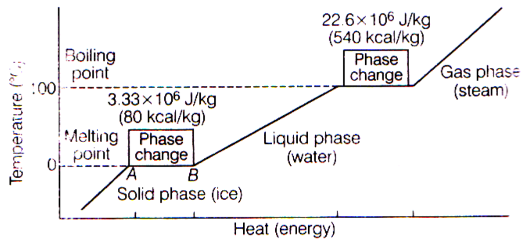
4 **(a)** The heat required during a change of state depends upon the heat of transformation and the mass of the substance undergoing a change of state. Thus, if mass *m* of a substance undergoes a change from one state to the other, then the quantity of heat required is given by

$$Q = mL \quad \text{or} \quad L = Q/m$$

where, L is known as latent heat and is a characteristic of the substance. Its SI unit is J kg^{-1}.

The value of L also depends on the pressure. Its value is usually quoted at standard atmospheric pressure.

5. **(c)** The latent heat for a solid-liquid state change is called the **latent heat of fusion** (L_f), and that for a liquid-gas state change is called the **latent heat of vaporisation** (L_v). A plot of temperature *versus* heat energy for a quantity of water is shown in figure.



For 1 kg mass $H_B - H_A$ = Latent heat of fusion.

6. **(a)** Heat lost by water $= m_i s_w (\theta_i - \theta_f)_w$

$= (0.30\text{ kg})(4186\text{ J kg}^{-1}\text{ K}^{-1})(50.0\text{ °C} - 6.7\text{ °C})$

$= 54376.14\text{ J}$

Heat required to melt ice $= m_i L_f = (0.15\text{ kg})\, L_f$

Heat required to raise temperature of ice water to final temperature $= m_i s_w (\theta_f - \theta_i)_f$

$= (0.15\text{ kg})(4186\text{ J kg}^{-1}\text{ K}^{-1})(6.7\text{ °C} - 0\text{ °C})$

$= 4206.93\text{ J}$

Heat lost = Heat gained.

$54376.14\text{ J} = (0.15\text{ kg})\, L_f + 4206.93\text{ J}$

$L_f = 3.34 \times 10^5\text{ J-kg}^{-1}$

7. *(b)* We have, mass of the ice $m = 3\,\text{kg}$

Specific heat capacity of ice, $Sice = 2100\ \text{J kg}^{-1}\text{K}^{-1}$

Specific heat capacity of water, S_{water}

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

Latent heat of fusion of ice, $S_{ice} = 3.35 \times 10^5\ \text{J kg}^{-1}$

Latent heat of steam, $L_{steam} = 2.256 \times 10^6\ \text{J kg}^{-1}$

Now, Q = heat required to convert 3 kg of ice at $-12°\text{C}$ to steam at $100°\text{C}$.

Q_1 = Heat required to convert ice at $-12°\text{C}$ to ice at $0°\text{C}$

$= mS_{ice}\,\Delta T_1 = 3 \times 2100 \times [0-(-12)]°\text{C} = 75600\ \text{J}$

Q_2 = Heat required to melt ice at $0°\text{C}$ to water at $0°\text{C}$.

$= mL_{ice} = 3 \times (3.35 \times 10^5\ \text{J kg}^{-1}\text{K}^{-1})$

$= 1005000\ \text{J}$

Q_3 = Heat required to convert

Water at $0°\text{C}$ to water at $100°\text{C}$.

$= ms_w\Delta T_2 = (3\ \text{kg})(4186\ \text{J Kg}^{-1}\text{K}^{-1}) \times (100°\text{C})$

$Q_3 = 1255800\ \text{J}$

Q_4 = Heat required to convert water at $100°\text{C}$ to steam at $100°\text{C}$

$= mL_{steam} = 3 \times (2.256 \times 10^6\ \text{J kg}^{-1}\text{K}^{-1}) = 6768000\ \text{J}$

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

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

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

8.

(b) Here, $m = 60\,\text{kg} = 60 \times 10^3\,\text{g}$, $c = 0.83\ \text{cal-g}^{-1}\,°\text{C}^{-1}$

$Q = 200\ \text{kcal} = 2 \times 10^6\ \text{cal}$

Amount of heat required for a person.

$\therefore \quad Q = mc\Delta T$

$$\Rightarrow \quad \Delta T = \frac{Q}{mc} = \frac{2 \times 10^6}{60 \times 10^3 \times 0.83}$$

$= 40.16\,°\text{C}$

9. *(b)* Heat lost by water in cooling from 25°C to 10°C

$Q = mc\Delta T = 200 \times 1 \times (25-10) = 3000\ \text{cal}$

Here, gained by ice at $-14°\text{C}$ to change into water at 10°C.

$Q = (mc\Delta T)_{ice} + mL + (mc\Delta T)_{water}$

$= m \times 0.5 \times 14 + m \times 80 + m \times 1 \times 10$

$= 97\ \text{m cal}$

According to principle of calorimetry, $97\,m = 3000$

Mass of ice $(m) = \frac{3000}{97} = 31\,\text{g}$

10. *(a)* Given, $L_1 = L_2 = L = 0.1\,\text{m}$, $A_1 = A_2 = A = 0.02\,\text{m}^2$

$K_1 = 79\ \text{W m}^{-1}\text{K}^{-1}$, $K_2 = 109\ \text{W m}^{-1}\text{K}^{-1}$, $T_1 = 373\,\text{K}$ and $T_2 = 273\,\text{K}$.

Under steady state condition, the heat current (H_1) through iron bar is equal to the heat current (H_2) through brass bar.

So, $H = H_1 = H_2$

$$= \frac{K_1 A_1 (T_1 - T_0)}{L_1} = \frac{K_2 A_2 (T_0 - T_2)}{L_2}$$

For $A_1 = A_2 = A$ and $L_1 = L_2 = L$, this equation leads to

$K_1 (T_1 - T_0) = K_2 T_0 - T_2$

Thus, the junction temperature T_0 of the two bars is

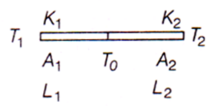
$$T_0 = \frac{(K_1 T_1 + K_2 T_2)}{(K_1 + K_2)}$$

$$= \frac{(79\ \text{W m}^{-1}\text{K}^{-1})(373\,\text{K}) + (109\ \text{W m}^{-1}\text{K}^{-1})(273\,\text{K})}{79\ \text{W m}^{-1}\text{K}^{-1} + 109\ \text{W m}^{-1}\text{K}^{-1}}$$

$= 315\,\text{K}$

11. *(b)* Thermal conductivity of the compound bar *i.e.*,

$$\frac{K_1 A_1 T_1 - T_0}{L_1}$$



$$\frac{K_2 A_2 (T_0 - T_2)}{L_2}$$

$$= \frac{K_{eq} A_{eq} (T_1 - T_2)}{L_1 + L_2}$$

For, $A_1 = A_2 = A_{eq}$ and $L_1 = L_2 = L$

$$K_1(T_1 - T_0) = K_2(T_0 - T_2) = K_{eq}\frac{(T_1 - T_2)}{2}$$

From first equality, $K_1T_1 - K_1T_0 = K_2T_0 - K_2T_2$

$$\Rightarrow \quad T_0 = \frac{K_1T_1 + K_2T_2}{K_1 + K_2}$$

$$\text{So,} \quad K_1\left(T_1 - \frac{K_1T_1 + K_2T_2}{K_1 + K_2}\right) = K_{eq}\left(\frac{T_1 - T_2}{2}\right)$$

$$\Rightarrow K_1\left(\frac{K_2(T_1 - T_2)}{K_1 + K_2}\right) = K_{eq}\left(\frac{T_1 - T_2}{2}\right) = K_{eq} = \frac{2K_1K_2}{K_1 + K_2}$$

$$K_{eq} = \frac{2K_1 K_2}{K_1 + K_2}$$

$$= \frac{2 \times (79\ \text{W m}^{-1}\text{K}^{-1}) \times (109\ \text{W m}^{-1}\text{K}^{-1})}{79\ \text{W m}^{-1}\text{K}^{-1} + 109\ \text{W m}^{-1}\text{K}^{-1}}$$

$= 91.6\ \text{W m}^{-1}\text{K}^{-1}$

Heat current (measured in Joule/sec) is analogus to electric current (measured in coulomb/sec)

12. *(b)* Heat current flows through the compound bar *i.e.*,

$$H' = H = \frac{K_{eq}\, A\,(T_1 - T_2)}{2L}$$

$$= \frac{(91.6\,\text{W m}^{-1}\text{K}^{-1}) \times (0.02\,\text{m}^2) \times (373\,\text{K} - 273\,\text{K})}{2 \times (0.1\,\text{m})}$$

$$= 916.1\,\text{W} = 916.1\,\text{Js}^{-1}$$

13. *(b)* Convection is a mode of heat transfer by actual motion of matter. It is possible only in fluids. Convection can be natural or forced. In natural convection, gravity plays an important part.

14. *(b)* Here, $A = 1000\,\text{cm}^2$, $x = 0.4\,\text{cm}$,

$$T_1 - T_2 = 37 - (-5) = 42°\text{C}$$

$$K = 2.2 \times 10^{-3}\,\text{cal s}^{-1}\,\text{cm}^{-1}\,\text{K}^{-1}$$

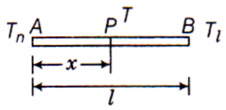
Rate of loss of heat

$$= H = \frac{Q}{t} = \frac{KA\,(T_1 - T_2)}{x}$$

$$= \frac{2.2 \times 10^{-3}\text{cal -s}^{-1}\text{cm}^{-1}\text{K}^{-1} \times 1000\,\text{cm}^{-2} \times 42}{0.4\text{cm}}$$

$$= 231\,\text{cal s}^{-1}$$

15. *(b)*



T_h = Higher temperature

T_l = Lower temperature

Heat current $H = \dfrac{\Delta Q}{\Delta t} = \dfrac{KA(T_h - T_l)}{l} = \dfrac{KA(T_h - T)}{x}$

$\Rightarrow \quad \dfrac{x}{l}(T_h - T_l) = T_h - T$

$\Rightarrow \quad T = T_h - \left(\dfrac{T_h - T_l}{l}\right)x$

$\Rightarrow$ T decreases linearly with x from T_h to T_l.

16. *(b)* Suppose area of the bottom of the tank = $A\,\text{cm}^2$

Volume of water that vaporises in 9 min (or 540 s)

$$= A \times 1\,\text{cm}^3$$

Mass of water that vaporises in 540 s

$$= A\,\text{cm}^2 \times 1\,\text{g cm}^{-3} = \text{Ag}$$

$\therefore \qquad Q = mL = A \times 540\,\text{cal}$

But $\qquad Q = \dfrac{KA\,(T_1 - T_2)}{x} \times t$

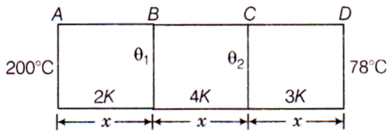
or $\qquad T_1 - T_2 = \dfrac{Qx}{KAt}$

$$= \frac{A \times 540 \times 2}{0.2 \times A \times 540} = 10$$

Total temperature of the furnance *i.e.*,

$$T_1 = T_2 + 10 = 100 + 10 = 110°\text{C}$$

17. *(a)* Suppose θ_1 and θ_2 be the temperatures of junctions B and C, respectively.



In the steady state, the rate of flow of heat through each bar will be same.

$$\frac{Q}{t} = \frac{2K \times A\,(200 - \theta_1)}{x}$$

$$= \frac{4K \times A\,(\theta_1 - \theta_2)}{x}$$

$$= \frac{3K \times A\,(\theta_2 - 18)}{x}$$

$$2\,(200 - \theta_1) = 4\,(\theta_1 - \theta_2) = 3(\theta_2 - 18)$$

$200 - \theta_1 = 2\theta_1 - 2\theta_2$ and $4\theta_1 - 4\theta_2 = 3\theta_2 - 54$

$\Rightarrow 3\theta_1 - 2\theta_2 = 200$ and $4\theta_1 - 7\theta_2 = -54$

$\Rightarrow \qquad (-8 + 21)\theta_2 = (800 + 162)$

$\Rightarrow \quad \theta_2 = \dfrac{962}{13} = 74°\text{C}$

$\theta_1 = \dfrac{200 + 2 \times 74}{3} = 116°\text{C}$

18. *(b)* The rate of loss of heat depends on the difference in temperature between the body and its surroundings. Also, *refer to solution.no.* 183.

19. *(c)* According to Newton's law of cooling, the rate of loss of heat, $-dQ/dt$ of the body is directly proportional to the difference of temperature $\Delta T = (T_2 - T_1)$ of the body and the surroundings. The law holds good only for small difference of temperature. Also, the loss of heat by radiation depends upon the nature of the surface of the body and the area of the exposed surface. We can write

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

where, k is a positive constant depending upon the area and nature of the surface of the body. Suppose a body of mass m and specific heat capacity s is at temperature T_2. Let T_1 be the temperature of the surroundings. If the temperature falls by a small amount dT_2 in time dt, then the amount of heat lost is

$$dQ = ms\,dT_2$$

$\therefore$ Rate of loss of heat is given by

$$\frac{dQ}{dt} = ms\frac{dT_2}{dt}$$

From equation, $-\dfrac{dQ}{dt} = k\,(T_2 - T_1)$

and $\qquad \dfrac{dQ}{dt} = ms\dfrac{dT_2}{dt}$

$\Rightarrow \qquad -ms\dfrac{dT_2}{dt} = k\,(T_2 - T_1)$

$\Rightarrow \qquad \dfrac{dT_2}{T_2 - T_1} = \dfrac{k}{ms}dt = -k\,dt$

where, $\qquad K = k\,/\,\text{ms}$

On integrating, $\log_e\,(T_2 - T_1) = -Kt + C$

$\Rightarrow \qquad T_2 = T_1 + C'e^{-Kt}$, where $C' = e^c$

Above equation enables to calculate the time of cooling of a body through a particular range of temperature.

20. **(c)** The loss of heat by radiation depends upon the nature of surface of the body and the area exposed surface.

Also, *refer to solution no.* 186.

Heat radiated per unit time, by body

$= \text{Heat current} = H = \frac{\Delta Q}{\Delta t} = \varepsilon\sigma A T^4$

Here, ε = Emissivity if body depend on nature of suface of body

A = Exposed area of the body

σ = Stefan-Boltzmann constant

T = Temperature of body

If surrounding temperature is T_s, then net loss of thermal energy by body per unit time $= \varepsilon\sigma A(T^4 - T_5{}^4)$.

21. **(d)** In first case, $T_1 = 60°C$, $T_2 = 40°C$

$T_0 = 10°C, t = 7 \text{ min} = 420 \text{ s}.$

According to Newton's law of cooling, we get

$$mc\frac{T_1 - T_2}{t} = k\left[\frac{T_1 + T_2}{2} - 10\right]$$

$$mc\frac{(60-40)}{420} = k\left[\frac{60+40}{2} - 10\right]$$

$$mc \times \frac{20}{420} = k \times 40$$

In second case, $T_1 = 40°C, T_2 = ?, T_0 = 10°C$

and $t = 7 \text{ min} = 420 \text{ s}$

$$mc \times \frac{40 - T_2}{420} = k\left[\frac{40 + T_2}{2} - 10\right]$$

On dividing Eq. (ii) by Eq. (i), we get

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

$$20 + \frac{T_2}{2} - 10 = 80 - 2T_2$$

On solving, we get $T_2 = 28°C$.

22. **(c)** Power radiated *i.e.*, $E = A\sigma T^4 = 4\pi r^2 \sigma T^4$

When radius is halved and temperature is doubled, power radiated becomes,

$$E' = 4\pi\left[\frac{r}{2}\right]^2 \times \sigma\ (2T)^4 = 4 \times 4\pi r^2\ \sigma T^4 = 4E$$

$$= 4 \times 450 = 1800 \text{ W}$$

23. **(a)** Here, in Ist case, $T_1 = 81°C$, $T_2 = 79°C$, $T_0 = 30°C$ and $t = 1$ min. As fall in temperature, in accordance with Newton's law of cooling expression is

$$-\frac{dT}{dt} = K(T - T_0), \text{ we can write}$$

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

$$\frac{81 - 79}{1 \text{min}} = -K\left[\frac{81 + 79}{2} - 30\right]$$

$$\Rightarrow \quad \frac{2}{1 \text{min}} = -K \times 50 \quad \text{...(i)}$$

and in 2nd case, $T_1' = 61°C$, $T_2' = 59°C$. If time of cooling be t', then

$$\frac{61 - 59}{t'} = K\left[\frac{61 + 59}{2} - 30\right] \text{ or } \frac{2}{t'} = -K \times 30 \quad \text{...(ii)}$$

On dividing Eq. (i) by Eq. (ii), we get

$$t' = \frac{50}{30}\text{min} = \frac{5}{3}\text{min} = 1 \text{min } 40 \text{ s}$$

24. **(b)** When a metallic rod is heated it expands. Its moment of inertia (I) about a perpendicular bisector increases. According to law of conservation of angular momentum, its angular speed (ω) decreases, since $\omega \propto 1/I$.

25. **(b)** According to linear expansion, we get

$$L = L_0(1 + \alpha\Delta\theta)$$

$$\frac{L_1}{L_2} = \frac{1 + \alpha(\Delta\theta_1)}{1 + \alpha(\Delta\theta_2)} = \frac{10}{L_2}$$

$$= \frac{1 + 11 \times 10^{-6} \times 20}{1 + 11 \times 10^{-6} \times 19}$$

$$\Rightarrow \quad L_2 = 9.99989$$

Length is shorter by

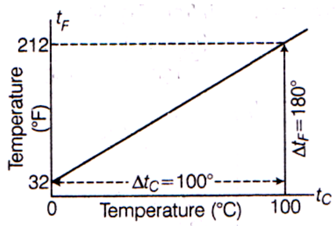
$$= 10 - 9.99989 = 0.00011 = 11 \times 10^{-5} \text{ cm}$$

26. **(a)** Here, coefficient of volumetric expansion *i.e.*,

$$\rho = \frac{\Delta V}{V \times \Delta T} = \frac{0.24}{100 \times 40} = 6 \times 10^{-5}/°C$$

$$\Rightarrow \quad \alpha = \frac{\rho}{3} = 2 \times 10^{-5}/°C$$

27 **(d)** A relationship for converting between the two scales may be obtained from a graph of Fahrenheit temperature (t_F) *versus* Celsius temperature (t_C) in a straight line whose equation is



$$\frac{t_F - 32}{180} = \frac{t_C}{100}$$

28. *(d)* Let initial temperature in Fahrenheit and Celsius scale be t_{F_1} and t_{C_1}, respectively and the final temperature be t_{F_2} and t_{C_2}, respectively.

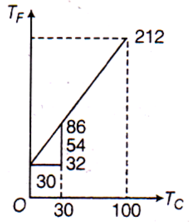
From relation, $\dfrac{t_F - 32}{180} = \dfrac{t_C}{100}$

or, $\dfrac{t_{F_1} - 32}{180} = \dfrac{t_{C_1}}{100}$ ...(i)

or, $\dfrac{t_{F_2} - 32}{180} = \dfrac{t_{C_2}}{100}$ ...(ii)

Subtracting Eq. (i) from Eq. (ii),

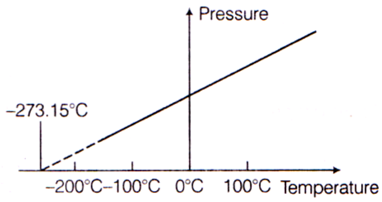
$$\frac{(t_{F_2} - t_{F_1})}{180} = \frac{t_{C_2} - t_{C_1}}{100}$$



Given, $t_{C_2} - t_{C_1} = 30\,°C$

$\Rightarrow$ $t_{F_2} - t_{F_1} = \dfrac{180}{100} \times 30°F = 54°F$

29. *(c)* Low density gases obey gas laws, which may be combined into a single relationship.



Notice that, since pV = constant and V/T = constant for a given quantity of gas, then pV/T should also be a constant.

This relationship is known as ideal gas law. It can be written in a more general form that applies not just to a given quantity of a single gas but to any quantity of any dilute gas and is known as **ideal gas equation.**

$$\frac{pV}{T} = \mu R$$

or $$pV = \mu RT$$

where, μ is the number of moles in the sample of gas and R is called universal gas constant.

$$R = 8.31\ \text{J mol}^{-1}\,\text{K}^{-1}$$

In equation $pV = \mu RT$, we have learnt that the pressure and volume are directly proportional to temperature $pV \propto T$. This relationship allows a gas to be used to measure temperature in a constant volume gas thermometer. Holding the volume of a gas constant, it gives $p \propto T$.

Thus, with a constant volume gas thermometer, temperature is read in terms of pressure. A plot of pressure *versus* temperature gives a straight line in this case.

30 *(a)* If heat absorbed is enough to raise the temperature of the body, then expansion occurs. The increase in the dimensious of a body due to the increase in its temperature is called thermal expansion.

31. *(d)* It is our common experience that most substances expand on heating and contract on cooling. A change in the temperature of a body causes change in its dimensions.

32. *(d)* Considering the fractional change in volume, $\dfrac{\Delta V}{V}$, of a substance for temperature change ΔT and define the coefficient of volume expansion, α_V as

$$\alpha_V = \left(\frac{\Delta V}{V}\right)\frac{1}{\Delta T}$$

33. *(a)* Let l be the length and A the cross-sectional area of the brass wire clamped rigidly between two supports. When it is cooled, it contracts in length and exerts a pulling force on each support. As a consequence of Newton's third law, a tension is developed in the wire.

If $-\Delta l$ be the contraction in length when the temperature falls through $-\Delta T$, we have

$$-\Delta l = \alpha l(-\Delta T)$$

where, α is the coefficient of linear expansion of brass.

$\therefore$ Longitudinal strain in the wire, $\dfrac{\Delta l}{l} = \alpha \Delta T$

The corresponding stress is $Y \times$ strain $= Y\alpha\Delta T$

The tension F developed in the wire is, therefore

F = Stress $\times$ Cross-sectional area $= Y\alpha\Delta T \times A = YA\alpha\Delta T$

Here, $A = \pi r^2 = 3.14\,(1.0 \times 10^{-3}\ \text{m})^2 = 3.14 \times 10^{-6}\ \text{m}^2$

and $\Delta T = 27° - (-39°) = 66°C$

$\therefore F = (0.91 \times 10^{11}\ \text{Nm}^{-2})\,(3.14 \times 10^{-6}\ \text{m}^2)\,(2.0 \times 10^{-5}\ °C^{-1})\,(66°C)$

$= 377\ \text{N} = 3.77 \times 10^2\ \text{N}.$

34. Temperature of interface,

$$\theta = \frac{K_1\theta_1 l_2 + K_2\theta_2 l_1}{K_1 l_2 + K_2 l_1}$$

It is given that $K_{Cu} = 9K_s$. So, if $K_s = K_1 = K$, then

$$K_{Cu} = K_2 = 9K$$

$$\Rightarrow \quad \theta = \frac{9K \times 100 \times 6 + K \times 0 \times 18}{9K \times 6 + K \times 18}$$

$$= \frac{5400\,K}{72\,K} = 75°C$$

35. Total energy radiated from a body

$$Q = A\varepsilon\sigma T^4 t \quad \text{or} \quad \frac{Q}{t} \propto AT^4$$

$$\frac{Q}{t} \propto r^2 T^4 \qquad (\because A = 4\pi r^2)$$

$$\frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^2\left(\frac{T_1}{T_2}\right)^4 = \left(\frac{8}{2}\right)^2\left[\frac{273+127}{273+527}\right]^4 = 1$$

36. According to Wien's displacement law,

$$\lambda_m T = b \quad \text{or} \quad \lambda_m \propto \frac{1}{T}$$

where, b is Wien's constant whose value is 2.9×10^{-3} mK.

$$\frac{(\lambda_m)_S}{(\lambda_m)_F} = \frac{T_F}{T_S}.$$

or $$T_F = T_S \times \frac{(\lambda_m)_S}{(\lambda_m)_F} = 5500\text{ K} \times \frac{(5.5 \times 10^{-7}\text{ m})}{(11 \times 10^{-7}\text{ m})} = 2750\text{ K}$$

37. According to Wien's displacement law,

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

$$\therefore \quad \frac{(\lambda_m)_1}{(\lambda_m)_2} = \frac{T_2}{T_1}$$

Here, $$\frac{T_1}{T_2} = \frac{3}{2}, (\lambda_m)_1 = 4000\text{ Å} = 4000 \times 10^{-10}\text{ m}$$

$$\therefore \quad (\lambda_m)_2 = \frac{4000 \times 10^{-10} \times 3}{2} = 6000\text{ Å}$$

38. The surface temperature of the stars is determined using Wien's displacement law. According to this law, $\lambda_m T = b$, where, b is Wien's constant, whose value is 2.898×10^{-3} mK.

39. Heat is extracted from the source means heat is given to the system (or gas) or Q is positive. This is positive only along the path ABC.

Heat supplied,

$$\therefore \quad Q_{ABC} = \Delta U_{ABC} + W_{ABC}$$

$$= nC_V(T_f - T_i) + \text{Area under } p\text{-}V \text{ graph}$$

$$\left[\text{For monoatomic gas, } C_V = \frac{3R}{2}\right]$$

$$= n\left(\frac{3}{2}R\right)(T_C - T_A) + 2p_0V_0$$

$$= \frac{3}{2}(nRT_C - nRT_A) + 2p_0V_0$$

$$= \frac{3}{2}(p_CV_C - p_AV_A) + 2p_0V_0$$

$$= \frac{3}{2}(4p_0V_0 - p_0V_0) + 2p_0V_0 = \frac{13}{2}p_0V_0$$

40. The work done during the process from P to Q = area $PQRSTP$ (positive sign is to be taken due to expansion along PQ)

Area of triangle PQR + area of rectangle $PRST$

$$= \frac{1}{2} \times 2V \times 2p + p \times 2V = 4pV$$

Work done during process from R to P = – Area $RSTP$ (negative sign due to compression in atom RP)

$$= -ST \times PT = -2V \times 1p = -2pV$$

Hence, the work done in the complete cycle

$$= 4pV - 2pV = 2pV$$

41. The work done = area of p-V graph

$$= \text{area of triangle } ABC$$

$$= \frac{1}{2} \times 3p \times 2V = 3pV$$

42. Work done, $\Delta W = p\Delta V$

At constant pressure

$$\Delta W = p(V_f - V_i) = nR(T_f - T_i)$$

At constant temperature,

$$\Delta W = nRT \ln\left(\frac{V_f}{V_i}\right) = nRT \ln\left(\frac{p_i}{p_f}\right)$$

$$\therefore \quad \Delta W_{AB} = 1 \times R \times (2T - T) = RT$$

$$\Delta W_{BC} = 1 \times R \times 2T \ln\frac{2p}{p} = 2RT \ln 2$$

$$\Delta W_{CD} = 1 \times R \times (T - 2T) = -RT$$

$$\Delta W_{DA} = 1 \times R \times T \ln\left(\frac{p}{2p}\right) = RT \ln\left(\frac{1}{2}\right)$$

Net work done in the complete cycle is

$$\Delta W = \Delta W_{AB} + \Delta W_{BC} + \Delta W_{CD} + \Delta W_{DA}$$

$$= RT + 2RT \ln 2 - RT + RT \ln\left(\frac{1}{2}\right)$$

$$= 2RT \ln 2 + RT \ln 1 - RT \ln 2$$

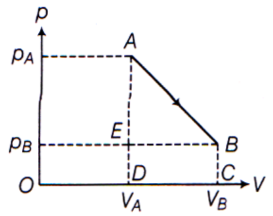
$$= 2RT \ln 2 - RT \ln 2 = RT \ln 2 \quad (\because \ln 1 = 0)$$

43. The area under p-V diagram = Work done

or $$W = AD \times DC = (2 \times 10^5 - 1 \times 10^5)\text{ Nm}^{-2} \times (4 - 2) \times 10^{-6}\text{m}^3$$

$$= 1 \times 10^5 \times 2 \times 10^{-6}\text{J} = 0.2\text{ J}$$

44. The p-V diagram is shown as below



Work done = area of $ABCDEA$

$$= \text{area of } \Delta ABE + \text{area of rectangle } BCDE$$

$$= \frac{1}{2}(p_A - p_B)(V_B - V_A) + p_B(V_B - V_A)$$

$$= \left[\frac{1}{2}(p_A - p_B) + p_B\right](V_B - V_A)$$

$$= \frac{1}{2}(p_A + p_B)(V_B - V_A)$$

45. Since, work is done by the system, so it is positive. Therefore,

$$\Delta W = 30\text{ J}$$

Heat given to the system, $\Delta Q = 40$ J

According to first law of thermodynamics, change in internal energy is given by

$$\Delta U = \Delta Q - \Delta W = 40 - 30 = 10\text{ J}$$