HINTS & SOLUTIONS

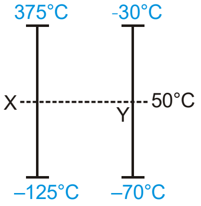
EXERCISE - 1

Single Choice

1. For centigrade and Fahrenheit scale

$$\frac{F-32}{212-32}=\frac{C-0}{100-0} \Rightarrow C=\frac{100}{180}\times(140-32)=60°C$$

2. Let θ = temperature on X–scale corresponding to 50°C on Y–scale



$$\Rightarrow \frac{X-(-125)}{375-(-125)}=\frac{50-(-70)}{-30-(-70)} \Rightarrow X=1375$$

3. Slope of line AB

$$=\frac{\Delta C}{\Delta F}=\frac{100-0}{212-32}-\frac{100}{180}=\frac{5}{9}$$

4. $\frac{X-LFP}{UFP-LFP}$ = constant (for all temperature scales)

where

LFP → lower fixed point UFP → Upper fixed point

$$\frac{X-(-5)}{95-(-5)}=\frac{C-0}{100-0} \Rightarrow \frac{60+5}{95+5}=\frac{C}{100} \Rightarrow C=65°C$$

5. If we take two fixed points as tripe point of water and 0 K. Then

$$\frac{T_X-0}{200}=\frac{T_Y-0}{450} \Rightarrow 450\,T_X=200\,T_Y \Rightarrow 9T_X=4T_Y$$

6. Let at temperature θ, volume increases by 2% then according to question

$100=98\,[1+3.3\times10\,(\theta-4)] \Rightarrow \theta=60.4+4=64.4\,°C$

7. Expansions of a metal is same as photographic enlargement. $\Rightarrow d_1$ will increase by 0.3%

8. $$\Delta L=6\times10^{-5}=L\alpha\theta \Rightarrow \theta=\frac{6\times10^{-5}}{1\times12\times10^{-6}}=5°C$$

9. $$\Delta L=\Delta L_{thermal}-\Delta L_{contact\ force}=0 \Rightarrow \alpha_1 L\theta=\frac{FL}{AY_1}\ (rod-1)$$

$$\alpha_2 L\theta=\frac{FL}{AY_2}\ (rod-2) \Rightarrow Y_1\alpha_1=Y_2\alpha_2$$

10. Coefficient of linear expansion of brass is greater than that of steel.

11. Pressure at the bottom in both arms will be equal

$$\left(\frac{\rho_0}{1+\gamma t_1}\right).l_1=\left(\frac{\rho_0}{1+\gamma t_2}\right)l_2 \Rightarrow \gamma=\frac{l_1-l_2}{l_2t_1-l_1t_2}$$

12. Strain

$$t=\frac{\Delta l}{l}=-\alpha\Delta\theta=-12\times10^{-6}\times(75-25)=-6\times10^{-4}$$

13. Clearance = R'–R but $2\pi R'=2\pi R\,(1+\alpha_s\Delta T)$

$\Rightarrow R'-R=R\alpha_s\Delta T$

$=(6400)\,(1.2\times10^{-5})\,(30)=2.3$ km

14. $l=l_0(1+\alpha\Delta T) \Rightarrow l-l_0=l_0\alpha\Delta T$

$$\Rightarrow \frac{l_0\alpha_A\Delta T}{l_0\alpha_B\Delta T}=\frac{104-100}{106-100}=\frac{4}{6} \Rightarrow \frac{\alpha_A}{\alpha_B}=\frac{2}{3}$$

15. For rod A Δ● = ●$_0\,\alpha_A(100)$

For rod B $\frac{\Delta l}{2}$ = 2●$_0\alpha_B(100)$

For rod C 2Δ● = $x\alpha_A(100)$ + (3●$_0-x)\alpha_B(100)$

$\Rightarrow x=\frac{5}{3}$ ●$_0$ & 3●$_0$–$x=\frac{4}{3}l_0$

16. $x=l'_A-l'_B=l_A(1+\alpha_A\Delta T)-l_B(1+\alpha_B\Delta T)=l_A-l_B$

$\Rightarrow l_A\alpha_A=l_B\alpha_B$

17. $\Delta l=\int$ Expansion in dx $=\int[(\alpha_0+\alpha_1x)dx]\Delta T$

$$=100\int_0^2(1.76\times10^{-5}+1.2\times10^{-6}x)dx$$

$$=100\left[(1.76\times10^{-5})x+(1.2\times10^{-6})\left(\frac{x^2}{2}\right)\right]_0^2$$

$=3.76$ mm

18. For simple pendulum $T=2\pi$

$$\sqrt{\frac{l}{g}} \Rightarrow T\propto l^{1/2} \Rightarrow \frac{\Delta T}{T}=\frac{1}{2}\frac{\Delta l}{l}=\frac{1}{2}\alpha\Delta\theta$$

Assuming clock gives correct time at temperature

$$\theta_0 \Rightarrow \frac{6}{24\times3600}=\frac{1}{2}\alpha(\theta_0-20)\ \&\ \frac{6}{24\times3600}$$

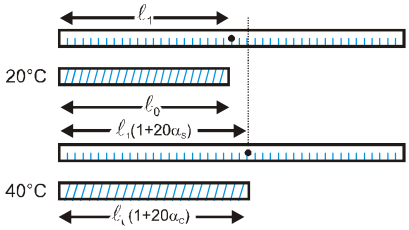
$$=\frac{1}{2}\alpha(40-\theta_0) \Rightarrow \theta_0=30°C \Rightarrow \alpha=1.4\times10^{-5}\ °C^{-1}$$

19. ✈ $d\bullet = \alpha \bullet_0 dT \quad \therefore \Delta l = \int dl = \int_{T_1}^{T_2} (aT - bT^2) l_0 dT$

$$= l_0 \left[\frac{a}{2}(T_2^2 - T_1^2) - \frac{b}{3}(T_2^3 - T_1^3)\right] = \left[\frac{3}{2} a T_1^2 - \frac{7b}{3} T_1^3\right] l_0$$

20. $\gamma_r = \gamma_1 + 3\alpha_1 = \gamma_2 + 3\alpha_2 \Rightarrow \alpha_2 = \frac{\gamma_1 - \gamma_2 + 3\alpha_1}{3}$

21.



$\bullet_0 (1+20\,\alpha_C) = \bullet_1 (1+20\alpha_S) \Rightarrow l_1 = \left(\frac{1+20\alpha_C}{1+20\alpha_S}\right) l_0$

22. Newton's law of cooling

$$\frac{\Delta\theta}{\Delta t} = k[\theta - \theta_0]$$

θ_0 = surrounding's temperature

$\Rightarrow \frac{80-60}{t} = k\left[\frac{80+60}{2} - 30\right]$ ...(i)

and $\frac{60-50}{t} = k\left[\frac{60+50}{2} - 30\right]$ ...(ii)

$\Rightarrow t = 48$ sec

23. Let θ = junction temperature

Net heat current at junction is zero

$3k(100-\theta) + k(0-\theta) + 2k(50-\theta) = 0 \Rightarrow \theta = \frac{200}{3}$ °C

24. From Stefan's law : $\Delta \dot{Q} = \sigma A T^4$

$\Rightarrow \frac{1cal}{s-m^2} \times \frac{4.2J}{cal} = 5.67 \times 10^{-8} \times 1 \times T^4 \Rightarrow$ T= 100 K

25. ✈ $t \propto (x_2^2 - x_1^2)$

For $x_1 = 0, x_2 = 1$ cm

$7 \propto (1^2 - 0^2)$

For $x_1 = 1$cm, $x_2 = 2$cm

$t \propto (2^2 - 1^2) \Rightarrow \frac{7}{t} = \frac{1}{3} \Rightarrow t = 21$ hrs

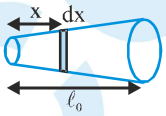
26. $\frac{\text{Power}}{\text{Area}}$ = Intensity

Power absorbed by the foil = Intensity at foil × Area of foil

$\Rightarrow \quad P = \frac{P_0}{4\pi d^2} \times A = \left(\frac{\sigma A_0 T^4}{4\pi d^2}\right) A$

Now $\quad P' = \frac{\sigma A_0 (2T)^4 \times A}{4\pi (2d)^2} = 4P$

27. $dR_H = \frac{dx}{KA} = \frac{dx}{KA_0(1+\alpha x)}$



$R_H = \int dR_H = \int_0^1 \frac{dx}{KA_0(1+\alpha x)} = \frac{1}{KA_0}\left(\frac{ln(1+\alpha x)}{\alpha}\right)_0^1$

$= \frac{1}{KA_0\alpha} ln(1 + \alpha l_0)$ **or** Check dimensionally

28 ✈ $\left(\frac{\Delta Q}{\Delta t}\right)_A = \left(\frac{\Delta Q}{\Delta t}\right)_B$

$\therefore \frac{K_A A(100-70)}{30} = \frac{K_B A(70-35)}{70}$

$\Rightarrow K_A = \frac{K_B}{2} \Rightarrow \frac{K_A}{K_B} = \frac{1}{2}$

29. $\frac{Q}{t} = \sigma A T^4$ = same but $T_{red} < T_{green}$

as $\lambda_{red} T_{red} = \lambda_{green} T_{green}$ (see VIBGYOR)

$\Rightarrow$ Area of red star is greater

30. According to Wien's law

$\lambda_m \propto 1/T \Rightarrow \nu_m \propto T$.

As the temperature of body increases, frequency corresponding to maximum energy in radiation (ν_m) increases. Also area under the curve

$$\int E_\nu d\nu \propto T^4$$

31. Entire KE gets converted into heat.

$\Delta KE = ms\,\Delta\theta \Rightarrow 10 \times 10 \times 10 = 2 \times 4200 \times \Delta\theta$

$\Rightarrow \Delta\theta = 0.12$°C

32. Rate of cooling of water = Rate of cooling of alcohol

$\Rightarrow \frac{(250+10) \times 1 \times (5)}{130} = \frac{(200s+10) \times 5}{67}$

$\Rightarrow$ Specific heat of alcohol $s = 0.62$

33. Amount of energy utilised in climbing

$mgh = 0.28 \times 10 \times 4.2$

$\Rightarrow h = \dfrac{0.28 \times 10 \times 4.2}{60 \times 10} = 1.96 \times 10^{-2}\ m = 1.96\ cm$

34. $H_C = ms\Delta\theta = ms\,(1)°C$

$H_K = ms\,\Delta\theta = ms\,(1)K = ms(1)°C$

$H_F = ms\,\Delta\theta = ms\,(1°F) = ms(5/9)°C$

$\therefore\ H_C = H_K > H_F$

35. M= mass of hallstone falling

m = mass of hallstone melting

As Mgh = mL.

So $\dfrac{m}{M} = \dfrac{gh}{L} = \dfrac{10 \times 10^3}{33 \times 10^3} = \dfrac{1}{33}$

36. Water has high specific heat and due to this it absorber more heat in rise of temperature.

37. Heat lost = Heat gained

$m_{steam} \times 540 = 1100 \times 1 \times (80 - 15) + 20 \times 1 \times (80 - 15)$

$\therefore$ mass of steam condensed = 0.13 kg

38. If intermolecular forces vanish water behaves as gas.

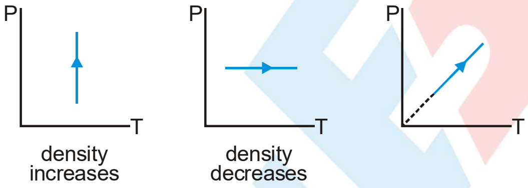
Number of moles of water $= \dfrac{4.5 \times 10^3}{18} = 250$

Total volume of water at STP

$= 22.4 \times 250 \times 10^{-3}\ m^3 = 5.6\ m^3$

39. When water is cooled to form ice, the energy is released as heat so mass of water decreases.

40.



density increases

density decreases

For equation : $\left(\text{Q } P = \dfrac{\rho RT}{M_w}\right)$

At constant temperature $\rho \propto p$

For 1st graph : $\rho \propto P$ At constant temperature.

For 2nd graph : $\left(\text{Q } P = \dfrac{\rho RT}{M_w}\right)$

At constant P, $\rho \propto \dfrac{1}{T}$

For 3rd graph L: $\dfrac{dP}{dT} = \text{constant} \Rightarrow P \propto T$

$\Rightarrow$ density ρ = constant

41. Heat removed in cooling water from 25^0C to 0^0C

$= 100 \times 1 \times 25 = 2500$ cal

Heat removed in converting water into ice at 0^0C

$= 100 \times 80 = 8000$ cal

Heat removed in cooling ice from

0^0 to $-15^0C = 100 \times 0.5 \times 10 = 500$ cal

Total heat removed in 1hr 50min

$= 2500 + 8000 + 500 = 11000$ cal

Heat removed per minute $= \dfrac{11000}{110} = 100$ cal/min

42. Volume can't be negative.

At constant pressure

$V \propto T$ or $V\ \alpha\ (t + 273)$

43. If temperature is doubled, pressure will also be doubled as $P = \dfrac{\rho RT}{M_w} \Rightarrow 100\%$ increase

44. Ideal gas equation : PV = nRT

So at $V = V_0$; $RT_1 = \left(\dfrac{P_0}{2}\right)(V_0)$ and at $V = 2V_0$,

$RT_2 = \left(\dfrac{4P_0}{5}\right)(2V_0) \Rightarrow T_2 - T_1 = \dfrac{11P_0V_0}{10R}$

45. $\dfrac{3}{4}$ th volume of air at 0°C occupies entire volume at θ ,

As $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2} \Rightarrow \dfrac{3/4\,V}{273+60} = \dfrac{V}{273+\theta} \Rightarrow \theta = 171°C$

46. Total translational KE $= \dfrac{3}{2}nRT = \dfrac{3}{2}PV$

47. Number of moles remain constant

$n_1 + n_2 = n_1' + n_2' \Rightarrow \dfrac{P_1V_1}{RT_1} + \dfrac{P_2V_2}{RT_2} = \dfrac{P_1'V_1'}{RT_1'} + \dfrac{P_2'V_2'}{RT_2'}$

$\Rightarrow \dfrac{PV}{273} + \dfrac{PV}{273} = \dfrac{(1.5P)V}{R \times 273} + \dfrac{(1.5P)V}{R \times T}$

$\Rightarrow T = 273 \times 3\,K = (273 \times 3 - 273)\,°C = 546°C$

48. $v_{rms} = \sqrt{\dfrac{3KT}{m}} \Rightarrow T = \dfrac{mv_{rms}^2}{3K}$ ✈ $T \propto mv_{rms}^2$

49. $\gamma = \dfrac{n_1C_{P1} + n_2C_{P2}}{n_1Cv_1 + n_2Cv_2}$

$\gamma = 1.5\ \therefore C_{P1} = \dfrac{5R}{2}; C_{P2} = \dfrac{7R}{2}$

$C_{V1} = \dfrac{3R}{2}; C_{V2} = \dfrac{5R}{2}$; then $n_1 = n_2$

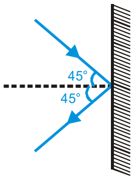
50. Here $V = aT + b$ where $a, b > 0$

So $P = \frac{nRT}{aT + b} = \frac{nR}{a + b/T}$ but $\frac{b}{T_2} < \frac{b}{T_1}$ so $P_2 > P_1$

51. Change in momentum $= 2mv\cos(45°)$

$= 2 \times 3.32 \times 10^{-27} \times 10^3 \times \frac{1}{\sqrt{2}}$

$= 4.7 \times 10^{-24}$ kg ms^{-1}.



52. $\Delta U_1 =$ +ve; $\Delta U_2 = 0 \Rightarrow \Delta U_3 = $ –ve

$\therefore$ $\Delta U_1 > \Delta U_2 > \Delta U_3$

As volume increases, $\Delta W =$ +ve.

53. $PV = nRT \Rightarrow P = \frac{\rho}{M_w} RT$

$\Rightarrow$ $\rho = \frac{PM_w}{RT} = \frac{(10^5)(28 \times 10^{-3})}{8.3 \times 273}$ kg m^{-3} = 1.25 g/litre

54. $PT^{11} =$ constant & $PV = nRT$

$\Rightarrow$ $V \propto T^{12} \Rightarrow \frac{\Delta V}{V} = 12\frac{\Delta T}{T} \Rightarrow \gamma_v = \frac{\Delta V}{V\Delta T} = \frac{12}{T}$

55. Internal energy and volume depend upon states.

56. When water is heated from 0°C to 4°C, its volume decreases.

$\therefore$ $P\,\Delta V$ is negative

Hence $C_p - C_v < 0 \Rightarrow C_p < C_v$

57. $\Delta U = 2P_0\Delta V$ & $W = P_0\Delta V$

So $Q = W + \Delta U = 3P_0\Delta V = 3P_0V_0$

58. $f_{eq} = \frac{f_1n_1 + f_2n_2 + f_3n_3}{n_1 + n_2 + n_3} = \frac{(5n)(3) + (n)(5) + (5n)(6)}{5n + n + 5n} = \frac{50}{11}$

59. $V \propto T^4 \Rightarrow V \propto (PV)^4$

$\Rightarrow$ $P^4V^3 =$ constant $\Rightarrow$ $PV^{3/4} =$ constant

$\therefore$ $C = C_v + \frac{R}{1 - x} = 3R + \frac{R}{1 - 3/4} = 3R + 4R = 7R$

60. $U = a + bPV = a + bnRT$

$\Rightarrow \Delta U = bnR\Delta T = nC_v\Delta T$

$\Rightarrow C_v = bR \Rightarrow C_p = bR + R$

$\Rightarrow$ $\gamma = \frac{C_p}{C_v} = \frac{bR + R}{bR} = \frac{b + 1}{b}$

EXERCISE - 2

Part # I : Multiple Choice

1. $DC^2 = L_2{}^2 - \frac{L_1^2}{4} \Rightarrow 0 = 2L_2\,\Delta L_2 - \frac{2L_1\Delta L_1}{4}$

$\Rightarrow 0 = 2L_2(\alpha_2L_2\theta) - \frac{2L_1(\alpha_1L_1\theta)}{4} \Rightarrow \alpha_1 = 4\alpha_2$

2. All dimensions increase on heating.

3. A part of liquid will evaporate immediately sucking latent heat from the bulk of liquid. Hence a part of liquid will freeze.

5. $\Delta Q_{vap} = \Delta Q_{freezing}$

$m.(\eta L) = M(L) \Rightarrow M = \eta m$

L = latent heat of freezing

m = mass of vapour

M = mass of freezed

$\therefore$ Fraction of water which freezed

$= \frac{M}{m + M} = \frac{\eta M}{m + \eta m} = \frac{\eta}{1 + \eta}$

6. $Q_1 = \Delta U + W_1$; $Q_2 = \Delta U + W_2$

Ratio of specific heats

$\frac{C_1}{C_2} = \frac{\left(\frac{\Delta Q_1}{\Delta T}\right)}{\left(\frac{\Delta Q_2}{\Delta T}\right)} = \frac{\left(\frac{\Delta U}{\Delta T} + \frac{\Delta W_1}{\Delta T}\right)}{\left(\frac{\Delta U}{\Delta T} + \frac{\Delta W_2}{\Delta T}\right)} < 1$ (✈ $W_2 > W_1$)

7. Water at 4°C has highest density

8. Mixture may attain intermediate temperature or terminal temperatures of fusion or vapourisation.

9. $Q = \Delta U + W$

Q = +ve, as heat is absorbed from the atmosphere

W = –ve as the volume decrease

$\therefore$ $\Delta U = Q - W =$ +ve – (–ve) = +ve

$\therefore$ Internal energy increases.

10. For insulated chambers $n_1 + n_2 = n'_1 + n_2'$

(final pressures become equal)

$\frac{PV}{RT} + \frac{2P.2V}{RT} = \frac{P}{RT}[3V] \Rightarrow P' = \frac{5P}{3}$

For left chamber

$PV = P'V' = \frac{5P}{3}V' \Rightarrow V' = \frac{3V}{5}$

For right chamber

$4PV = P'V' = \frac{5P}{3}V' \Rightarrow V' = \frac{12V}{5}$

11. $H_A = (6\ \text{cal/s}) \times (6-2)\ \text{s}$

$H_B = (6\ \text{cal/s}) \times (6.5-4)\ \text{s}$

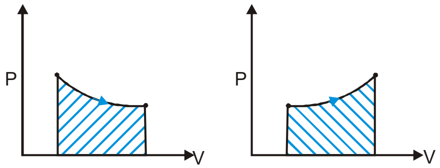
$$\therefore \frac{H_A}{H_B} = \frac{4}{2.5} = \frac{8}{5}$$

13. **(i)** $PV^2 = C \Rightarrow TV = C$

If volume expands temperature decreases.

(ii) $P = KV^2 \Rightarrow \frac{V^3}{T} = \text{constant}$

If volume expands, temperature increases



(i) $PV^2 = C$ (ii) $P = KV^2$

$Q = \Delta U + W$

$Q_2 > Q_1$ as $W_2 > W_1$ & $\Delta U_2 > \Delta U_1$

14. $\frac{P^2}{\rho} = \text{constant}$

$P = \rho\frac{RT}{M}$ (Ideal gas equation)

$$\Rightarrow \frac{P^2}{\rho} = \frac{P}{\rho}\left(\frac{\rho RT}{M}\right) = PT\left(\frac{R}{M}\right) = \text{constant}$$

$\therefore$ The graph of the above process on the P–T diagram is hyperbola.

For the above process

$$\left(\frac{P^2}{\rho}\right)_1 = \left(\frac{P^2}{\rho}\right)_2 \Rightarrow \frac{P^2}{\rho} = \frac{P_2^2}{\rho/2} \Rightarrow P_2 = \frac{P}{\sqrt{2}} \qquad \text{...(i)}$$

and $P_1T_1 = P_2T_2 \Rightarrow PT = \frac{P}{\sqrt{2}}T_2 \Rightarrow T_2 = \sqrt{2}\,T$ ...(ii)

15. $Q = \Delta U + W \Rightarrow +Q = \Delta U + P_0(V_2 - V_1)$

$$\Rightarrow Q = \Delta U + P_0\left(\frac{1}{\rho_2} - \frac{1}{\rho_1}\right) \Rightarrow \Delta U = Q + P_0\left(\frac{1}{\rho_1} - \frac{1}{\rho_2}\right)$$

16. Ideal gas equation $P = \frac{\rho}{M}.RT$

For state A $\quad P_0 = \frac{\rho_0}{M}RT_0$

For state B $\quad 3P_0 = \frac{\rho}{M}R2T_0 \Rightarrow \rho = \frac{3}{2}\rho_0$

17. $v_A = \sqrt{\frac{3RT}{m}} = \frac{w}{\sqrt{3}}$; $v_B = \sqrt{\frac{3RT}{2m}} = v \Rightarrow \frac{w^2}{v^2} = \frac{2}{3}$

18. Average KE per molecule in A & B $= \frac{4KT}{\pi}$

$$(v_{rms})_A = \sqrt{\frac{3RT}{M_A}};\ (v_{rms})_B = \sqrt{\frac{3RT}{M_B}}$$

$$\Rightarrow \frac{(v_{rms})_A}{(v_{rms})_B} = \sqrt{\frac{M_B}{M_A}} = \sqrt{\frac{M_B}{16M_B}} = \frac{1}{4}$$

No. of mole of A $= \frac{m_A}{M_A}$

No. of mole of B $= \frac{m_B}{M_B} = \frac{m_{A/2}}{M_{A/16}} = 8n_A$

Pressure exerted by a gas in the vessel depends on the number of molecules present inside.

19. $(v_{rms})_L = (v_{avg})_R\ \sqrt{\frac{3RT}{M_1}} = \sqrt{\frac{8RT}{\pi M_2}} \Rightarrow \frac{M_1}{M_2} = \frac{3\pi}{8}$

20. $v_P = \sqrt{\frac{2RT}{M}}$; $\bar{v} = \sqrt{\frac{8RT}{\pi M}}$; $v_{rms} = \sqrt{\frac{3RT}{M}}$

21. Average speed

$$v_{avg} = \frac{1+2+....+N}{N} = \frac{N(N+1)}{2.N} = \frac{N+1}{2}$$

rms speed

$$v_{rms} = \sqrt{\frac{1^2+2^2+3^2+......+N^2}{N}}$$

$$= \sqrt{\frac{N(N+1)(2N+1)}{6N}} = \sqrt{\frac{(N+1)(2N+1)}{6}}$$

$$\therefore \frac{v_{rms}}{v_{avg}} = \sqrt{\frac{(N+1)(2N+1)}{6}} \times \frac{2}{(N+1)} = \frac{2}{\sqrt{6}}\sqrt{\left(\frac{2N+1}{N+1}\right)}$$

22. $Q = \Delta U + W$ and $\Delta U = nC_V\Delta T$

ΔU can be zero if ΔT is zero or $Q - W$ is zero

23. Fig A : $W_A = +ve$ Fig B : $W_B = +ve$

Fig C : $W_C = +ve$ Fig D : $W_D = -ve$

$\therefore$ In process Fig–(D), heat is released.

24. For any process $\Delta U = nC_V\Delta T$

In adiabatic process

$Q = \Delta U + W = 0 \Rightarrow \Delta U = -W$

For any process

$$C = \frac{\Delta U}{n\Delta T} + \frac{W}{n\Delta T} = \frac{Q}{n\Delta T} = \frac{\Delta U}{n\Delta T} + \frac{P}{n}\left(\frac{\Delta V}{\Delta T}\right)$$

For $Q = 0$, $C = 0$ (adiabatic process)

25. At constant volume, work done by gas is zero.

26. Slope of isothermal process $m_1 = \frac{\Delta P}{\Delta V} = -\frac{P}{V}$

Slope of adiabatic process

$$m_2 = \frac{\Delta P}{\Delta V} = -\frac{\gamma P}{V} = -\gamma m_1 = \frac{C_P}{C_v} m_1$$

27. $PV^{\gamma} = C; \ell n P + \gamma \ell n V = \ell n C$

$\Rightarrow \quad \ell n P = -\gamma \ell n V + \ell n C \Rightarrow y = mx + c$

$$\Rightarrow m = -\gamma = -\frac{-[2.10 - 2.38]}{(1.30 - 1.10)} = -1.4$$

$\therefore$ The gas is diatomic

28. $W_{AB} = (2V_0 - V_0)P_0 = P_0V_0$

[Isobaric process]

$$W_{BC} = \left| nR(2T_0) \ln \frac{V_0}{2V_0} \right| = 2P_0V_0 . \ell n2$$

[Isothermal process]

$$\therefore \frac{Q_{AB}}{W_{BC}} = \frac{\frac{3}{2} P_0V_0 + P_0V_0}{2P_0V_0 . \ln 2} = \frac{5}{4 \ln 2}$$

29. Final pressure $= \frac{kx_0}{S}$

Work done by gas = P.E. stored in spring = $1/2kx_0^2$

Change in internal energy $\Delta U = |-\Delta W| = 1/2\, kx_0^2$

As gas expands, ΔT is negative.

30. $W_{OBC} = W_{ODA}$

$\therefore$ Net work done $= W_{OBC} - W_{ODC} = 0$

31. For constant pressure process Q

$= nC_P\Delta T = 30nC_P$

For constant volume process Q

$$= nC_V\Delta T = n\left(\frac{5}{7} C_P\right) \Delta T \Rightarrow \Delta T = 42°C = 42K$$

32. Work done = Area of ABC with V–axis

$= P_0(2V_0 - V_0) + 0 = P_0V_0 = nRT_0 = RT_0$

Change in internal energy $= nC_V\Delta T$

$$= 1 \times \frac{3}{2} R \times (4T_0 - T_0) = \frac{9}{2} RT_0$$

$\therefore$ Heat absorbed

$$= \frac{9}{2} RT_0 + RT_0 = \frac{11}{2} RT_0$$

33. $C_P - C_V = R; M(0.20 - 0.15) = 2$ [M = molar mass]

$$\Rightarrow M = \frac{2}{0.05} = 40 \text{ g}$$

$$\frac{C_P}{C_V} = \gamma = \frac{0.2}{0.15} = \frac{4}{3} = 1 + \frac{2}{f}$$

$\Rightarrow$ f = degrees of freedom = 6

34. **Ans. (C)**

$\Delta U_{CA} = nC_V(T_A - T_C)$

$$= 1 \times \frac{3}{2} R \times (300 - 450) = (-225 R)$$

$\Delta U_{AB} = nC_V(T_B - T_A)$

$$= 1 \times \frac{3}{2} R \times (600 - 300) = +450 R$$

$\Delta U_{BC} = nCv(T_C - T_B)$

$$= 1 \times \frac{3}{2} R \times (450 - 600) = -225R$$

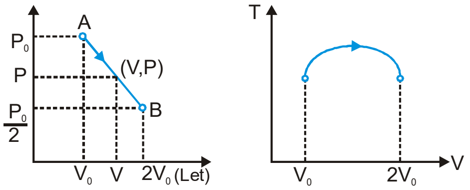
$\Delta U_{ABCA} = \Delta U_{CA} + \Delta U_{AB} + \Delta U_{BC} = 0$

35. $W_{\text{adiabatic}} = \frac{nR(T_1 - T_2)}{\gamma - 1} = 6R$

$$\Rightarrow \frac{1 \times R(T_1 - T_2)}{5/3 - 1} = 6R \Rightarrow T_2 = (T - 4)K$$

36. Work done in process 1–3 is greater than that in process 1–2. While change in internal energy is same for both processes $\therefore Q_2 > Q_1$.

37.



Let V_0 = initial volume = $2V_0$ = final volume

V = volume of any state

$$\text{then} \quad \frac{P_0 - P_0/2}{2V_0 - V} = \frac{P - P_0/2}{2V_0 - V}$$

$$\Rightarrow \quad nRT = PV = V\left[\frac{3P_0}{2} - \frac{P_0}{2V_0} V\right]$$

$\therefore$ T–V curve is a parabola with vertex above.

Hence temperature first increases then decreases.

38. For sphere $kA\left(-\frac{dT}{dr}\right) = P$

$$\Rightarrow k\int(-dT) = \int\frac{dr.P}{A} \Rightarrow -k\int_0^T dT = \int_{r_1}^{r_2}\frac{dr.P}{4\pi r^2}$$

$$\Rightarrow kT = \frac{P}{4\pi}\left(\frac{r_2-r_1}{r_1r_2}\right) \Rightarrow t=(r_2-r_1)=\frac{kT}{P}4\pi R^2$$

39. Intensity in first case

$$I_1 = \frac{P_1}{4\pi R_1^2} = \frac{\sigma AT_1^4}{4\pi d_1^2}$$

Intensity in second case

$$I_2 = \frac{P_2}{4\pi R_2^2} = \frac{\sigma AT_2^4}{4\pi d_2^2}$$

Given $I_1 = I_2 \Rightarrow \frac{\sigma AT_1^4}{4\pi d_1^2} = \frac{\sigma AT_2^4}{4\pi d_2^2} \Rightarrow \frac{d_2}{d_1} = \left(\frac{T_2}{T_1}\right)^2$

40. For body A $P = \sigma AT^4 \Rightarrow \frac{P}{A} = 100 = \sigma \times 300^4$

For body B $\Rightarrow \frac{P}{A} = (\sigma T^4)\in = (1-0.5-0.3)\times[\sigma\times 300^4]$

$$= 0.2 \times 100 = 20\ W/m^2$$

41. For black body

$$\lambda_0 T = \frac{\lambda_0}{2}T' \Rightarrow T^1 = 2T$$

$$\frac{P}{P'} = \frac{\sigma AT^4}{\sigma AT'^4} = \frac{1}{16} \Rightarrow P'T' = (16P)(2T) = 32PT$$

42. For surface areas to be same

$$S_{sphere} = S_{cube} \Rightarrow 4\pi R^2 = 6a^2 \Rightarrow \frac{a}{R} = \sqrt{\frac{2\pi}{3}}(>1)$$

Volume ratio

$$\frac{V_{sphere}}{V_{cube}} = \frac{\frac{4}{3}\pi R^3}{a^3} = \frac{2R}{a} = \sqrt{\frac{6}{\pi}}(>1)$$

∴ (Mass of water in sphere) > (Mass of water in cube)
Energy host by radiation depends on the surface area. Hence initial rate of energy loss by the two area equal. But mass of water inside the sphere is greater, hence it will cool slowly.

43. From Stefan's law of cooling :

$$e\sigma A(T^4 - T_0{}^4) = ms\left(-\frac{dT}{dt}\right)$$

$$\Rightarrow 1 \times 5.8 \times 10^{-8} \times \pi \times (0.08)^2 \times (500^4 - 300^4)$$

$$= 10 \times 90 \times 4.2 \times \left(-\frac{dT}{dt}\right) \Rightarrow \left(-\frac{dT}{dt}\right) = 0.067°\ C/s$$

44. Newton's law of cooling implies that rate of cooling is proportional to temperature difference if the temperature difference between body and surrounding is small.
Then,

$$\left(-\frac{d\theta}{dt}\right)_2 = \tan\phi_2\ \alpha\ (\theta_2 - \theta_0) \text{ and}$$

$$\left(\frac{d\theta}{dt}\right)_1 = \tan\phi_1\alpha\ (\theta_1 - \theta_0) \Rightarrow \frac{\tan\phi_2}{\tan\phi_1} = \left(\frac{\theta_2-\theta_0}{\theta_1-\theta_0}\right)$$

45. For same rate of heat transfer the body having higher conductivity will have lower temperature difference. If cylinder with higher conductivity is connected with hot reservoir first then the function temperature T_b, will be closer to hot reservoir temperature.

46. $KA\left(-\frac{dT}{dx}\right) = \dot{Q} \Rightarrow \left(\frac{\alpha}{T}\right)A\left(-\frac{dT}{dx}\right) = \dot{Q}$

$$\Rightarrow -\int_{T_1}^{T_2}\frac{dT}{T} = \frac{\dot{Q}}{\alpha A}\int_0^2 dx \qquad ....(i) \qquad \&$$

$$\Rightarrow -\int_{T_1}^{T}\frac{dT}{T} = \frac{\dot{Q}}{\alpha A}\int_0^x dx \qquad ...(ii)$$

$$\Rightarrow \ln\left(\frac{T_1}{T_2}\right) = \left(\frac{\dot{Q}}{\alpha A}\right)L \quad \text{and} \quad \ln\left(\frac{T_1}{T}\right) = \left(\frac{\dot{Q}}{\alpha A}\right)x$$

$$\Rightarrow T = T_1\left(\frac{T_2}{T_1}\right)^{x/L}$$

47. From newton's law of cooling.

$$\sigma A(T^4 - T_0{}^4) = ms\left(-\frac{dT}{dt}\right)$$

$$\Rightarrow \sigma.4\rho r^2[(T_0 + \Delta T)^4 - T_0{}^4] = \rho\frac{4}{3}\pi r^3 c\left(-\frac{dT}{dt}\right)$$

$$\Rightarrow \left(\frac{12\sigma T_0^3}{Prc}\right)(T - T_0) = -\frac{dT}{dt}$$

$$\Rightarrow K(T - T_0)dt = -dT \Rightarrow k\int_0^t dt = -\int_{T_1}^{T}\frac{dT}{(T - T_0)}$$

$$\Rightarrow T = T_0 + (T_1 - T_0)e^{-kt} \text{ where } K = \frac{12\sigma T_0^3}{r\rho c}$$

48. For the cube, net resistance $= \frac{5R}{6}$

(Where R = thermal resistance of each side)

$$H = \frac{100-0}{5R/6}$$

For side A

$$\frac{H}{3} = \frac{100-\theta_A}{R} \Rightarrow \theta_A = 60°C$$

49. $H = \frac{T_1 - T_2}{R}$ and $2H = \frac{T_1 - T_2}{R'} \Rightarrow R' = \frac{R}{2}$

(where R & R' are thermal resistances).

$$R = \frac{1}{\frac{L}{kA} + \frac{3L}{kA}} \Rightarrow R' = \frac{1}{\frac{kA}{3L} + \frac{k'A}{3L}}$$

$\Rightarrow k' = \frac{7k}{3}$ (k' = cond. of ADB wire).

50. Heat lost

$$= \sigma A (T^4 - T_0^4) = -\sigma 4\pi r^2 (T_0^4 - T^4)$$

$$= \frac{d(mL)}{dt} = \rho L \frac{dv}{dt} = \rho L 4\pi r^2 \frac{dr}{dt}$$

$$\Rightarrow -\sigma 4\pi r^2 (T_0^4 - T^4) = \sigma L 4\pi r^2 \frac{dr}{dt}$$

$\Rightarrow$ radius decreases with time

51. Heat current flow rate is uniform everywhere.

52. For same power of radiation

$P_A = P_B = P_C \Rightarrow e_A \sigma A T_A^4 = e_B \sigma A T_B^4 = e_C \sigma A T_C^4$

& $\lambda_A T_A = \lambda_B T_B = \lambda_C T_C$ $(e_A : e_B : e_C = 1 : \frac{1}{2} : \frac{1}{4})$

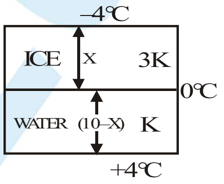
$\Rightarrow \sqrt{T_A . T_C} = T_B$ or

$\sqrt{e_A T_A}\sqrt{e_C T_C} = e_B T_B$ & $\sqrt{\lambda_A . \lambda_C} = \sqrt{\lambda_B}$

53. $T_P = 50°C$; $T_Q = 45°C$

$\therefore$ Heat will flow from P to Q.

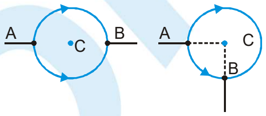
54. $\dot{Q} = \frac{KA(4-0)}{10-x} = \frac{3KA(0+4)}{x} \Rightarrow x = 7.5$ m



55. $R = \frac{1}{\frac{KA}{L/2} + \frac{KA}{L/2}} = \frac{KA}{4L}$;

$$R' = \frac{1}{\frac{KA}{3L/4} + \frac{KA}{L/4}} = \frac{3}{4}R$$

$$H_I = \frac{\Delta T}{R} = 1.2\,W$$



$$H_{II} = \frac{\Delta T}{3R/4} = \frac{4}{3}\frac{\Delta T}{R} = \frac{4}{3} \times 1.2 = 1.6\,W$$

56. Rate of cooling

$$= ms\left(-\frac{d\theta}{dt}\right) = 4\sigma A T_0^3 \Delta T$$

$\Rightarrow 4\sigma A \times T_0^3 (50-20) = 10$

and $4\sigma A \times T_0^3 (35-20) = ms\left(-\frac{d\theta}{dt}\right) = ms\left(\frac{0.2}{60}\right)$

$$\Rightarrow ms = \frac{60}{0.2} \times \left(\frac{15 \times 10}{30}\right) = 1500\ J/°C$$

58. Wien's displacement law.

$\lambda_1 T_1 = \lambda_2 T_2 = b = 2.8 \times 10^{-3}$ km

$\Rightarrow 3000 \times \lambda_1 = T_2 \times (\lambda_2) \cong 3 \times 10^{-3}$ km

$\Rightarrow \lambda_1 = 1\ \mu m$ & $[\lambda_2 - \lambda_1] = 9\ \mu m$

$\Rightarrow \lambda_2 = 10\ \mu m$

$\Rightarrow T_2 = 300$ K

59. For a grey body

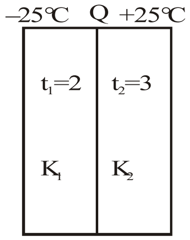
$\alpha + r + t = 1$ if $\alpha = 0.4, r = 0.6$

then $t = 1 - 0.4 - 0.6 = 0.$

The body is opaque

60. **(i)** $\dot{Q} = \frac{K_1 A(\theta + 25)}{t_1} = \frac{K_2 A(25-\theta)}{t_2}$

$$\Rightarrow \frac{KA(\theta+25)}{2} = \frac{KA(25-\theta)}{3} \Rightarrow \theta = -5°C$$



(ii) $\dot{Q} = \frac{K_1A(\theta + 25)}{t_1} = \frac{K_2A(25 - \theta)}{t_2}$

$\Rightarrow \frac{2A(\theta + 25)}{2} = \frac{3A(25 - \theta)}{3} \Rightarrow \theta = 0°C$

61. $\dot{Q} = \frac{T_A - T_B}{\frac{L}{k_3A}} = \frac{T_A - T_B}{\frac{L}{k_1A} + \frac{L}{k_2A}} \Rightarrow k_3 = \frac{k_1.k_2}{k_1 + k_2}$

62. $\text{Fig A}: 20 = \left(\frac{100 - 0}{\frac{L}{kA} + \frac{L}{kA}}\right) \times 4$ ...(i)

$\text{Fig A}: 20 = Q = (100 - \theta)\left[\frac{kA}{L} + \frac{kA}{L}\right]t$ ...(ii)

Equation (i) ÷ (ii) $1 = \frac{4/2}{2/t}$ $t = 1$ min.

63. For an elemental spherical shells,

$\dot{Q} = K4\pi r^2\left(-\frac{dT}{dr}\right) \Rightarrow \dot{Q}\int_{r_1}^{r_2}\frac{dr}{r^2} = -4\pi K\int_{T_1}^{T_2} dT$

$\Rightarrow \dot{Q}\left(\frac{r_2 - r_1}{r_1r_2}\right) = 4\pi K(T_1 - T_2) \Rightarrow \dot{Q} \propto \left(\frac{r_1.r_2}{r_2 - r_1}\right)$

64. $\dot{Q} = \frac{T_2 - T_1}{\frac{x}{KA} + \frac{4x}{2K.A}} = \frac{KA(T_2 - T_1)}{3x} = \left[\frac{KA(T_2 - T_1)}{x}\right]f$

then $f = 1/3$

65. Let x= percentage of water solidified

then heat lost = Heat gained

$\Rightarrow x \times 3.36 \times 10^5 = (100 - x) \times 21 \times 10^5$

$\Rightarrow x = \frac{100}{1.16} = 86.2\%$

66. $P = P_0 - aV^2$

From ideal gas equation $PV = nRT$

$\Rightarrow RT = (P_0 - aV^2)V$ (n=1)

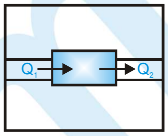
$\Rightarrow T = \left(\frac{P_0V - aV^3}{R}\right) \Rightarrow \frac{dT}{dV} = 0 = \left(\frac{P_0 - 3aV^2}{R}\right)$

$\Rightarrow V = \sqrt{\frac{P_0}{3a}}$ and $\frac{d^2T}{dV^2} = -\frac{6aV}{R}$ (< 0)

$\therefore T_{max} = \frac{(P_0 - aV^2)V}{R} = \frac{2P_0}{3R}\sqrt{\frac{P_0}{3a}}$

67. He and Ne are monatomic gas.

68. $Q_1 + 36 = Q_2$



$\Rightarrow \frac{KA(100 - \theta)}{L} + 36 = \frac{KA(\theta - 4)}{L}$

$\Rightarrow \theta = 76°C$

69. Area under the curve is equal to number of molecules of the gas sample.

Hence $N = \frac{1}{2}aV_0 \Rightarrow aV_0 = 2N$

$$V_{avg} = \frac{1}{N}\int_0^{\infty} vN(V)dV = \frac{1}{N}\int_0^{V_0} C.\left(\frac{a}{V_0}V\right)dV = \frac{2}{3}V_0$$

$\Rightarrow \frac{V_{avg}}{V_0} = \frac{2}{3}$

$$V_{rms}^2 = \frac{1}{N}\int_0^{\infty} V^2N(V)dV = \frac{1}{N}\int_0^{V_0} V^2\left(\frac{a}{V_0}V\right)dV = \frac{V_0^2}{2}$$

$\Rightarrow \frac{V_{rms}}{V_0} = \frac{1}{\sqrt{2}}$

Area under the curve from $0.5\,V_0$ to V_0 is 3/4 of total area

70. $Q = W = nRT \bullet n\frac{V_f}{V_i}$

$T = \frac{Q}{nR\ln V_f/V_i} = \frac{1500}{0.5 \times 25/3 \times \ln 3}$

$= \frac{1500}{0.5 \times 25/3 \times 1} = 360K$

71. At 30° true length is given by $= SR(1 + \alpha_{zinc}\Delta T)$

$= 100(1 + 26 \times 10^{-6} \times 30) = 100.078$ cm

At 0°, True length is given by

$= \frac{SR(1 + \alpha_{zinc}\Delta T)}{(1 + \alpha_{glass}\Delta T)} = \frac{100.078}{(1 + 8 \times 10^{-6} \times 30)} = 100.054$ cm

72. Length $1 = 1_0(1 + \alpha\Delta T) = \bullet_0(1 + 20\alpha)$

Area $A = A_0(1 + \beta\Delta T) = 6\bullet_0^2(1 + 40\alpha)$

Volume $V = V_0(1 + \gamma\Delta T) = \bullet_0^3(1 + 3\alpha\Delta T) = \bullet_0^3(1 + 60\alpha)$

Density $\rho = \frac{\rho_0}{1 + \gamma\Delta T} = \frac{\rho_0}{1 + 60\alpha}$

73. $\bullet = \frac{\Delta V}{A_0} = \frac{V_0(\gamma - 3\alpha)t}{A_0}$

74. Tensile Stress $=(Y_{steel})\left(\frac{\Delta l}{l}\right)=Y_S\left(\alpha_b-\alpha_S\right)\Delta T$

$=200\times10^9\,(0.8\times10^{-5})\,(200)=3.2\times10^8\ \text{Nm}^{-2}$

$=0.32\ \text{GNm}^{-2}$

75. At normal temperature $C_v=\frac{f}{2}R=\frac{5}{2}R$

At any temperature $C_p-C_v=\left(\frac{f}{2}+1\right)-\frac{f}{2}R=R$

from process $T=k_1V^2$ and

ideal gas equation $PV=nRT$

we have $PV^{-1}=\text{constant}\Rightarrow x=-1$

$$\Rightarrow C=C_v+\frac{R}{1-x}=C_v+\frac{R}{1+1}=C_v+\frac{R}{2}$$

At normal temperature $C=\frac{5}{2}R+\frac{R}{2}=3R$

76.

Required heat	Available heat
10 g ice (0^0C)	5 g steam (100^0C)
$\downarrow$800 cal	$\downarrow$2700 cal
10 g water (0^0C)	5 g water (100^0C)
$\downarrow$1000 cal	
10 g water (100^0)	

So available heat is more than required heat therefore final temperature will be 100^0C.

Mass of vapour condensed $=\frac{800+1000}{540}=\frac{10}{3}$ g

Total mass of water $=10+\frac{10}{3}=\frac{40}{3}=13\frac{1}{3}$ g

Total mass of steam

77. $$C_{Pmix}=\frac{n_1Cp_1+n_2Cp_2+n_3Cp_3}{n_1+n_2+n_3}$$

$$=\frac{(4)\left(\frac{7}{2}R\right)+2\left(\frac{5}{2}R\right)+1(4R)}{4+2+1}=\frac{16}{7}R$$

78. $PV^2=\text{constant}\Rightarrow P\propto V^{-2}\Rightarrow\frac{\Delta P}{P}=-2\frac{\Delta V}{V}$

$$\Rightarrow \text{Bulk modulus } K=\frac{\Delta P}{-\frac{\Delta V}{V}}=2P$$

As $PV=nRT$ So $K\propto\frac{1}{V^2}$ and $K\propto T^2$

79. $C=C_V+\frac{R}{1-x}=\frac{3}{2}R+\frac{R}{1-x}<0$

$$\Rightarrow\frac{5-3x}{1-x}<0\Rightarrow 1<x<1.67$$

Part # II : Assertion & Reason

1 C	2 B	3 D	4 A	5 A	6 A	7. A
8 C	9 D	10. A	11. D	12. A	13. A	14. A
15. D	16. D	17. D	18. A	19. A	20. A	21. C
22. A	23. A	24. A	25. A	26. A	27. C	28. A
29. A	30. A	31. A	32. B			

EXERCISE - 3

Part # I : Matrix Match Type

1. Isobaric process $\Rightarrow$ P = constant

Isothermal process $\Rightarrow$ T = constant

$\Rightarrow \Delta U=0\Rightarrow$ U=constant

Isoentropy process

$$\Rightarrow\Delta S=\frac{\Delta Q}{T}=0\Rightarrow\Delta Q=0$$

No heat exchange

Isochoric process $\Rightarrow$ V = constant $\Rightarrow dW=PdV=0$

2. When A & B are mixed $ms\,(T-20)=(2m)\,s\,(40-T)$

$$\Rightarrow T=\frac{100}{3}=33.3°C$$

When A & C are mixed

$ms(T-20)=(3m)\,s\,(60-T)\Rightarrow T=50°C$

When B & C are mixed

$(2m)\,s\,(T-40)=(3m)\,s\,(60-T)\Rightarrow T=52°C$

When A, B & C are mixed

$ms\,(T-20)+(2m)s(T-40)=(3m)\,s\,(60-T)\Rightarrow T=46.67°C$

3. Let $R_{BC}=R$ then $R_{AB}=R_{AC}=2R$ as $R=\frac{1}{kA}$

$$\frac{100-T_B}{2R}=\frac{T_B-0}{R}\Rightarrow T_B=67.7°C$$

$$\left(\frac{\Delta Q}{\Delta t}\right)_{AB}=\left(\frac{\Delta Q}{\Delta t}\right)_{BC}\ \text{and}\ \left(\frac{\Delta Q}{\Delta t}\right)_{AB}=\frac{2}{3}\left(\frac{\Delta Q}{\Delta t}\right)_{AC}$$

4. From given V–T graph we cannot tell the nature of gas

slope of V–T graph $=\frac{nR}{P}$

From graph $\left(\frac{nR}{P}\right)_A>\left(\frac{nR}{P}\right)_B\Rightarrow\left(\frac{n}{P}\right)_A>\left(\frac{n}{P}\right)_B$

$\Rightarrow$ Cannot say anything about $\frac{n_A}{n_B}$ & $\frac{P_A}{P_B}$

5. **For(A)** as $PV = \frac{1}{3} mNv^2_{rms} = \frac{2}{3} E$ so in $P = \frac{2}{3} E$,

E is translational kinetic energy of unit volume.

For (B):

In U = 3RT, U is not internal energy of one mole as for monoatomic gas U = 3/2 nRT

For (C) :

In $W = P(V_f - V_i)$; w is work done in isobaric process.

For (D) : In $\Delta U = nC_V \Delta T$

ΔU is change in internal energy for every process.

6. As $Q = nCdT$ and $dT = \frac{Q}{nC}$

Therefore molar heat constant C is the determining factor for rate of change of temperature of a gas as heat is supplied to it. It is minimum for isochoric process of a monoatomic gas $\left(C_V = \frac{3}{2}R\right)$, resulting in greatest slope $\left(\frac{dT}{Q}\right)$ i.e. curve 1.

For isobaric process of monoatomic gas and isochoric process of diatomic gas, their heat capacities are same $\left(\frac{5}{2}R\right)$, therefore both are represented by curve 2.

For isobaric process of diatomic gas $C_P = \frac{7}{2}R$ that is represented by curve 3.Q axis represent isothermal process and ΔT axis represent adiabatic process.

7. Initially rate of heat flow will be maximum at A and minimum at B as there is no temperature difference across section B.

In steady state $\frac{dQ}{dt}$ will be same.

In steady state $\frac{dQ}{dt} = -KA\frac{dT}{dx} = \text{same}$

$$\& \quad \frac{dT}{dt} = 0 \Rightarrow \left(\frac{dT}{dx}\right) \propto \frac{1}{A} \Rightarrow \left(\frac{dT}{dx}\right)$$

will be maximum at B & minimum at A

8. Isothermal bulk modulus $= P = \frac{RT}{V}$

Adiabatic bulk modulus $= \gamma P = \frac{5RT}{3V}$

Slope of PV graph in isothermal process

$$\frac{P}{V} = -\frac{RT}{V^2}$$

Slope of P–V graph in adiabatic process

$$\frac{\gamma P}{V} = -\frac{5P}{3V}$$

9. $W = \int PdV = \int_{V_0}^{4V_0} 2VdV = \left(V^2\right)_{V_0}^{4V_0} = 15V_0^2 = 15 \text{ units}$

From $PV = nRT$, $2V^2 = nRT$

$$\Rightarrow 2\left(V_2^2 - V_1^2\right) = nR(\Delta T) \Rightarrow nR\Delta T = 30V_0^2$$

$$\Delta U = nC_V\Delta T = \frac{nR}{\gamma - 1}\Delta T = \frac{30V_0^2}{\gamma - 1} = \frac{30(1)^2}{7/5 - 1} = \frac{30}{2}(5)$$

$$= 75 \text{ units}$$

$Q \quad = 75 + 15 = 90 \text{ units}$

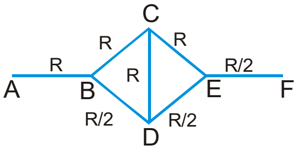
Molar heat capacity

$$C = C_V + \frac{R}{1 - x} = \frac{5}{2}R + \frac{R}{1-(-1)} = \frac{5}{2}R + \frac{R}{2} = 3R$$

$$= 3 \times \frac{25}{3} = 25 \text{ units}$$

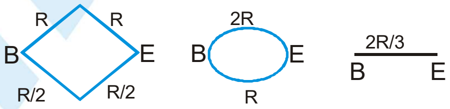
10. **For (A)**

$$R_y = \frac{1}{K_Y A} = \frac{1}{2K_X A} = \frac{R}{2}$$



No heat current flows through rod CD

So



For (B)

For (C)

Total heat current form A to F,

$$I = \frac{100 - 0}{\frac{13}{6}R} = \frac{600}{13R}$$

Let temperature of B be T_B then

$$I = \frac{100 - T_B}{R} = \frac{600}{13R} \Rightarrow T_B = \frac{700}{13}\text{°C}$$

For (D)

As heat current is inversely proportional to heat resistance.

So heat current in $BD = \left(\frac{2R}{R+2R}\right)I = \frac{2}{3}I$

$$\Rightarrow \frac{T_B - T_D}{R/2} = \frac{2}{3}I = \frac{2}{3}\left(\frac{600}{13R}\right)$$

$$\Rightarrow T_D = \frac{700}{13} - \frac{200}{13} = \frac{500}{13}\text{°C}$$

11. $P = \frac{\rho}{M_W} RT$

For (A) :

For AB $P \propto V \Rightarrow T \propto V^2 \Rightarrow T \propto \rho^{-2}$
For BC $V = \text{constant} \Rightarrow \rho = \text{constant}$
For CA $P = \text{constant} \Rightarrow \rho T = \text{constant}$

For (B)

For AB $P \propto T \Rightarrow \rho = \text{constant}$
For BC $T = \text{constant} \Rightarrow P \propto \rho$
For CA $P = \text{constant} \Rightarrow \rho T = \text{constant}$

For (C)

For AB $P = \text{constant} \Rightarrow \rho T = \text{constant}$
For BC $T = \text{constant} \Rightarrow P \propto \rho$
For CA $V = \text{constant} \Rightarrow \rho = \text{constant}$

For (D)

For AB $\rho \propto T \Rightarrow P \propto T^2$
For BC $T = \text{constant} \Rightarrow P \propto \rho$
For A $\rho = \text{constant} \Rightarrow P \propto T$

Part # II : Comprehension

Comprehension#1

1. $P \propto V \Rightarrow PV^{-1} = \text{constant} \Rightarrow x = -1$

$$\Rightarrow C = C_v + \frac{R}{2} = \frac{5R}{2} + \frac{R}{2} = 3R$$

2. $Q = nC\Delta T = n(3R)\Delta T = n(3R)(3T) = 9nRT = 9P_1V_1$

Comprehension#2

1,2 Let heat is supplied at a rate of $k_1$cal/min then

$k_1 \times 1 = m(0.5)\theta_1$
$k_1 \times 4 = m(80)\ k_1 \times 2 = m(1)\ (\theta_2)$
$\Rightarrow \quad k_1 = 20\text{ m} \Rightarrow \theta_1 = 40°C, \theta_2 = 40°C$
Therefore initial temperature $= -40°C$
Final temperature $= +40°C$

Comprehension#3

1. Since P is constant = 1 atm, heat added will cause temperature rise.From the phase diagram, A will sublime while B will first melt and then boils.

2. From the phase diagram, at 2 atm & 220 K, A is gas & B is solid

Comprehension#4

1. On increasing temperature (giving heat), U increases. Now r_{avg} increases for A while decreases for B.

2. The equilibrium remain unchanged but average distance increases.

3. We have $\Delta r_{avg} = \left(\frac{1.0003 - 0.9999}{2}\right) r_0$
(from equilibrium position)

$$\therefore \frac{\Delta r}{r_0} = \alpha\Delta T \Rightarrow \alpha = 2 \times 10^{-5} / K$$

Comprehension#5

1. L et M be the mass of solid

$$\therefore \text{Volume displaced} = \frac{1 \times M}{2 \times \rho_s}$$

$$\text{Thrust force} = \rho_L \times \frac{M}{2\rho_s} g = Mg \qquad \therefore \rho_L = 2\rho_S$$

2. If $\gamma_{Liq} > \gamma_{solid}$ Also $\rho_L Vg = Mg$

As T ↑, ρ_L↓, so V displaced ↑
Fraction of solid submerged should increased.

3. If fraction of solid submerged doesn't change, then

$$\frac{\rho_0 V_0 (1 + 3\alpha\Delta T)}{(1 + \gamma_{Liq}\Delta T)} = \text{constant} \Rightarrow \gamma_{liq} = 3\alpha_S$$

4. If h doesn't change
$V = Ah \quad \therefore \gamma_L = 2\alpha_S$

5. If volume change in solid is zero.

$$\text{Let at T', solid sinks} \quad \rho_0 \frac{V}{2} g = V\rho_S g(\text{Initially})$$

$$\text{Finally } \rho_T Vg = V\rho_S g = \frac{\rho_0}{2}$$

$$\rho_T = \frac{\rho_0}{(1 + \gamma_L \Delta T)} = \frac{\rho_0}{2} \Rightarrow 2 = 1 + \gamma_L \Delta T = \Delta T = \frac{1}{\rho_L}$$

$$\Rightarrow \text{Temperature} = T + \frac{1}{\gamma_L}$$

Comprehension#6

1. At temperature above 4°C, temperature of water above is less as compared to below as water is heated by radiation of longer wavelength.

2. At temperature below 4°C, temperature above is less as compared to below & thus water remain is it is due to higher volume at the upper surface.

3. $\frac{Ldm}{dt} = \frac{\Delta T \cdot kA}{x}, dm = \rho Adx$

$$\Rightarrow \frac{L\rho Adx}{dt} = \frac{\Delta TkA}{x} = L\rho \frac{x^2}{2} = \Delta Tk \times t$$

Thickness, $x \propto t^{1/2}$

4. Transition of ice starts from the top & decreases below to the bottom.

Comprehension#7

1. As $Q = n_A C_{vA}\Delta T = n_B C_{vB}\Delta T \Rightarrow n_A C_{vA} = n_B C_{vB}$

But volume is constant $\Rightarrow \frac{n_A}{n_B} = \frac{\Delta P_A}{\Delta P_B} = \frac{2.5}{1.5} = \frac{5}{3}$

$$\Rightarrow \frac{C_{vB}}{C_{vA}} = \frac{5}{3} = \frac{5/2R}{3/2R}$$

$\Rightarrow$ Gas B is diatomic & gas A is monoatomic

2. As $n_A = \frac{5}{3} n_B$ so $\frac{125}{M_A} = \frac{5}{3}\left(\frac{60}{M_B}\right)$

$\Rightarrow 5\,M_B = 4M_A \Rightarrow$ Gas A = Ar , gas B = O_2

3. Number of molecules in A = $n_A N_A$

$$= \frac{125}{40} N_A = 3.125 N_A$$

4. $U = nC_V T = \frac{125}{40} \times \frac{3}{2} \times 2 \times 300 = 2812.5$ cal

Comprehension#8

2. **Ans. (D)**

$$\frac{\Delta Q}{t} = \frac{1 \times 4200 \times 2}{20} \text{J / sec} = 420\text{W}$$

3. $\frac{d\theta}{dt} = +K\left(T_S - T_L\right) \Rightarrow \frac{2}{20} = K(40) \Rightarrow K = \frac{1}{400}$

$$\int_{60°}^{40} \frac{d\theta}{(20-\theta)} = +K\int_0^t dt \; ; \; \ln(20-\theta)\Big|_{60}^{40} = -\frac{1}{400}t$$

$$\Rightarrow \ln\left(\frac{20}{40}\right) = -\frac{1}{400}t \quad \Rightarrow \quad t = 277\text{s}$$

Comprehension#9

1. $M_{mix} = \frac{n_1 M_1 + n_2 M_2}{n_1 + n_2} = \frac{5 \times 4 + 2 \times 2}{7} = \frac{24}{7}$ g

2. $C_{V_{mix}} = \frac{\frac{5}{2} \times 2R + \frac{3}{2} \times 5R}{7} = \frac{f_{mix}}{2} R = f_{mix} = 3.57$

3. $C_{V\,mix} = \frac{\frac{5}{2} \times 2R + \frac{3}{2} \times 5R}{7}, C_{P_{mix}} = \frac{\frac{7}{2} \times 2R + \frac{5}{2} \times 5R}{7}$

$$\gamma_{mix} = \frac{C_{P_{mix}}}{C_{V_{mix}}} = 1.56$$

4. Internal energy He = 100 J

Internal energy H = 200 J

while mixing, they don't interact

Internal energy of mix = (100 + 200) J = 300 J

Comprehension#10

1. Stress developed at junction are same

2. As cross sectional area is same & equal and opposite force acting on both rods.

So F/A= same.

3. Let shifting in junction be x towards right then

$$\left(\frac{\Delta l}{l}\right)_1 = \frac{l_1\alpha_1\Delta T - x}{l_1}, \left(\frac{\Delta l}{l}\right)_2 = \frac{l_2\alpha_2\Delta T + x}{l_2}$$

But $Y_1\left(\frac{\Delta l}{l}\right)_1 = Y_2\left(\frac{\Delta l}{l}\right)_2$

So $x = \frac{l_1 l_2 (Y_1\alpha_1 - Y_2\alpha_2)\Delta T}{Y_1 l_2 + Y_2 l_1}$

Comprehension#11

1. $\frac{Q_1}{Q_2} = \frac{T_1}{T_2} \Rightarrow Q_1 = \left(\frac{T_1}{T_2}\right) Q_2 = \left(\frac{300}{273}\right)(80) = 87.9\,kcal$

2. $W = Q_1 - Q_2 = 87.9 - 80 = 7.9$ kcal = 33.18 kJ

3. $\beta = \frac{T_2}{T_1 - T_2} = \frac{273}{27} = 10.1$

Comprehension#12

1. Change is entropy = $\frac{\Delta Q}{T}$

$\Rightarrow$ Unit of entropy = JK^{-1}

2. When milk is heated, its entropy increases as it is irreversible process.

3. After a long time disorder is increased.

Comprehension#13

1. $450 = m(0.5)(150) \Rightarrow m = 6g$

2. $L = \frac{Q}{m} = \frac{800 - 450}{6} = \frac{350}{6} = \frac{175}{3}$ cal/g

3. $s = \frac{Q}{m\Delta T} = \frac{200}{6(240-150)} = \frac{10}{27}$ cal/g°C

Comprehension#14

1. $Q_{BC} = 0 \Rightarrow \Delta U_{BC} = -W_{BC} = -400\text{ J}$

2. For complete cycle Q = W
$\Rightarrow Q_{AB} + Q_{BC} + Q_{CA} = W_{AB} + W_{BC} + W_{CA}$
$\Rightarrow 700 + 0 + (-100) = 700 + 400 + W_{CA}$
$\Rightarrow W_{CA} = -500\text{ J}$

3. $\eta = \dfrac{W_{net}}{Q_{input}} \times 100 = \dfrac{600}{700} \times 100 = \dfrac{600}{7} = 85.71\%$

Comprehension#15

1. $\eta = \dfrac{T_1 - T_2}{T_1} = 0.5 \Rightarrow T_1 = 560\text{K}$

$$\eta' = 0.7 = \frac{T_1' - T_2}{T_1'} = \frac{T_1' - 280}{T_1'} \Rightarrow \frac{2800}{3}$$

$$\Rightarrow T_1' - T_1 = \frac{1120}{3}$$

2. $\eta_{max} = \dfrac{T_1 - T_2}{T_1} \times 100 = \dfrac{600 - 300}{600} \times 100 = 50\%$

3. $\eta = 1 - \dfrac{T_2}{T_1} = \dfrac{1}{6}; \eta' = 1 - \dfrac{T_2}{T_1 + 100} = \dfrac{1}{3} \Rightarrow T_2 = \dfrac{1000}{3}\text{K}$

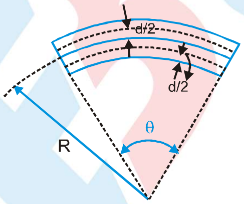
EXERCISE - 4

Subjective Type

1. Here:

$$\left(R + \frac{d}{2}\right)\phi = L(1 + \alpha_1 \Delta T) \quad ...(i)$$

$$\left(R - \frac{d}{2}\right)\phi = L(1 + \alpha_2 \Delta T) \quad ...(ii)$$

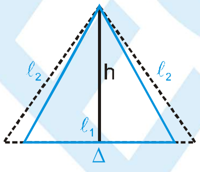


$$\Rightarrow R = \frac{d\left[1 + \left(\dfrac{\alpha_1 + \alpha_2}{2}\right)\Delta T\right]}{(\alpha_1 - \alpha_2)\Delta T}$$

Since $\left(\dfrac{\alpha_1 + \alpha_2}{2}\right)\Delta T << 1$

$$= \frac{d}{(\alpha_1 - \alpha)\Delta T} = \frac{d}{(\alpha_1 - \alpha_2)(t_2 - t_1)}$$

2.



$$h^2 = L_2^2 - \frac{l_1^2}{4} = \text{constant}$$

$$\Rightarrow 2L_2 \Delta L_2 - \frac{2L_1 \Delta L_1}{4} = 0$$

$$\Rightarrow 4L_2(L_2\alpha_2\Delta T) = L_1(L_1\alpha_1\Delta T)$$

$$\Rightarrow 4L_2^2\alpha_2 = L_1^2\alpha_1$$

3. (i) Thermal current $= \dfrac{\text{Temperature difference}}{R_H}$

where $\dfrac{1}{R_H} = \dfrac{K_1 A}{\lambda} + \dfrac{K_2 A}{\lambda} = \dfrac{\left(K_1 + K_2\right)a^2}{a}$

$= (60 + 40)(3 \times 10^{-2}) = 3\text{ WK}^{-1}$

$\Rightarrow$ Thermal current

$= 80 \times 3 = 240\text{ W}$

(i) Ratio of thermal currents

$$\frac{H_{Cu}}{H_{Al}} = \frac{K_{Cu}}{K_{Al}} = \frac{60}{40} = 1.5$$

4. $Q = KA\dfrac{(\theta_1 - \theta_2)t}{l} = mL \Rightarrow m \times 335 \times 10^3$

$$= 0.01 \times \frac{0.54 \times 45 \times 6 \times 60 \times 60}{5 \times 10^{-2}} \Rightarrow m = 0.261\text{ kg}$$

Therefore mass of ice left in the box after 6 hours
$= (4 - 0.261)\text{ kg} = 3.739\text{ kg}$

5. In steady state rate of flow of heat in the whole system will be same.

$$\frac{KA(200 - \theta_1)}{\lambda} = \frac{2KA(\theta_1 - \theta_2)}{\lambda} = \frac{1.5KA(\theta_2 - 18)}{\lambda}$$

$\Rightarrow 200 - \theta_1 = 2\theta_1 - 2\theta_2 \;\&\; 2\theta_1 - 2\theta_2 = 1.5\theta_2 - 27$

$\Rightarrow \theta_1 = 116°\text{C}, \theta_2 = 74°\text{C}$

6. (i) Temperature gradient

$$= \frac{T_1 - T_2}{l} = \frac{100 - 0}{1} = 100°\text{C/m}$$

(i) Steady state temperature of element dx : T = 100 (1–x)
Heat absorbed by the element to reach steady state

$dQ = (dm)s\,\Delta T = (\lambda dx)s(T - 0)$

$\Rightarrow dQ = 20\,[100\,(1 - x)]\,dx$

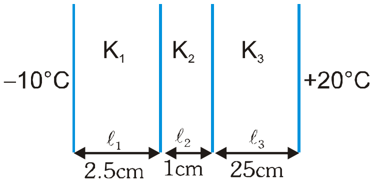
Total heat absorbed by the rod

$$Q = \int dQ = 2000 \int_0^1 (1 - x)\,dx = 1000\text{ J}$$

7. $\dfrac{\Delta Q}{\Delta t} = \text{same So } \dfrac{KA(20 - 10)}{l} = \dfrac{2KA(10 - \theta)}{l}$

$\Rightarrow 2\theta = 10 \Rightarrow \theta = 5°\text{C}$

8.



Power required

$$= \frac{K_{eq}A\left(T_1 - T_2\right)}{l}$$

$$= \frac{1}{\left(\frac{l_1}{K_1} + \frac{l_2}{K_2} + \frac{l_3}{K_3}\right)}\left[\frac{A\left(T_1 - T_2\right)}{l}\right]$$

$$= \frac{A\left(T_1 - T_2\right)}{\frac{l_1}{k_1} + \frac{l_2}{k_2} + \frac{l_3}{k_3}}$$

$$= \frac{(137)(30)}{\left(\frac{2.5}{0.125} + \frac{1}{1.5} + \frac{25}{1}\right) \times 10^{-2}} = 9000\ \text{W}$$

9. By using Wien's displacement law

$$T = \frac{b}{\lambda_m} = \frac{2.89 \times 10^{-3}}{1.5 \times 10^{-6}} = 1927\,\text{K}$$

10. Let m = mass of steam required per hour

Heat needed

$= (10 \times 1000\ \text{kg}) \times (1\text{cal/g}) \times (80–20)$

$= 60 \times 10^4\ \text{cal/hour}$

Heat supplied

$= m \times 1 \times (150 - 100) + m \times 540 + m \times 1 \times (100 - 90)$

Heat needed = Heat supplied

$\Rightarrow\ 60 \times 10^4 = 600\,m = 1000\ \text{gm} = 1\ \text{kg}$

11. (i) ✈ $P_A = P_B$

$\therefore\ e_A\,\sigma A_A\,T_A^{\,4} = e_B\,\sigma A_B T_B^{\,4}$

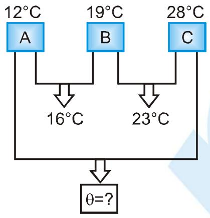
$$\Rightarrow\ T_B = \left(\frac{e_A}{e_B}\right)^{1/4} T_A = \left(\frac{0.01}{0.81}\right)^{\frac{1}{4}} 5802 = 1934\text{K}$$

(ii) According to Wein's displacement law

$$\lambda_A T_A = \lambda_B T_B \Rightarrow \lambda_B = \left(\frac{5802}{1934}\right)\lambda_A \Rightarrow \lambda_B = 3\lambda_A$$

Also $\lambda_B - \lambda_A = 1\ \mu\text{m} \Rightarrow \lambda_B - \frac{\lambda_B}{3} = 1\mu\text{m} \Rightarrow \lambda_B = 1.5\ \mu\text{m}$

13. When A & B are mixed



$mS_A 12 + m\,S_B 19 = m(S_A + S_B)16 \Rightarrow\ 3S_B = 4S_A$ ...(i)

When B & C are mixed

$mS_B 19 + mS_C 28 = m(S_B + S_C)23 \Rightarrow\ 4S_B = 5S_C$ ...(ii)

when A & C are mixed

$mS_A 12 + mS_C 28 = m(S_A + S_C)\theta \Rightarrow \theta = 20.3°\text{C}$

14. Heat needed to bring ice to freezing point

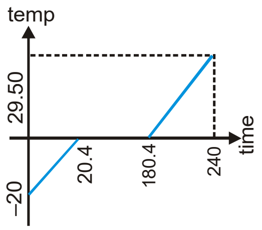
$= 10 \times 0.2 \times 20 + 200 \times 0.5 \times 20$

$= 40 + 2000 = 2040$ cal

$$\text{Time taken to reach } 0°\text{C} = \frac{2040}{100}\ \text{s} = 20.4\ \text{s}$$

Heat needed to melt ice

$= 2040 + 200 \times 80 = 18040$ cal



$$\text{Time taken to melt ice} = \frac{18040}{100} = 180.4\ \text{sec}$$

Heat taken in 4 min $= 100 \times 4 \times 60 = 24{,}000$ cal

Let

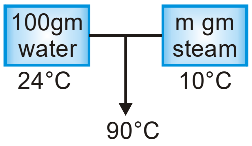
θ = final temperature then

heat lost = heat gained

$18040 + 10 \times 0.2 \times \theta + 200 \times 1 \times (\theta - 0) = 24{,}000$

$$\Rightarrow\ \theta = \frac{24000 - 18040}{202} = 29.50°\text{C}$$

15. Heat gained = Heat lost



$100 \times 1 \times (90 - 24) = m \times 540 + m \times 1 \times (100 - 90) \Rightarrow m = 12\ \text{g}$

16. Heat lost $= \frac{3}{4}\left(\frac{1}{2}mv^2\right)$

Heat gained $= ms(327–27) + mL$

As heat lost = Heat gained

So $\frac{3}{4}\left(\frac{1}{2}mv^2\right) = ms \times 300 + m \times L$

$\Rightarrow \frac{3}{8}v^2 = 0.03 \times 1000 \times 4.2 \times 300 + 6 \times 1000 \times 4.2$

$\Rightarrow v = 12.96$ m/s

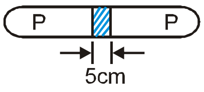
17. **(i)** At triple point (temperature = –56.6°C) & pressure = 5.11 atm), the solid, the liquid & the vapour phases of CO_2 co–exist.

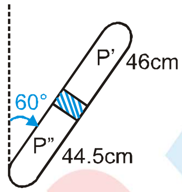
(ii) Fusion point & boiling point both decrease on decreasing pressure.

(iii) Critical temperature is 31.1°C and critical pressure is 73.0 atm. On temperature higher than critical temperature it can't be liquified.

(iv) (A) Vapour (B) Solid (C) liquid

18. $P'' = P' + 5\cos 60° = (P' + 2.5)$ cm of Hg





For constant temperature process :

$$P \times \left(\frac{46 + 44.5}{2}\right) = P' \times 46 = (P' + 2.5)(44.5)$$

$\Rightarrow P' = \frac{44.5 \times 2.5}{1.5}$ & $P = 75.4$ cm of Hg

19. No. of moles (initially) = No. of moles (finally)

$$\frac{76 \times V_0}{273} + \frac{76 \times V_0}{273} = \frac{PV_0}{273} + \frac{PV_0}{335}$$

$\Rightarrow P = 83.83$ cm of Hg

20. No. of moles withdrawn $= n_1 - n_2 = \frac{\Delta m}{M}$

$$\Rightarrow \Delta m = M(n_1 - n_2) = M\left(\frac{P_1V_1}{RT_1} - \frac{P_2V_2}{RT_2}\right)$$

$$= 32\left[\frac{15 \times 10^5 \times 30 \times 10^{-3}}{300 \times 8.314} - \frac{11 \times 10^5 \times 30 \times 10^{-3}}{290 \times 8.314}\right]$$

$= 0.139$ kg

21. Let m = mass of neon gas then

$n = \left(\frac{m}{20} + \frac{28 - m}{40}\right)$ from $PV = nRT$

$$\Rightarrow 10^5 \times 0.2 = \left(\frac{m}{20} + \frac{28 - m}{40}\right) \times 8.314 \times 300$$

$m_{Ne} = 4.074$ g; $m_{Argon} = 23.926$ g

22. $\frac{R}{C_P} = 0.4 \Rightarrow C_P = \frac{R}{0.4} = \frac{5}{2}R \Rightarrow C_v = C_P - R = \frac{3}{2}R$

(i) Atomicity = Monatomic,
Degree of freedom = 3

(ii) $C_v = \frac{3}{2}R \Rightarrow \gamma = \frac{C_P}{C_V} = \frac{5}{3}$

(iii) Mean gram–molecular kinetic energy

$= \frac{3}{2}R \times 300 = 450\,R$

23. **(i)** Dotted lines correspond to ideal gas

(ii) $T_1 > T_2$
(On high temp. real gas behaves as ideal gas)

(iii) $\frac{PV}{T} = \frac{m}{M}.R = \frac{10^{-3}}{32 \times 10^{-3}} \times 8.314 = 0.26$ J/K

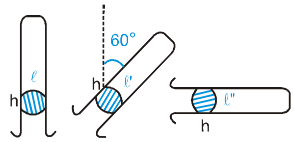
24. For gas trapped in the tube

$P_1V_1 = P_2V_2 = P_3V_3$

$\Rightarrow$ (76–h)A● = (76–hcos60°)A●' = 76 × A●

$\Rightarrow$ 66 × 40 = 71 × ●' = 76 × ●"

● = 37.2 cm & ●" = 34.7 cm



25. **(i)** Let $\dot{n}$ = number of collisions per second per unit area, change in momentum = 2mv

$\therefore$ Pressure exerted on wall $= \dot{n}(2mv) = P_0$

$$\Rightarrow \frac{\dot{n} \times 2 \times 32 \times 10^{-3}}{6.02 \times 10^{23}} \times \sqrt{\frac{3 \times 8.3 \times 300}{0.032}} = 10^5$$

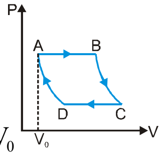
$\Rightarrow \dot{n} = 1.95 \times 10^{27}$

(ii) If vessel is suddenly stopped then KE will utilized in increase in temperature.

So $\frac{1}{2}MV_0^2 = nC_v\Delta T$

$$\Rightarrow V_0 = \sqrt{\frac{2nC_v\Delta T}{M}} = \sqrt{\frac{2C_v\Delta T}{M_w}} = 36\ ms^{-1}$$

26. $V_A = V_0 = \frac{nRT_A}{P_A} = \frac{2R \times 300}{2} = 300R$



$V_B = \frac{nRT_B}{P_B} = \frac{2R \times 400}{2} = 400R = \frac{4}{3}V_0$

$V_C = \frac{nRT_C}{P_C} = \frac{2R \times 400}{1} = 800\,R = \frac{8}{3}V_0$

$V_D = \frac{nRT_D}{P_D} = \frac{2R \times 300}{1} = 600\,R = 2V_0$

For cyclic process

$\Delta U = 0, Q = W$

$$W_{A\to B} = P_A(V_B - V_A) = 2\left(\frac{4V_0}{3} - V_0\right) \times 10^5 = \frac{2V_0}{3} \times 10^5$$

$$W_{B\to C} = P_B V_B \bullet n2 = 2 \times 10^5 \times \frac{4V_0}{3} \bullet n2 = \frac{8V_0}{3} \bullet n2 \times 10^5$$

$W_{C\to D} = P_C(V_D - V_C)$

$$= 10^5\left(2V_0 - \frac{8V_0}{3}\right) = -\frac{2V_0}{3} \times 10^5$$

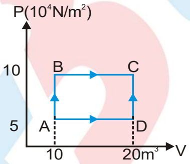
$W_{D\to A} = -P_D V_D. \bullet n2 = -10^5 \times 2 \times \bullet n2$

$\therefore W = W_{A\to B} + W_{B\to C} + W_{C\to D} + W_{D\to A} = 1152\ J$

(i) $\therefore Q = 1152\ J$ (ii) $W = 1152\ J$ (iii) $\Delta U = 0$

27. **(i)** $T_A = \frac{P_A V_A}{nR} = \frac{5 \times 10^4 \times 10}{\left(\frac{2000}{4}\right) \times 8.314} = 120.3°K$

$T_B = \frac{P_B V_B}{nR} = 2T_A = 240.6°\ K$



$T_C = \frac{P_C V_C}{nR} = 2T_B = 481.3°\ K$

$T_D = \frac{P_D V_D}{nR} = T_B = 240.6°K$

(ii) No. we can not predict the direction of reaction.

(iii) Process ABC :

$W = P\Delta V = 10 \times 10^4 \times (20 - 10) = 10^6\ J$

$$\Delta U = nC_V\Delta T = \left(\frac{2000}{4}\right)\left(\frac{3R}{2}\right) \times (T_C - T_A)$$

$= 2.25 \times 10^6\ J$ $\therefore Q = 3.25 \times 10^6\ J$

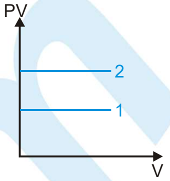
Process ADC →

$W = 5 \times 10^4 \times (20 - 10) = 0.5 \times 10^6\ J$

$\Delta U = nC_V(T_C - T_A) = 2.25 \times 10^6\ J$

$\therefore Q = 2.75 \times 10^6 J$

28. **(i)** $P_1V_1 = nRT_1$ and $P_2V_2 = nRT_2$



✈ $P_2V_2 > P_1V_1$

$\Rightarrow nRT_2 > nRT_1 \Rightarrow T_2 > T_1$

For same volume, $P_1V = nRT_1$

✈ $T_1 < T_2$ & $P_2V = nRT_2$

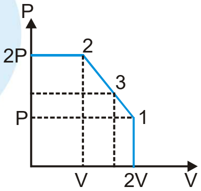
$\Rightarrow P_1 < P_2$

(ii) $P_2V_2 = P_1V_1 = 2PV = P2V \Rightarrow T_1 = T_2$

For state 3:

Let $V_3 = 3V/2$

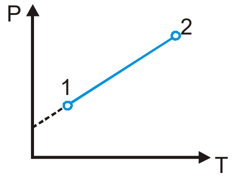
$P_3 = 3P/2$ then



$P_3V_3 = \frac{3P}{2}\frac{3V}{2} = \frac{9}{4}PV$

$\therefore T_3 > T_2$ & $T_3 > T_1$

(iii) $P = mT + C \Rightarrow \frac{P - C}{T} = m$



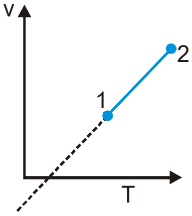
$$\Rightarrow \left(\frac{P_1 - C}{T_1}\right) = \left(\frac{P_2 - C}{T_2}\right)$$

From ideal gas equation

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{P_1V_1}{P_2V_2} = \frac{T_1}{T_2} = \left(\frac{P_1 - C}{P_2 - C}\right)$$

$$\Rightarrow \frac{V_1}{V_2} = \frac{\left(1 - \frac{C}{P_1}\right)}{\left(1 - \frac{C}{P_2}\right)} < 1 \Rightarrow V_1 < V_2$$

(iv) $V = mT - C\,;\ \frac{V_1 + C}{T_1} = \frac{V_2 + C}{T_2}$



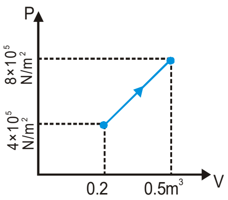
then $P_1V_1 = nRT_1$

$P_2V_2 = nRT_2 \Rightarrow \frac{P_1V_1}{P_2V_2} = \frac{nRT_1}{nRT_2}$

$$\Rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2} \times \frac{V_2}{V_1} = \left(\frac{V_1 + C}{V_1}\right)\left(\frac{V_2}{V_2 + C}\right)$$

$$\frac{P_1}{P_2} = \left(1 + \frac{C}{V_1}\right)\frac{1}{\left(1 + \frac{C}{V_2}\right)} > 1 \quad \therefore P_1 > P_2$$

29. (i) Work done by gas



$$= \frac{1}{2}(4+8) \times 10^5 \times (0.5–0.2)$$

$$= 1.8 \times 10^5 \text{ J}$$

(ii) Increase in internal energy

$$\Delta U = nC_V\,\Delta T = \frac{nR(T_2 - T_1)}{\gamma - 1} = \frac{P_2V_2 - P_1V_1}{\gamma - 1}$$

$$= \frac{(8 \times 0.5 - 4 \times 0.2) \times 10^5}{\frac{5}{3} - 1} = 4.8 \times 10^5 \text{ J}$$

(iii) Amount of heat supplied

$Q = \Delta U + W = 6.6 \times 10^5$ J

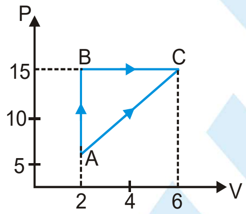
(iv) Molar specific heat of the gas

$$= \frac{Q}{n\Delta T} = \frac{6.6 \times 10^5 \times R}{(P_2V_2 - P_1V_1)} = 17.1 \text{ J/mole–K}$$

30. (i) $W_{AC} < W_{ABC}$ (Area under PV–graph gives work)

(ii) $U_A = 10$J

$Q_{AC} = 200$ J



$$\Delta W_{AC} = \frac{1}{2} \times (6 - 2) \times (15 + 5)$$

$$= \frac{4 \times 20}{2} = 40 \text{ J}$$

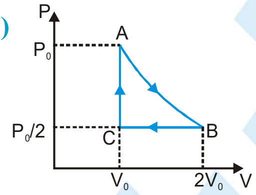
$\Rightarrow Q = \Delta U + W \Rightarrow 200 = (U_C - 10) + 40$

$\Rightarrow U_C = 200 + 10 - 40 = 210 - 40 = 170$ J

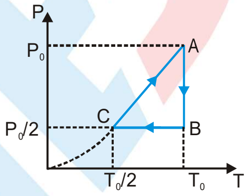
(iii) $Q_{AB} = \Delta U_{AB} + W_{AB} = (U_B - U_A) + W_{A\to B}$

$= (20 – 10) + 0 = 10$ J

31. (i)



(ii)



(iii) Work done by gas $W_{AB} = nR(T_A)\,●n\,\frac{V_B}{V_A}$

$= 3RT_A●n2$

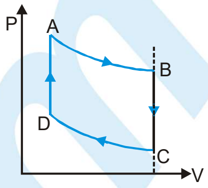
$$W_{BC} = \frac{P_0}{2}(V_0 - 2V_0)$$

$$= -\frac{P_0V_0}{2} = \frac{-nRT_A}{2} = -\frac{3}{2}RT_A \Rightarrow W_{CA} = 0$$

$\therefore\ W_{ABCA} = RT_A(3 \times 0.693 - 1.5) = 0.58\,RT_A$

$\therefore\ \Delta Q_{ABCA} = W_{ABCA} = 0.58\,RT_A$

32. Given that



$T_A = 1000$ K n=1

$$P_B = \left(\frac{2}{3}\right)P_A, \gamma = 5/3$$

$$P_C = \left(\frac{1}{3}\right)P_A, \left(\frac{2}{3}\right)^{2/5} = 0.85$$

For process A→B

$$P_A^{1-\gamma}T_A^{\gamma} = P_B^{1-\gamma}T_B^{\gamma}$$

$$T_B = T_A\left(\frac{P_A}{P_B}\right)^{\frac{1-\gamma}{\gamma}} = 1000 \times \left(\frac{3}{2}\right)^{-2/5}$$

$$= 1000 \times 0.85 = 850\,\text{k}$$

For Process B → C

$$\frac{P_B}{T_B} = \frac{P_C}{T_C} \Rightarrow T_C = T_B\left(\frac{P_C}{P_B}\right) = 850 \times \frac{1}{2} = 425 \text{ K}$$

(i) $W_{A\to B} = \frac{nR(T_A - T_B)}{\gamma - 1}$

$$= \frac{1 \times 8.314 \times (1000 - 850)}{\left(\frac{5}{3} - 1\right)} = 1870.2 \text{ J}$$

(ii) $\Delta Q_{B\to C} = \Delta U_{B\to C} + \Delta W_{B\to C} = nC_V\Delta T + 0$

$$= n.\frac{3}{2}R(T_C - T_B) = 1 \times \frac{3}{2} \times 8.314\,(425 - 850)$$

$= –5300.175$ J

(iii) For process A → B

$$P_AV_A^{\gamma} = P_BV_B^{\gamma} \Rightarrow \left(\frac{V_B}{V_A}\right)^{\gamma} = \frac{P_A}{P_B} = \frac{3}{2}$$

For Process C → D

$P_CV_C^{\gamma} = P_DV_D^{\gamma}$

$$\Rightarrow \left(\frac{V_C}{V_D}\right)^{\gamma} = \left(\frac{V_B}{V_A}\right)^{\gamma} = \frac{3}{2} = \frac{P_D}{P_C} \Rightarrow P_D = \frac{3}{2}P_C$$

At end points A and D

$$\Rightarrow \frac{P_A}{T_A} = \frac{P_D}{T_D} \Rightarrow \frac{3P_C}{1000} = \frac{\left(\frac{3P_C}{2}\right)}{T_D} \Rightarrow T_D = 500 \text{ K}$$

33. (i) For adiabatic process $T_1V_1^{\gamma-1} = T_2.V_2^{\gamma-1}$

$\Rightarrow 300\,V^{5/3-1} = T_2.(2V)^{5/3-1} \Rightarrow T_2 = 189\text{ K}$

(ii) Change in internal energy

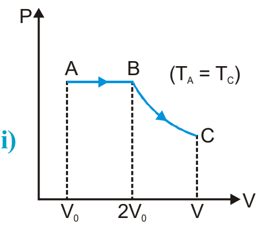
$$\Delta U = nC_V\Delta T = n\frac{3}{2}R(T_2 - T_1)$$

$$= 2\times\frac{3}{2}\times 8.314\times(189-300) = -2767\text{ J}$$

(iii) Work done by gas $= \dfrac{P_1V_1 - P_2V_2}{\gamma-1} = \dfrac{nR(T_1 - T_2)}{\gamma-1}$

$= 2767\text{ J}$

34. (i)



(ii) Process AB

$$\frac{V_A}{T_A} = \frac{V_B}{T_B} \Rightarrow T_B = \frac{V_B}{V_A}T_A = 2T_A = 600\text{ K}$$

Process BC

$$T_BV_B^{\gamma-1} = T_CV_C^{\gamma-1}$$

$\Rightarrow V_C = 80\sqrt{2}$ Litre $= 113$ L

For end states A & C $\dfrac{P_A.V_A}{T_A} = \dfrac{P_CV_C}{T_C} = nR$

$\Rightarrow P_C = 0.44\times 10^5\text{ N/m}^2$

(iii) Work done

$W_{AB} = P_A(2V_0 - V_0) = nRT_A = 600R;\ W_{BC}$

$$= \frac{nR(T_B - T_C)}{\gamma-1} = \frac{3}{2}nR(600-300) = 900R$$

35. For polytropic process $T_1V_1^{n-1} = T_2V_2^{n-1}$

$\Rightarrow TV^{n-1} = \dfrac{T}{2}(5.66V)^{n-1} \Rightarrow 2 = 5.66^{n-1}$

Taking log both sides $\ln 2 = (n-1)\ln 5.66$

$\Rightarrow n = 1.4 = 1 + \dfrac{2}{f} \Rightarrow f = 5$

(i) ∴ Degrees of freedom = 5

(ii) Work done by gas

$$= -\frac{P_1V_1 - P_2V_2}{\gamma-1} = \frac{PV - P_2(5.66V)}{1.4-1} = 12.3PV$$

Where $P_2V_2^{\gamma} = P_1V_1^{\gamma} \Rightarrow P_2 = P\left(\dfrac{1}{5.66}\right)^{1.4}$

36. $PV^{\gamma} = \text{constant} \Rightarrow (10^5)\,(6)^{5/3} = (P_2)\,(2)^{5/3}$

$\Rightarrow P_2 = (10^5)(3)^{5/3}\text{ Nm}^{-2}$

$$W = \frac{P_1V_1 - P_2V_2}{\gamma-1}$$

$$= \frac{(10^5)(6\times10^{-3}) - (10^5\times 3^{5/3})(2\times10^{-3})}{\frac{5}{3}-1} = -972\text{ J}$$

37. Number of moles $n = \dfrac{PV}{RT} = \dfrac{(1.6\times10^6)(0.0083)}{(8.3)(300)} = \dfrac{16}{3}$

Heat is supplied at cosntant volume

So $Q = nC_V\Delta T$

$$\Rightarrow T_2 = T_1 + \frac{Q}{nC_V} = 300 + \frac{2.49\times10^4}{\left(\frac{16}{3}\right)\left(\frac{3R}{2}\right)}$$

$$= 300 + 375 = 675\text{ K}$$

As V = constant So $\dfrac{P_2}{P_1} = \dfrac{T_2}{T_1}$

$$\Rightarrow P_2 = \left(\frac{675}{300}\right)(1.6\times10^6) = 3.6\times10^6\text{ Nm}^{-2}$$

38. (i) For a cyclic process

$Q_1 + Q_2 + Q_3 + Q_4 = W_1 + W_2 + W_3 + W_4$

$\Rightarrow W_4 = Q_1 + Q_2 + Q_3 + Q_4 - W_1 - W_2 - W_3$

$= 5960 - 5585 - 2980 + 3645 - 2200 + 825 + 1100 = 765\text{ J}$

(ii) $\eta = \dfrac{W_{net}}{Q_{given}} = \dfrac{W_1 + W_2 + W_3 + W_4}{Q_1 + Q_4}$

$$= \frac{2200 - 825 - 1100 + 765}{5960 + 3645} = 0.1082$$

39. $\gamma_{mix} = \dfrac{n_AC_{P_A} + n_BC_{P_B}}{n_AC_{V_A} + n_BC_{V_B}}$

$$\Rightarrow \frac{19}{13} = \frac{(1)\left(\frac{5}{2}R\right) + n_B\left(\frac{7}{2}R\right)}{(1)\left(\frac{3}{2}R\right) + n_B\left(\frac{5}{2}R\right)} \Rightarrow n_B = 2\text{ mole}$$

40. The maximum temperature of the gas will be during process BC.

Process BC can be represented by straight line,

$y = mx + C$

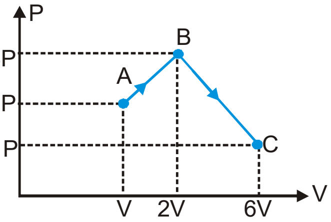
So $P = mV + C$

Putting point B & C gives

$3P = 2mV + C$ ....(i)

$\Rightarrow \quad P = 6mV + C$ ...(ii)

So subtracting $2P = -4mV$ So $m = -\frac{P}{2V}$



From (ii) $P = -\frac{P}{2V} \cdot 6V + C \Rightarrow C = 4P$

Hence we get equation as

$$y = \left(-\frac{P}{2V}\right)x + 4P \qquad ...(iii)$$

where y is pressure and x is volume of gas.
Putting y from above. Now we have

$$xy = nRT \Rightarrow \left(-\frac{P}{V}x^2 + 4Px\right) = nRT \qquad ....(iv)$$

For maximum temperature $\frac{dT}{dx} = 0$

$$\Rightarrow \left(-\frac{2P}{2V}x + 4Px\right) = 0$$

Hence $x = 4V$ Putting in (iii)
We get $nRT_{max} = 2P(4V) = 8PV$

So $T_{max} = \frac{8PV}{nR} \Rightarrow x = 8$

41. PT = constant ⇒ P^2V = constant ⇒ $PV^{1/2}$ = constant

For this process $C = C_V + \frac{R}{1 - 1/2} = C_V + 2R$

$$\Rightarrow C_V = 37.35 - 2(8.314) = 20.722 = \frac{5}{2}R$$

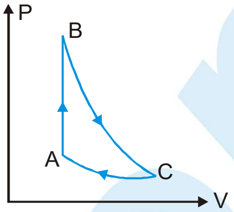
$$\Rightarrow \frac{f}{2}R = \frac{5}{2}R \Rightarrow f = 5$$

42. Slope

$$= -\frac{\gamma P}{V} = -\tan 37° \Rightarrow \frac{mP}{V} = \tan 37°$$

$$\Rightarrow m = \left(\frac{V}{P}\right)\left(\frac{3}{4}\right) = \left(\frac{4\times10^5}{2\times10^5}\right)\left(\frac{3}{4}\right) = \frac{3}{2} = 1.5$$

43. $PV = nRT \Rightarrow n = \frac{PV}{RT} = \frac{(10^3)(10^{-3})}{(25/3)(3)} = \frac{1}{25}$



For process AB

$W = 0, Q = \Delta U = nC_V\Delta T$

$$= \left(\frac{1}{25}\right)\left(\frac{3}{2}R\right)(300-3) = \frac{297}{2} = 148.5 \text{ J}$$

For process BC

$$Q = 0, W = \frac{nR}{\gamma - 1}(T_1 - T_2) = \frac{\left(\frac{1}{25}\right)\left(\frac{25}{3}\right)}{\left(\frac{5}{3} - 1\right)}[300 - 3]$$

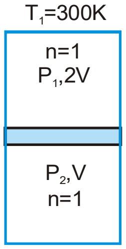
$$= 148.5 \text{ J and } \Delta U = -W = -148.5 \text{ J}$$

For process CA ⇒ $\Delta U = 0$

$$W = nRT \ln\left(\frac{V_A}{V_C}\right) = -6.9 \text{ J and } Q = W = -6.9 \text{ J}$$

$$\text{Thermal efficiency} = \frac{W_{net}}{Q_{supplied}} = \frac{148.5 - 6.9}{148.5} = 0.954$$

44. $P_1A + Mg = P_2A$



Extra force needed

$= P_2'A - P_1'A - Mg$

$= P_2'A - P_1'A - P_2A + P_1A$

$= (\Delta P_2)A - (\Delta P_1)A$

$$= \left[\frac{nR\Delta T}{V} - \frac{nR\Delta T}{2V}\right]A = \frac{5000}{3} \text{N}$$

45. $\Delta U = nC_V\Delta T$, $Q = nC_P\Delta T$ and

$$W = nR\Delta T = (1)\left(\frac{25}{3}\right)(100) = \frac{2500}{3} \text{ J}$$

$$\Delta U = n(C_P - R)\Delta T = nC_P\Delta T - nR\Delta T$$

$$= 1000 - (1)\left(\frac{25}{3}\right)(100) = \frac{500}{3} \text{ J}$$

46. New length of gas column $= \frac{h}{2} + \frac{h}{16} = \frac{9}{16}h$

New volume of gas

$$= \left(\frac{9}{16}h\right) A = \frac{9}{16} V_0 \Rightarrow P = P_0 + kx$$

As $PV^{\gamma} = \text{constant}$ so $P_0V_0^{1.5} = P\left(\frac{9}{16}V_0\right)^{1.5}$

$$\Rightarrow P = \frac{64}{27}P_0 = P_0 + kx \Rightarrow kx = \frac{37}{27}P_0$$

But $kx = (3700)\left(\frac{h}{16}\right)$ so $(3700)\left(\frac{h}{16}\right) = \left(\frac{37}{27}\right)(10^5)$

Now $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$$\Rightarrow (273)(V_0)^{0.5} = (T_2)\left(\frac{9}{16}V_0\right)^{0.5}$$

$$\Rightarrow T_2 = \frac{4}{3} \times 273 = 364\text{ K}$$

48. Final volume of chamber $= V_0 + Ax = 3.2 \times 10^{-3}\text{ m}^3$

Final pressure in chamber $= P_0 + \frac{kx}{A} = 2 \times 10^5 \text{N/m}^2$

From ideal gas equation $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$$T_2 = (P_2V_2)\left(\frac{T_1}{P_1V_1}\right) = 800\text{ K}$$

Work done by gas $= \int_0^{0.1}\left(P_0 + \frac{Kx}{A}\right) Adx = 120\text{ J}$

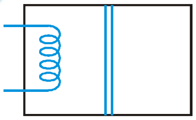
Change in internal energy $\Delta U = nC_v\Delta T$

$$\Rightarrow \quad \Delta U = \left(\frac{P_1V_1}{RT_1}\right)\left(\frac{3}{2}R\right)\Delta T = 600\text{ J}$$

$\therefore$ Heat Supplied $= 120 + 600 = 720$ J

49. (i) For the right chamber

$$P_0^{1-\gamma}T_0^{\gamma} = \left(\frac{243P_0}{32}\right)^{1-\gamma}.T_2^{\gamma}$$



$$\Rightarrow \quad T_2 = \frac{9}{4}T_0 \text{ and } \frac{P_0.V_0}{T_0} = \frac{\left(\frac{243P_0}{32}\right).V_2}{\left(\frac{9}{4}T_0\right)}$$

$$\Rightarrow \quad V_2 = \frac{9}{4} \times \frac{32}{243}V_0 = \frac{8}{27}V_0$$

For the left chamber

$$\frac{P_0V_0}{T_0} = \frac{P_1.V_1}{T_1} \quad \text{where } P_1 = \frac{243}{32}P_0$$

$$V_1 = 2V_0 - \frac{8}{27}V_0 = \frac{46}{27}V_0$$

$$\Rightarrow \quad T_1 = \frac{T_0}{P_0V_0} \times \left(\frac{243}{32}P_0\right)\left(\frac{46}{27}V_0\right) = \frac{9 \times 23}{16}T_0$$

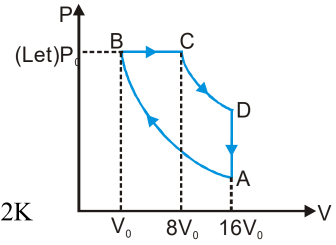
$$= 12.94\,T_0$$

(ii) Work done by the gas in the right chamber :

$$\frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{nR(T_1 - T_2)}{\gamma - 1} = \frac{1 \times R\left(T_0 - \frac{9}{4}T_0\right)}{\left(\frac{5}{3} - 1\right)}$$

$$= -\frac{3}{2} \times R \times \frac{5}{4}T_0 = -1.875\,RT_0$$

50. Let $V_B = V_0$



Process $A \rightarrow B$

$T_AV_A^{\gamma-1} = T_BV^{\gamma-1}$

$\Rightarrow T_B = 909$ K

Process $B \rightarrow C$

$\frac{V_B}{T_B} = \frac{V_C}{T_C} \Rightarrow T_C = 7272$K

Process $C \rightarrow D$:

$T_CV_C^{\gamma-1} = T_DV_D^{\gamma-1} \Rightarrow T_D = 5511.15$ K

Heat flow

Process $A \rightarrow B$ $\quad Q_{AB} = 0$

Process $B \rightarrow C$ $\quad Q_{BC} = nC_P\Delta T$

$$= 1 \times \frac{7}{2}R(T_C - T_B) = 185156.937\text{J}$$

Process $C \rightarrow D$ $\quad Q_{CD} = 0$

Process $D \rightarrow A$ $\quad Q_{DA} = nCv\Delta T$

$$= 1\left(\frac{5}{2}R\right)(T_A - T_D) = -108313.753\text{ J}$$

$\therefore$ Efficiency

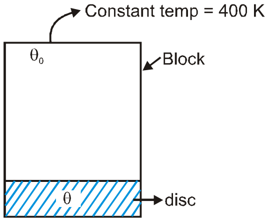
$$\eta = \frac{\text{work output}}{\text{Heat input}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$$

$$= \left(1 - \frac{108313.753}{185156.937}\right) \times 100\%$$

$$\eta = 41.50\%$$

Note : please read $V_C/V_D = ½$ instead of $V_C/V_D = 2$ in the question.

51.



θ = temperature of disc

θ_0 = constant temperature

Heat input to disc $\dfrac{KA(\theta_0 - \theta)}{L}$

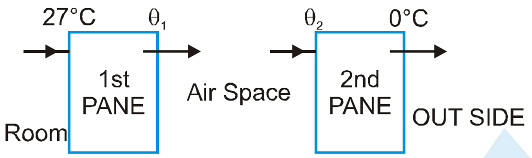
Heat utilised by disc = ms $\dfrac{d\theta}{dt}$

(where s = specific heat of disc)

$$\Rightarrow ms\frac{d\theta}{dt} = \frac{KA(\theta_0 - \theta)}{L} \Rightarrow \int_{300}^{350}\frac{d\theta}{\theta_0 - \theta} = \frac{KA}{msL}\int_0^t dt$$

$$\Rightarrow t = \frac{msL}{KA}\bullet n\left(\frac{\theta_0 - 300}{\theta_0 - 350}\right) \Rightarrow t = 166.32 \text{ sec}$$

52. Heat flow for three sections will be same.



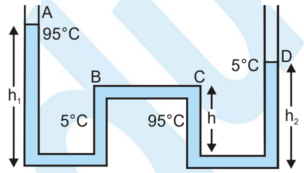
$$\therefore \quad \frac{27 - \theta_1}{\left(\frac{L}{KA}\right)_{1\text{st Pane}}} = \frac{\theta_1 - \theta_2}{\left(\frac{L}{KA}\right)_{A.S.}} = \frac{\theta_2 - 0}{\left(\frac{L}{KA}\right)_{2\text{nd Pane}}}$$

$\Rightarrow \quad Q_1 = 26.48°C ; \quad Q_2 = 0.52°C$

Heat flow rate

$$\frac{d\theta}{dt} = \frac{27 - \theta_1}{\left(\frac{L}{KA}\right)_{1\text{st Pane}}} = \frac{27 - 26.48}{\left(\frac{0.01}{0.8 \times 1}\right)} = 41.6 \text{ watt}$$

53.



Pressure at the bottom of A – B limb :

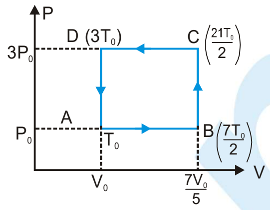
$P_0 + \rho_{95}gh_1 = P_B + \rho_5 gh$ ...(i)

Pressure at the bottom of C–D limb :

$P_B + \rho_{95}\, gh = P_0 + \rho_5 \times\, g \times h_2\, (P_B = P_C)$ ...(ii)

Solving we get, $\gamma = 2 \times 10^{-4}\,°C^{-1}$ $\therefore\ \alpha = \dfrac{2}{3} \times 10^{-4}\,°C^{-1}$

54. For each state



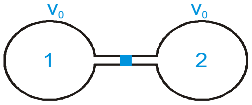
$$n = \frac{P_0V_0}{T_0} = \frac{P_0.(7V_0\ /\ 2)}{T_B} = \frac{3P_0(7V_0\ /\ 2)}{T_C} = \frac{3P_0V_0}{T_D}$$

$$\Rightarrow T_B = \frac{7}{2}T_0 ; T_C = \frac{21}{2}T_0 \Rightarrow T_D = 3T_0.$$

$\therefore$ Heat absorbed $= (nC_P.\,\Delta T)_{A\to B} + (nC_v\Delta T)_{B\to C}$

$$= n4R\left(\frac{5}{2}T_0\right) + n\,3R(7T_0) = 31.nR\,T_0 = 31P_0V_0$$

$$\text{Work done} = (3P_0 - P_0)\,(V_0 - \frac{7}{2}V_0) \quad = -5P_0V_0$$



55. n_1= no. of moles in vessel–1

n_2 = no. of moles in vessel–2

P_1 = initial pressure in both vessels

P_2 = final pressure in both vessels.

Initially

volume of vessel–1 = volume of vessel–2

$$\frac{n_1RT_0}{P_1} = \frac{n_2RT_0}{P_1} \Rightarrow n_1 = n_2$$

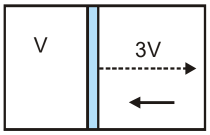
$$\text{Finally,}\quad V_1 = \frac{n_1RT_1}{P_2}\ \ \&\ \ V_2 = \frac{n_2.RT_2}{P_2} = \left(\frac{n_1R}{P_2}\right)T_2$$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2} = \frac{275}{271}\ \&\ V_1 + V_2 = V_0 + \lambda A$$

Displacement of mercury droplets

$$\Delta L = \frac{V_1 - V_2}{A} = \frac{4}{546}\left(\frac{V_0 + \lambda A}{A}\right) = 0.26\,m$$

56. In free expansion, temperature remains constant



Initial temperature $T_0 = \dfrac{P_0V_0}{nR}$

After compression $T_0(4V)^{\gamma-1} = T(V)^{\gamma-1} \Rightarrow T = 2T_0$

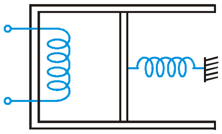
Change in internal energy $\Delta U = nC_V.\Delta T = n\left(\dfrac{R}{\gamma - 1}\right)$

$$\Delta T = \frac{nR(2T_0 - T_0)}{\gamma - 1}$$

$$= \frac{nRT_0}{\gamma - 1} = \frac{P_0V_0}{\gamma - 1} = \frac{(2\times10^5)\times(10^{-3})}{(1.5-1)} = 400\ \text{J}$$

57. Work done by gas

$$= \int_0^x P_0 A dx + \int_0^x kx.dx$$



$$\Rightarrow 50\ \text{J} = P_0Ax + \frac{kx^2}{2}$$

$$\Rightarrow 50 = 10^5 \times 4 \times 10^{-3} \times 0.1 + \frac{k}{2}(0.01)$$

Spring constant $\Rightarrow k = 2000$ N/m

Heat supplied

$Q = \Delta U + W = nC_V\Delta T + W$

$$= \frac{nR\Delta T}{\gamma - 1} + W = \frac{2\times 8.314 \times 50}{\left(\frac{5}{3}-1\right)} + 50 = 1295\ \text{J}$$

58. Let h_i = empty space over Hg–column

For constant temperature process

$P_1V_1 = P_2V_2 \Rightarrow 4 \times h_1 = 5h_2$

where $h_1 - h_2 = 1 \Rightarrow h_2 = 4$ & $h_1 = 5$

True Reading	Faulty Reading
73	69
75	70
74	x

(i) Total length of tube

$= 69 + 5 = 74$ cm or 70+4=74 cm

(i)i When faulty barometer reads 69.5 cm.

$P_1V_1 = P_2V_2$; $4h_1 = 4.5$ h; $h = 4.44$

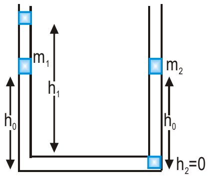
$\therefore$ True reading $= 69.5 + 4.44 = 73.94$

(iii) When the barometer reads 74 cm

$P_1V_1 = P_2V_2 \Rightarrow 4 \times 5 = (74 - x)^2 \Rightarrow x = 69.528$ cm

59. For equilibrium

$$\frac{m_1g}{A_1} + \rho gh_0 = \frac{m_2g}{A_2} + \rho gh_0$$



$m_1 = 2\text{kg}, m_2 = 1\text{kg}$

$$\Rightarrow \frac{2}{A_1} = \frac{1}{A_2}$$

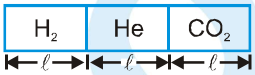
For final equilibrium $\frac{m_1g}{A_2} > \frac{m_2g}{A_1}$

$\therefore$ m_1 block will fall down

For constant temperature forces and pressure being constant $V_{\text{initial}} = V_{\text{final}}$

$h_0A_1 + h_0A_2 = h_1A_1 + h_2A_2 \Rightarrow h_1 = 30$ cm & $h_2 = 0$

60. $\theta_1 = 372°C$; $\theta_2 = -15°C$; $\theta_3 = 157°C$ $\gamma_{CO_2} = \frac{7}{5}$



For the H_2 gas

$$\frac{P_1V_1}{RT_1} = \frac{P_2V_2}{RT_2} \Rightarrow \frac{P_0Al}{645R} = \frac{P \times Al_1}{TR} \qquad \text{...(i)}$$

For the He gas $\frac{P_0Al}{258R} = \frac{P \times Al_2}{TR}$ ...(ii)

For the CO_2gas $\frac{P_0Al}{430R} = \frac{P \times Al_3}{TR}$ ...(iii)

$$\Rightarrow \frac{l_1}{l_2} = \frac{258}{645} = \frac{1}{2.5} \ \& \ \frac{l_1}{l_3} = \frac{430}{645} = \frac{1}{1.5}$$

$\Rightarrow \bullet_1 + \bullet_2 + \bullet_3 = 3\bullet \Rightarrow \bullet_1(1 + 2.5 + 1.5) = 3\bullet$

$\Rightarrow \bullet_1 = 0.6\,\bullet$ and $\bullet_2 = 2.5\,\bullet_1 = 1.5\bullet$

$\bullet_3 = 1.5 \times 0.6\bullet = 0.9\bullet$

For the entire system $\Delta U_1 + \Delta U_2 + \Delta U_3 = 0$

$$\Rightarrow \frac{n_1R(T-T_1)}{\gamma_1 - 1} + \frac{n_1R(T-T_2)}{(\gamma_2 - 1)} + \frac{n_3R(T-T_3)}{(\gamma_3 - 1)} = 0$$

$$\Rightarrow \frac{P\times0.6l - P_0l}{\left(\frac{7}{5}-1\right)} + \frac{(P\times1.5l - P_0l)}{\left(\frac{5}{3}-1\right)} + \frac{(P\times0.9l - P_0l)}{\left(\frac{7}{5}-1\right)} = 0$$

$$\Rightarrow P = \frac{13}{12}P_0$$

61. For the process

$$U = a\sqrt{V} \Rightarrow nC_vT = n\frac{5}{2}RT = a\sqrt{V}$$

$$\Rightarrow nRT = PV = \frac{2}{5}a\sqrt{V} \Rightarrow P = \frac{2}{5}\frac{a}{\sqrt{V}}$$

$$\Rightarrow W = \int PdV = \frac{4}{5}a\left(\sqrt{V}\right)_{V_i}^{V_f}$$

✈ $\Delta U = a\left(\sqrt{V}\right)_{V_i}^{V_f} = 100$

$$\therefore \quad W = \frac{4}{5}\Delta U = 80\ \text{J}$$

(i) $W = 80J$

$Q = \Delta U + W = 100\,J + 80J = 180\,J$

(ii) $C = \dfrac{\Delta Q}{n\Delta T} = \dfrac{\Delta U + W}{n\Delta T} = \dfrac{\Delta U + \frac{4}{5}\Delta U}{n\Delta T}$

$$= \frac{9}{5}\left(\frac{\Delta U}{n\Delta T}\right) = \frac{9}{5} \times \frac{5}{2}R = \frac{9}{2}R$$

62. For compartment C

$$P_0V_0^{\gamma} = P\left(\frac{4\,V_0}{9}\right)^{\gamma} \Rightarrow P = \frac{27}{8}P_0 \Rightarrow P_0.T_0^{\gamma/1-\gamma} = P.T^{\gamma/1-\gamma}$$

$$P_0\,T_0^{-3} = \left(\frac{27}{8}P_0\right) \times T^{-3} \Rightarrow T = \frac{3}{2}\,T_0$$

For compartment A

$$P_A = \frac{27}{8}\,P_0 \Rightarrow \frac{P_0\,V_0}{RT_0} = \frac{P_1\,V_1}{RT_1}$$

$$\Rightarrow T_1 = \frac{\frac{27}{8}P_0\left(2\,V_0 - \frac{4\,V_0}{9}\right)}{R} \times \frac{RT_0}{P_0\,V_0} = T_1 = \frac{21}{4}\,T_0$$

For compartment B

$$\frac{P_0\,V_0}{T_0} = \frac{P_1\,V_1}{T_1} \Rightarrow \frac{P_0V_0}{T_0} = \frac{P_1V_0}{\left(\frac{21}{4}T_0\right)} \Rightarrow P_1 = \frac{21}{4}P_0$$

(i) Final pressure in A $\dfrac{27}{8}P_0$

Final pressure in B $\dfrac{21}{4}P_0$

Final pressure in C $\dfrac{3}{2}P_0$

(ii) Final temperature in A $= \dfrac{21}{4}T_0$

Final temperature in B $= \dfrac{21}{4}T_0$

Final temperature in C $= \dfrac{3}{2}T_0$

(iii) Heat supplied by heater = $(\Delta U + W)$ all chambers

$$\begin{aligned} Q &= (\Delta U_1 + W_1) + (\Delta U_2 + W_2) + 0 \\ &= (\Delta U_1 - W_3) + (\Delta U_2 + 0) \\ &= \Delta U_1 + \Delta U_2 - W_3 \end{aligned}$$

$$= \frac{n_1 R\Delta T}{\gamma_1 - 1} + \frac{n_2 R\Delta T}{\gamma_2 - 1} - \left(\frac{n_3 R\Delta T}{\gamma_3 - 1}\right)$$

$$= \frac{17}{2}P_0V_0 + \frac{17}{2}P_0V_0 + P_0V_0 = 18\,P_0V_0$$

(iv) Work done by gas in chamber B = 0

Work done by gas in chamber C

$$= -\Delta U = \frac{-nR\Delta T}{\gamma - 1} = -P_0V_0$$

Work done by gas in chamber A

$$= (-)\,W_{\text{chamber}} = -(P_0V_0) = P_0V_0$$

(v) Heat flowing across piston –I

EXERCISE - 5

Part # I : AIEEE/JEE-MAIN

1. The temperature of gas molecules depends on the average kinetic energy associated with the disorderly motion (i.e., random motion) of the gas molecules. The orderly kinetic energy of the molecules of the gas container will increase in the lorry, whereas disorderly kinetic energy will still remain the same; hence the temperature of the gas molecules will remain unchanged.

2. $v_{rms} = \sqrt{\dfrac{3RT}{M}}$

Where T is the temperature of the gas molecules in kelvin and M is the molecular mass of the gas

$$v_{H_2} = v_{O_2} \Rightarrow \sqrt{\frac{T_{H_2}}{M_{H_2}}} = \sqrt{\frac{T_{O_2}}{M_{O_2}}} \Rightarrow \frac{T_{H_2}}{2} = \frac{320}{32}$$

$$\Rightarrow T_{H_2} = 20K$$

3. $\dfrac{n_1 + n_2}{\gamma - 1} = \dfrac{n_1}{\gamma_1 - 1} + \dfrac{n_2}{\gamma_2 - 1}$

$$\Rightarrow \frac{1+1}{\gamma - 1} = \frac{1}{(5/3) - 1} + \frac{1}{(7/5 - 1)}$$

$$\Rightarrow \frac{2}{\gamma - 1} = \frac{3}{2} + \frac{5}{2} = 4 \Rightarrow \gamma = \frac{3}{2} = \frac{24}{16}$$

4. Given $P \propto T^3$

✈ $PV = \mu RT$

$\therefore$ $P \propto (PV)^3 \Rightarrow P^3V^3 \propto P \Rightarrow P^2V^3 = \text{constant}$

$\Rightarrow PV^{3/2} = \text{constant} \Rightarrow \gamma = \dfrac{C_P}{C_V} = \dfrac{3}{2}$

5. Monoatomic $n_1 = 1$ $\quad \gamma_1 = \dfrac{5}{3}$

Diatomic $n_2 = 1$ $\quad \gamma_2 = \dfrac{7}{5}$

$$\frac{n_1 + n_2}{\gamma_{mix} - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1} \Rightarrow \gamma_{mix} = \frac{3}{2}$$

6. $$\frac{n_1+n_2}{\gamma_{mix}-1}=\frac{n_1}{\gamma_1-1}+\frac{n_2}{\gamma_2-1}$$

Number of moles in 16 g He =4

Number of moles in 16 g $O_2 = 0.5$

$$\gamma_{He}=\frac{5}{3} \qquad \gamma_{O_2}=\frac{7}{5}$$

On replacing $n_{He} n_{O_2}; \gamma_{He}, \gamma_{O_2}$ $\gamma_{mix}=1.62$

7. We have, molar heat capacity = molar mass × specific heat capacity per unit mass

$\therefore$ $C_p = 28\ C_p$ (for nitrogen) and $C_V = 28\ C_V$

Now $C_p - C_V = R$ or $28C_p - 28\ C_v = R$

$$\Rightarrow \quad C_p - C_v = \frac{R}{28}$$

8. $U = U_1 + U_2 \Rightarrow (n_1+n_2)\ C_vT = n_1C_vT_1 + n_2C_vT_2$

$$\Rightarrow T=\frac{(P_1V_1+P_2V_2)T_1T_2}{(P_1V_1T_2+P_2V_2T_2)}$$

9. $$v=\sqrt{\frac{\gamma RT}{M}} \Rightarrow \frac{v_1}{v_2}=\sqrt{\frac{\gamma_1M_2}{\gamma_2M_1}}=\sqrt{\frac{\frac{7}{5}\times 4}{\frac{5}{3}\times 32}}$$

$$\Rightarrow \frac{460}{v_2}=\sqrt{\frac{21}{25\times 8}} \Rightarrow v_2=460\sqrt{\frac{200}{21}}\ \text{m/s}$$

10. Energy of the diatomic gas

$$\frac{5}{2}nRT=\frac{5}{2}PV=\frac{5}{2}\times 8\times 10^4\times\frac{1}{4}=5\times 10^4\ \text{J}$$

11. $Q = ms\Delta\theta = 0.1\times 4184\times 20 = 8.4$ kJ

12. $$\left(n_1C_{v_1}T_1+n_2C_{v_2}T_2+n_3C_{v_3}T_3\right)$$

$$=(n_1+n_2+n_3)\,C_{V_{mix}}T$$

As $C_{V_1}=C_{V_2}$ so $T=\dfrac{n_1T_1+n_2T_2+n_3T_3}{n_1+n_2+n_3}$

13. Specific heat at low temperature is

$$C_p=32\left(\frac{T}{400}\right)^3 \quad\Rightarrow\quad Q=\int m.c.dT$$

$$=\int_{20}^{4}\frac{100}{1000}\times 32\left(\frac{T}{400}\right)^3 dT$$

$$=\frac{32}{10}\times\frac{1}{(400)^3}\left(\frac{T^4}{4}\right)$$

$$=\frac{32}{10\times(400)^3}\times\frac{1}{4}\left(20^4-4^4\right)$$

$$=\frac{32}{10\times(400)^3}\times\frac{1}{4}\times(160000-256)$$

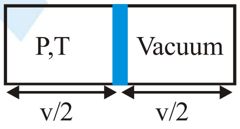
$= 0.002$ kJ

$$\beta=\frac{T_2}{T_1-T_2}=\frac{Q_2}{W} \Rightarrow \frac{20}{300-20}=\frac{0.02}{W}$$

$\Rightarrow$ $W = 0.028$ kJ

$$\Rightarrow \quad \frac{4}{300-4}=\frac{0.002}{W} \Rightarrow W=0.0148\ \text{kJ}$$

14. This is free expansion of the gas in which temperature will remain constant i.e. on the other side temperature will T.



Number of moles $n_1 = \dfrac{PV/2}{KT}$

Finally number of moles $n_2 = \dfrac{P'V}{KT}$

$n_1 = n_2$

$$\frac{PV}{2}=\frac{P^1V}{KT} \Rightarrow P'=\frac{P}{2}$$

15. All reversible engines work for different values of temperature of source and sink hence the efficiencies of all such engines are different.The incorrect statement is all reversible cycles have same efficiency.

16. When water is cooled to form ice, the energy is released as heat so mass of water decreases.

17. $\eta = 1-\dfrac{T_2}{T_1}=1 \Rightarrow \dfrac{T_2}{T_1}=0 \Rightarrow T_2=0$ or $T=\infty$

Which is not possible

18. Heat can't flow from the body at lower temperature to body at higher temperature is a consequences of second law of thermodynamics.

19. The instantaneous thermodynamic state of matter is denoted by pressure, volume and temperature.

20. $T_{source} = 627°C = 627 + 273 = 900K$

$T_{sin\,k} = 27°C = 27 + 273 = 300K$

Efficiency (n{krk)

$$(\eta) = 1 - \frac{T_{sink}}{T_{source}} = 1 - \frac{300}{900} = 1 - \frac{1}{3}$$

$$(\eta) = \frac{2}{3} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Work}}{\text{Heat Input}}$$

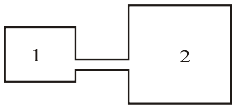
$$\Rightarrow \frac{2}{3} \times \text{Heat Input} = \text{Work}$$

$$\Rightarrow \frac{2}{3} \times 3 \times 10^6 \times 4.2 = \text{Work}$$

$$\Rightarrow \text{Work} = 8.4 \times 10^6\ \text{J}$$

21. Internal energy and entropy are state functions and not path functions.

22. Assume $T_1 > T_2$



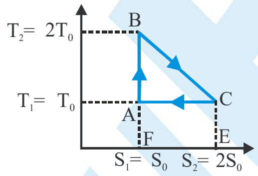
Heat given = Heat taken

$\mu_1 C_{v_1} (T_1 – T) = \mu_2 C_{v_2} (T – T_2)$

Here $C_{v_1} = C_{v_2}$ & $\mu_1 = \frac{P_1V_1}{T_1}$, $\mu_2 = \frac{P_2V_2}{T_2}$

23. The first law of thermodynamics does not introduce the concept of entropy.

24. Heat supplied Q = Area FBCEF



$$= T(S_2 – S_1) + \frac{1}{2}(T_2 – T_1)(S_2 – S_1)$$

Work done W = Area ABC

$$= \frac{1}{2}(T_2 – T_1)(S_2 – S_1)$$

$$\eta = \frac{W}{Q} = \frac{\frac{1}{2}(T_2 - T_1)(S_2 - S_1)}{T_1(S_2 - S_1) + \frac{1}{2}(T_2 - T_1)(S_2 - S_1)}$$

$$= \frac{T_2 - T_1}{T_2 + T_1} = \frac{2T_0 - T_0}{2T_0 + T_0} = \frac{1}{3}$$

25. The internal energy of a system is a state function, i.e., change in internal energy only depends on the initial and the final position and not on the path chosen.

Hence $\Delta U_1 = \Delta U_2$

26. $n_1 C_{v_1} T_1 + n_2 C_{v_2} T_2 = (n_1 C_{v_1} + n_2 C_{v_2}) T_f$

$$\therefore\ T_f = \frac{n_1 C_{v_1} T_1 + n_2 C_{v_2} T_2}{n_1 C_{v_1} + n_2 C_{v_2}}$$

$$= \frac{1 \times \frac{5}{2} RT_0 + 1 \times \frac{3}{2} R\left(\frac{7}{3} T_0\right)}{1 \times \frac{5}{2} R + 1 \times \frac{3}{2} R} = \frac{6RT_0}{4R} = \frac{3}{2} T_0$$

27. Work done in adiabatic process

$$W = \frac{\mu R(T_1 - T_2)}{\gamma - 1} \Rightarrow \gamma = 1 + \frac{R(T_2 - T_1)}{W}$$

$$= 1 + \frac{10^3 \times 8.3(7)}{146 \times 10^3} = 1 + 0.40 = 1.40$$

$\therefore$ The gas must be diatomic

28. Let η is the efficiency of heat engine and β is the corresponding coefficient of performance of a refrigerator working between the same temperature.

The relation between η and β is

$$\beta = \frac{1}{\eta} - 1 = 10 - 1 = 9 \quad \text{Also } \beta = \frac{\text{Output}}{\text{Input}}$$

$$= \frac{\text{Energy absorbed from the reservoir at lower temperature}}{\text{Work done on the system}}$$

$$\beta = 9 = \frac{\text{Energy absorbed}}{10\text{J}}$$

So, energy absorbed = 90 J

29. As a thermodynamic system is taken from state *i* to state *f*; then the internal energy of the system remains the same irrespective of the path followed

$(Q – W)_{iaf} = (Q – W)_{ibf} \Rightarrow 50 – 20 = 36 – W$

$\Rightarrow W = 6$ cal

30. W_{AB} = Work done in isobaric process

$= \mu R \Delta T = 2R \times (500 – 300) = 400R$

Work done on the gas = – 400R

31. W_{DA} = Work done in isothermal process

$$=2.303\,\mu RT\log\frac{P_1}{P_2}$$

$$=2.303\times 2R\times 300\log\frac{1\times 10^5}{2\times 10^5}$$

$$=2.303\times 2R\times 300\times(-0.3010)=-414R$$

Word done on the gas $=-(-414\,R)=414\,R$

32. $W_{ABCDA}=W_{AB}+W_{BC}+W_{CD}+W_{DA}$

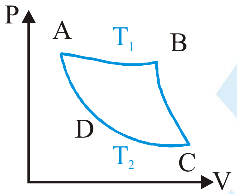
$$=\mu R(500–300)+2.303\mu R(500)\log\frac{2}{2}+\mu R(300–500)+2.303$$

$$\mu R(300)\log\frac{1}{2}=276R$$

Work done on the gas $=-276\,R$

33. $T_B=T_1, T_C=T_2, \gamma=1.4$

$V_B=V, V_C=32\,V$



$$T_BV_B^{\gamma-1}=T_CV_C^{\gamma-1}$$

$$\frac{T_C}{T_B}=\frac{T_2}{T_1}=\left(\frac{V_B}{V_C}\right)^{\gamma-1}$$

$$=\left(\frac{1}{32}\right)^{\gamma-1}=\frac{1}{4}$$

$$\eta=1-\frac{T_2}{T_1}=1-\frac{1}{4}=\frac{3}{4}=0.75$$

34. $\frac{1}{2}Mv^2=\frac{f}{2}R\Delta T$ and

$$\gamma=1+\frac{2}{f}\Rightarrow\Delta T=\frac{(\gamma-1)}{2R}Mv^2$$

35. $1-\frac{T_2}{T_1}=\frac{1}{6}\Rightarrow\frac{T_2}{T_1}=\frac{5}{6}$ ... (1)

and $1-\frac{T_2-62}{T_1}=\frac{1}{3}\Rightarrow\frac{T_2-62}{T_1}=\frac{2}{3}$ ... (2)

By solving equation (1) and (2)

$T_1=372$ K and $T_2=310$ K

36. $\Delta V=V_0(3\alpha)\Delta\theta$

$$=\frac{4}{3}(3.14)(10)^3[3\times 23\times 10^{-6}][100–0]$$

$$=28.9\text{ cc}$$

37. Strain $=\frac{l_2-l_1}{l_1}=\alpha t$ and $Y=\frac{\text{Stress}}{\text{Strain}}$

$\Rightarrow$ Stress $=Y\,\alpha\,t$

38. W = Area bounded by curve $=P_0V_0$

$$Q_{AB}=nC_V\Delta T=n\times\frac{3}{2}R\times\Delta T=\frac{3}{2}P_0V_0$$

$$Q_{BC}=nC_P\Delta T=n\times\frac{5}{2}R\times\Delta T=5\,P_0V_0$$

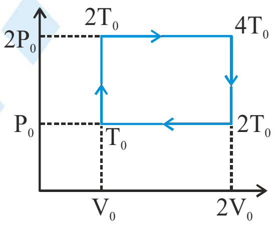
Total heat supplied

$$=\frac{3}{2}P_0V_0+5P_0V_0=\frac{13}{2}P_0V_0$$

$$\eta=\frac{W}{Q}\times 100=\frac{P_0V_0}{13P_0V_0}\times 100=15.4\%$$

40. $\eta=\left(1-\frac{T_2}{T_1}\right)\times 100\Rightarrow\frac{40}{100}=1-\frac{T_2}{500}\Rightarrow T_2=300$ K

Again $\frac{60}{100}=1-\frac{300}{T_1}\Rightarrow T_1=750$ K



$$\text{heat supplied}=nC_v(2T_0-T_0)+nC_p(4T_0-2T_0)$$

$$=\frac{n.3RT_0}{2}+\frac{D5R}{2}(2T_0)=\frac{13}{2}nRT_0=\frac{13}{2}P_0V_0$$

41. Amount of heat required by a body of any mass of undergo a unity change in temperature is known as heat capacity or thermal capacity of the substance.

42. Black board paint is more close to a black body.

43. Infrared radiations are detected by pyrometer.

44. The power radiated by a sphere of radius R at temperature T is

$$P=\varepsilon\sigma T^4(4\pi R^2)$$

Where

ε = emissivity of the material of sphere.

σ = Stefan's constant

T = Absolute temperature

R = Radius of the sphere

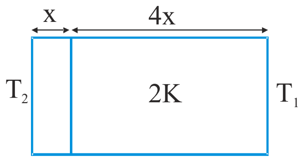
$$\Rightarrow\frac{P_1}{P_2}=\frac{T_1^4R_1^2}{T_1^4R_2^2}=\left(\frac{4000}{2000}\right)^4\left(\frac{1}{4}\right)^2=(2^4)\times\frac{1}{4^2}=\frac{16}{16}=1$$

45. According to Stefan's law, power radiated by a perfectly black body is

$P=\sigma AT^4;\ P=\sigma 4\pi R^2T^4$

$$\frac{P_2}{P_1}=\left(\frac{R_2}{R_1}\right)^2\left(\frac{T_2}{T_1}\right)^4 \Rightarrow P_2=64P_1$$

46.



R_1=Resistance of left part $=\dfrac{x}{KA}$

R_2=Resistance of right part $=\dfrac{4x}{2KA}=\dfrac{2x}{KA}$

Total Resistance $R_1+R_2=\dfrac{x}{KA}+\dfrac{2x}{KA}=\dfrac{3x}{KA}$

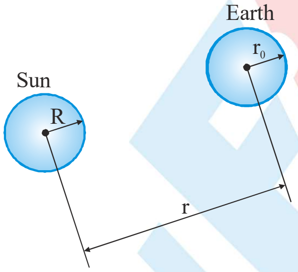
Thermal current $=\dfrac{T_2-T_1}{R}=\dfrac{K(T_2-T_1)A}{3x}$

Comparing with the given result $f=\dfrac{1}{3}$

47. Rate of flow of heat

$$=KA\left(\frac{\Delta T}{\Delta x}\right)=K(4\pi r_1r_2)\left(\frac{T_1-T_2}{r_2-r_1}\right)$$

48. According to Stefan's law



Power radiated by Sun $=\sigma(4\pi R^2)T^4$

Intensity of the sun received by the earth

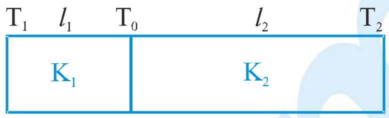
$$=\frac{\text{Power of the sun}}{4\pi r^2}$$

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

Radiant power incident on the earth $=I\left(\pi r_0^2\right)$

where $\left(\pi r_0^2\right)$ is the projection of the earth's area receiving the energy from the sun. $P=\dfrac{\sigma R^2T^4}{r^2}\left(\pi r_0^2\right)$

49. Let the temperature of the interface be T_0.



$$\text{Thermal current (I)}=\frac{\text{Temperature difference}}{\text{Thermal resitance}}$$

Thermal resistance $=\dfrac{1}{K}\dfrac{1}{A}$

$$\Rightarrow \frac{T_1-T_0}{l_1/K_1A}=\frac{T_0-T_2}{l_2/K_2A}$$

$$\Rightarrow T_0=\frac{K_1l_2T_1+K_2l_1T_2}{K_1l_2+K_2l_1}$$

50. In steady state, temperature decreases linearly along the bar. i.e. $\dfrac{dQ}{dt}=-KA\left(\dfrac{d\theta}{dx}\right)$

51. Rate of cooling $=-\dfrac{d\theta}{dt}=k(\theta-\theta_0)$

$$\frac{d\theta}{\theta-\theta_0}=-kdt \Rightarrow \int\frac{d\theta}{\theta-\theta_0}=-\int kdt$$

$\Rightarrow$ ●$n(\theta-\theta_0)=-kt+C \Rightarrow$ correct answer is (2)

52. $Y=\dfrac{\text{stress}}{\text{strain}} \Rightarrow \text{stress}=Y\times\text{strain}$

$$\frac{F}{S}=Y(\alpha\Delta T) \Rightarrow F=YS\alpha\Delta T$$

Therefore force by one part on other part

$=2F=2SY\alpha\Delta T$

53. By Newton's Law of cooling $T=T_S+(T_H-T_S)e^{-kt}$

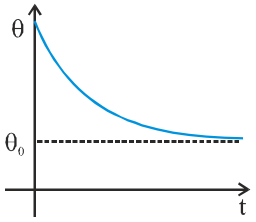
T_S → Temperature of surrounding

T_H → Temperature of body at $t=0$

K → constant

T → Temperature of body at time t

So graph is



54. **(i)** $\Delta s_1 = \int \frac{dQ}{T} = ms\int_{100}^{150} \frac{dT}{T} + ms\int_{150}^{200} \frac{dT}{T}$

$$= \ln\left(\frac{150}{100}\right) + \ln\left(\frac{200}{150}\right) \quad = \ln\left(\frac{3}{2}\right) + \ln\frac{4}{3}$$

$\Delta s_1 = \ln 2$

(ii) $\Delta s_2 = \int \frac{dQ}{T} = \int_{100}^{112.5} \frac{dQ}{T} + \int_{112.5}^{125} \frac{dQ}{T} + \ldots\ldots$

$$= \ln\left(\frac{112.5}{100}\right) + \ln\left(\frac{125}{112.5}\right) + \ldots..$$

$$= \ln\left(\frac{9}{8}\right) + \ln\left(\frac{10}{9}\right) + \ln\left(\frac{16}{15}\right) \quad = \ln\left(\frac{16}{8}\right) = \ln 2$$

55. $u = \frac{U}{V} \propto T^4 \Rightarrow P = \frac{1}{3}\left(\frac{U}{V}\right)$

Adiabatic expansion

$TV^{\gamma-1} = K \quad \Rightarrow TV^{\frac{\gamma}{4}} = C$

$\gamma - 1 = \frac{\gamma}{4} \quad \Rightarrow \quad \frac{3\gamma}{4} = 1 \Rightarrow \quad \gamma = \frac{4}{3}$

$TV^{\frac{\gamma}{4}} = C \Rightarrow TV^{\frac{1}{3}} = C \Rightarrow T\left(\frac{4}{3}\pi R^3\right)^{\frac{1}{3}} = C$

$T \propto \frac{1}{R}$

56. mean free path

$\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$

$n = \frac{\text{no. of molecules}}{\text{volume}}$

$v_{avg.} \propto \sqrt{T} \qquad T.V^{\gamma-1=C}$

$t = \frac{\lambda}{v_{avg.}} \propto \frac{V}{\sqrt{T}}$ $\quad v \rightarrow$ is volume

$\frac{V}{\sqrt{\frac{C}{v^{r-1}}}} \propto V^{\frac{\gamma+1}{2}} \Rightarrow v^q \propto v^{\frac{\gamma+1}{2}} \Rightarrow q = \frac{\gamma+1}{2}$

57. $T_{max.}$ at mid point

$$T = \frac{pv}{nR} = \frac{\left(\frac{3}{2}P_0\right)\left(\frac{3V_0}{2}\right)}{nR} = \frac{9}{4}\left(\frac{P_0V_0}{nR}\right)$$

58. $\frac{\Delta T}{T} \propto \Delta\theta$

$\frac{12}{4} = \frac{40-\theta}{\theta-20}$

$3\theta - 60 = 40 - \theta$

$4\theta = 100$

$\theta = 25°\,C$

$\Delta T = \frac{1}{2}\alpha\,\Delta\theta \times T \;; \quad 4 = \frac{1}{2}\alpha\, 5 \times 86400$

$\frac{8\times10^5}{5\times86400} = \alpha \;; \quad \frac{8000}{4320} = \alpha$

$\alpha = 1.85 \times 10^{-5}/°C$

59. $Pv^n = k$

$C = C_v + \frac{R}{1-n} \quad ; \quad C - C_v = \frac{R}{1-n}$

$1 - n = \frac{R}{C-C_v} \quad ; \quad n = 1 - \frac{R}{C-C_v}$

$n = \frac{C-C_v-R}{C-C_v} \quad ; \quad n = \frac{C-C_v-(C_p-C_v)}{C-C_v}$

$n = \frac{C-C_v-C_p+C_v}{C-C_v} \quad ; \quad n = \frac{C-C_p}{C-C_v}$

Part # II : IIT-JEE ADVANCED

1. Average rotational KE $= 2 \times \frac{1}{2}$ kT

(for diatomic gas)

2. Initial conditions $P_1V = n_1RT, P_2V = n_2RT$

Final condition $(P_1 - \Delta P)2V = n_1RT$

$$(P_2 - 1.5\Delta P)\,2V = n_2RT \Rightarrow \frac{n_1RT}{2V} = \Delta P$$

$\frac{n_2RT}{2V} = 1.5\,\Delta P \Rightarrow \frac{n_1}{n_2} = \frac{1}{1.5} = \frac{2}{3} \Rightarrow \frac{m_A}{m_B} = \frac{2}{3}$

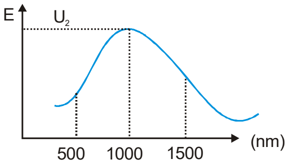
3. For A : $Q = nC_P\Delta T = (nC_P)(30)$

For B : $Q = nC_V\Delta T = nC_V\Delta T = nC_P(30)$

$\Rightarrow \Delta T = (30)\left(\frac{C_P}{C_V}\right) = 30 \times \frac{7}{5} = 42$ K

4. At 2880 K :

$$\lambda_m = \frac{b}{T} = \frac{2.88\times10^6\,\text{nm}-\text{K}}{2880\text{K}} = 1000\text{ nm}$$



Therefore $U_2 > U_1$ & $U_2 > U_3$

5. ✈ $v_{\text{sound}} = \sqrt{\frac{\gamma RT}{M_W}}$

$$\therefore \frac{v_{N_2}}{v_{He}} = \sqrt{\frac{\gamma_{N_2}}{M_{N_2}} \times \frac{M_{He}}{\gamma_{He}}} = \sqrt{\frac{7}{5}\times\frac{1}{28}\times\frac{4}{1}\times\frac{3}{5}} = \frac{\sqrt{3}}{5}$$

6. $$C_{V_{mix}} = \frac{n_1C_{V_1} + n_2C_{V_2}}{n_1+n_2} = \frac{(2)\left(\frac{5}{2}R\right)+4\left(\frac{3}{2}R\right)}{2+4} = \frac{11R}{6}$$

$$U = (n_1+n_2)\,C_{V\,mix}\,T = (6)\left(\frac{11R}{6}\right)T = 11RT$$

7. $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$ but $V = AL$

So $$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{5/3-1} = \left(\frac{L_2}{L_1}\right)^{2/3}$$

8. $\lambda_1T_1 = \lambda_2T_2 = \lambda_3T_3 = b$ so $T_1 > T_3 > T_2$

9. The temperature of ice will first increase from –10°C to 0°C. Heat supplied in this process will be: $Q_1 = mS_i(10)$

m=mass of ice

S_i = specific heat of ice

Then, ice starts melting

Temperature during melting will remain constant (0°C)

Heat supplied in the process will be $Q_2 = mL$

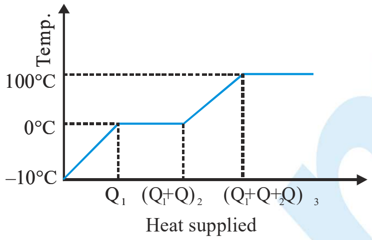
L = latent heat of melting

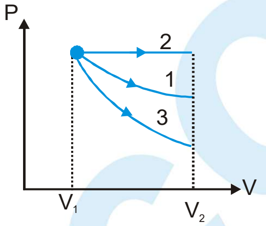
Now the temperature of water will increase from 0°C to 100°C.

Heat supplied will be $Q_3 = mS_w(100)$

where S_w = Specific heat of water

Finally water at 100°C will be converted into steam at 100°C and during this process temperature again remains constant. Temperature versus heat supplied graph will be as follows



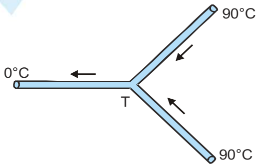
10. 

$W_2 > W_1 > W_3$

11. As P = constant

So $P\Delta V = nR\Delta T \Rightarrow \delta = \frac{\Delta V}{V\Delta T} = \frac{nR}{PV} = \frac{1}{T}$

12. $v_{\text{sound}} = \sqrt{\frac{\gamma RT}{M_W}}$ So $\frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$

13. 

$$\frac{kA(90-T)}{l} + \frac{kA(90-T)}{l} = \frac{kA(T-0)}{l}$$

$\Rightarrow 90 - T + 90 - T = T \Rightarrow 3T = 180 \Rightarrow T = 60°C$

14. If $dW = 0$, $dQ < 0$ then $dU < 0$

$\Rightarrow$ The temperature will decrease

15. As $\gamma_{\text{mono}} > \gamma_{\text{dia}}$ so 2 → monoatomic & 1 → diatomic

16. For complete cycle

$\Delta U = 0$ so $W = Q = 5$

$\Rightarrow W_{AB} + W_{BC} + W_{CA} = 5$ But $W_{BC} = 0$ &

$W_{AB} = 10\,(2-1) = 10 \Rightarrow W_{CA} = 5 - 10 = -5J$

17. At constant temperature PV = constant

So $PdV + VdP = 0 \Rightarrow \frac{dV}{dP} = -\frac{V}{P}$

$\Rightarrow \beta = -\frac{dV/dP}{V} = \frac{1}{P}$

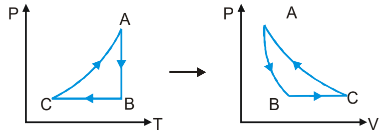
18. Black body radiates maximum number of wavelength and maximum energy if all other conditions (e.g., temperature surface area etc.) are same. So, when the temperature of black body becomes equal to the temperature of the furnace, the black body will ,radiate ,maximum energy and it will be brighted of all. Initially it will absorb all the radiant energy incident on it, so it is the darkest one.

19. For same temperature difference less time is taken for x, this means $e_x > e_y$.
According to Kirchoff's law

20. $\Delta l_1 = \Delta l_2 \Rightarrow l_1\alpha_a\Delta T = l_2\alpha_S\Delta T$

$$\Rightarrow \frac{l_1}{l_2} = \frac{\alpha_s}{\alpha_a} \Rightarrow \frac{l_1}{l_1 + l_2} = \frac{\alpha_s}{\alpha_a + \alpha_s}$$

21.



22.

2kg ice (-20°C)
↓ 20 kcal
2kg ice (0°C)
↓ 160 kcal
2 kg water (0°C)

5kg water (20°C)
↓ 100 kcal
5kg water (0°C)

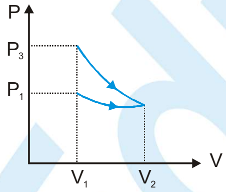
$\Rightarrow$ Final temperature 0°C

$$\text{Amount of ice melted} = \frac{100 - 20}{80} = 1\ \text{kg}$$

$\Rightarrow$ Final mass of water $= 5 + 1 = 6$ kg

23. Temperature of liquid oxygen will first increase in the same phase. Then, phase change (liquid to gas) will take place. During which temperature will remain constant. After that temperature of oxygen in gaseous state will further increase.

24.



$\Rightarrow W < 0$ & $P_3 > P_1$

25. $q_1 L = \frac{k(2A)(T_1 - T_2)}{1} \Rightarrow q_2 L = \frac{kA(T_1 - T_2)}{21}$

$$\Rightarrow \frac{q_2}{q_1} = \frac{1}{4}$$

26. Power radiated

$Q = e\sigma AT^4$ and $\lambda_m T = b$

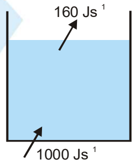
So $(300)\,T_1 = (400)\,T_2 = (500)\,T_3$

$\Rightarrow 3T_1 = 4T_2 = 5T_3$

and $A_1 : A_2 : A_3 = 4 : 16 : 36 = 1 : 4 : 9$

$$Q_A : Q_B : Q_C = \frac{1}{81} : \frac{4}{256} : \frac{9}{625} \Rightarrow Q_B \text{ is maximum.}$$

27. Net heat absorbed by water



$= 1000 - 160 = 840$ J/s

$$\frac{Q}{t} = \frac{ms\Delta T}{t}$$

$$840 = \frac{2 \times 4200 \times (77 - 27)}{t}$$

$\Rightarrow t = 500\ \text{s} = 8$ min 20 s

28. Heat transfer in warming of glass of bulb due to filament is through radiation.

29. The temperature of sun is a higher than that of welding arc which in turn greater than tungsten filament.

30. 1 calorie is the heat required to raise the temp. of 1g of water from 14.5 to 15.5°C at 760 mm of Hg.

32. $\gamma_V = \frac{\Delta V}{V\Delta T}$

$PT^2 = \text{constant}$ & $PV = nRT$

$$\Rightarrow V \propto T^3 \Rightarrow \frac{\Delta V}{V} = 3\frac{\Delta T}{T} \Rightarrow \frac{\Delta V}{V\Delta T} = \frac{3}{T} = \gamma_V$$

33. $P = \frac{\rho}{M}RT \Rightarrow \frac{P_1}{P_2} = \frac{\rho_1 M_2}{\rho_2 M_1} = \frac{4}{3} \Rightarrow \frac{\rho_1}{\rho_2} = \frac{4}{3} \times \frac{2}{3} = \frac{8}{9}$

34. For two rectangular blocks

$$R_1 = \frac{1}{kA} = 2R\ ;\ R_2 = \frac{1}{2kA} = R$$

In configuration 1
Equivalent thermal resistance = 3R
In configuration 2

Equivalent thermal resistance $= \frac{2}{3}R$

Rate of heat flow

$$\Delta Q_1 = \frac{\Delta T}{3R}t_1 \text{ and } \Delta Q_2 = \frac{\Delta T}{\frac{2R}{3}}t_2$$

$$\Rightarrow \frac{\Delta T}{3R}t_1 = \frac{3\Delta T}{2R}t_2 \Rightarrow t_2 = \frac{2}{9}t_1 = 2\text{sec.}$$

35. Process FG is isothermal

so work done $= nRT \ln\left(\dfrac{P_i}{P_f}\right)$

$= 32\,P_0V_0 \ln\left(\dfrac{32P_0}{P_0}\right) = 160\,P_0V_0 \ln 2.$

Process GE is isobaric

So work done

$= P|\Delta V| = P_0|(V_G - V_E)| = P_0|(32V_0 - V_0)| = 31\,P_0V_0$

Process FH is adiabatic

so $(32P_0)V_0^{5/3} = (P_0)V_H^{5/3} \Rightarrow V_H = 8V_0$

Since process FH is adiabatic so

$$\left|\frac{(P_HV_H - P_FV_F)}{(8-1)}\right| = \frac{|(P_0\,8V_0) - 32P_0V_0|}{\left(\frac{5}{3}-1\right)} = 36P_0V_0$$

Process G→H is isobaric so work done

$= P_0|(32V_0 - 8V_0)| = 24\,P_0V_0$

36. A **37.** B

MCQ's

1. $v_P = \sqrt{\dfrac{2kT}{m}}\,;\ \bar{v} = \sqrt{\dfrac{8kT}{\pi m}}\,,\ v_{rms} = \sqrt{\dfrac{3kT}{m}} \Rightarrow v_P < \bar{v} < v_{rms}$

Average KE of a molecule $= \dfrac{3}{2}kT = \dfrac{3}{4}mv_P^2$

2. There is a decrease in volume during melting of an ice slab. Therefore negative work is done by the ice–water system on to the surrounding $\Rightarrow W = -ve$

Heat is absorbed during melting

$\Rightarrow Q = +ve \quad \Rightarrow \Delta U = Q - W = +ve$

3. Radius of curvature $R = \dfrac{d}{(\alpha_1 - \alpha_2)\Delta T}$

4. $C_p - C_v = R$ Always constant

$\dfrac{C_p}{C_v} = \gamma$ decreases with atomicity

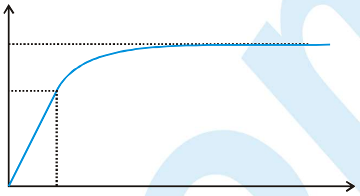
$(C_p + C_v)$ and $C_p.C_v$ depends on degree of freedom therefore it will be more for diatomic gas

5. (i) For isothermal process curve should be hyperbola.

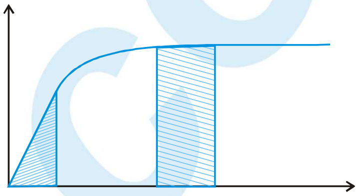
(ii) Work done & change in internal energy are both negative.

(iii) For higher pressure volume is increasing and lower pressure volume is decreasing.

6. (A) From 0 to 100 k the major part of graph lies in linear region and very small part in non-linear region, therefore to a reasonable approximation between 0 K – 100 K, graph of C vs T is linear.



(B) by comparing area under curve



(C) from 400 K to 500 K, Graph of C vs T become asymptotic hence rate of heat absorption become constant

(D) The rate of heat absorption increases as C is increasing.

7. B,D

8. $E_{mix.} = \dfrac{1\times\dfrac{3RT}{2} + 1\times\dfrac{5RT}{2}}{1+1} = 2RT$

$C_{Pmix} = 3R$

$\gamma_{mix} = \dfrac{3}{2}$

$M_{mix} = \dfrac{1\times4 + 1\times2}{1+1} = 3 \Rightarrow V_s = \sqrt{\dfrac{\gamma RT}{M_w}}$

$\dfrac{V_{mix}}{V_{He}} = \sqrt{\dfrac{\gamma_{mix}}{\gamma_{He}}\dfrac{M_{He}}{M_{mx}}} = \sqrt{\dfrac{3}{2}\times\dfrac{3}{5}\times\dfrac{4}{3}} = \sqrt{\dfrac{6}{5}}$

$V_{rms} \propto \dfrac{1}{\sqrt{M_V}} \Rightarrow \dfrac{V_{He}}{V_{H_2}} = \sqrt{\dfrac{M_{H_2}}{M_{H_e}}} = \sqrt{\dfrac{2}{4}} = \dfrac{1}{\sqrt{2}}$

9. Change in internal energy

$P_1V_1 = nRT_1$

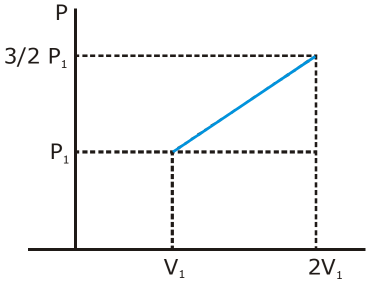
$\Delta U = nC_v dT = n\left(\dfrac{3}{2}R\right)(3T_1 - T_1)$

$= \dfrac{3}{2}nR\,(T_1) = 3nRT_1$ **So option B**

$\Delta U = 3P_1V_1$

$$\frac{P_1V_1}{P_2V_2} = \frac{nRT_1}{nRT_2}$$

$$\frac{P_1V_1}{P_2\left(2V_1\right)} = \frac{nRT_1}{nR\left(3T_1\right)}$$



$$P_2 = \frac{3}{2}P_1$$

$$w = \frac{1}{2} \times 2V_1 \times \frac{P_1}{2} + P_1\left(2V_1\right)$$

$$= \frac{P_1V_1}{2} + 2V_1P_1 \quad = \frac{5}{2}P_1V_1 \quad \Rightarrow V_1 = A$$

$dV = V_2 - V_1 = Ax = V_1$

$$x = \frac{V_1}{A}$$

$$F = kx = (P_2 - P_1)A \;\Rightarrow\; kx = \left(\frac{3}{2}P_1 - P_1\right)A$$

10. C **11.** A

Match the Column

1. Process J $\rightarrow$ K (isochoric) : $W = 0, \Delta U < 0 \Rightarrow Q < 0$

   Process K $\rightarrow$ L (isobaric) : $W > 0, \Delta U > 0 \Rightarrow Q > 0$

   Process L $\rightarrow$ M (isochoric) : $W = 0, \Delta U > 0 \Rightarrow Q > 0$

   Process M $\rightarrow$ J , $W < 0$, $\Delta U < 0 \Rightarrow Q < 0$

2. **(A) Bimetallic strip :** Works on the thermal expansion of solids (different solids expands by different length for the same rise of temperature). The energy is converted to kinetic energy.

   (B) Steam engine

   Energy is converted (heat–mechanical)

   (C) Incandescent lamp

   Heat → Light ; radiation from hot body.

   (D) Electric fuse

   Works on melting of fuse wire on heating.

   Heat → P.E. of molecules.

3. For (A)

   $Q = 0, W = PdV = 0$ so $\Delta U = 0 \Rightarrow T = \text{constant}$

   For (B) :

   $$P \propto V^{-2} \;\&\; PV = \mu RT \Rightarrow V \propto \frac{1}{T}$$

   Since volume increases so temperature decreases.

   For polytropic process PV^2 = constant

   $$C = C_v + \frac{R}{1-x} = C_v + \frac{R}{1-2} = \frac{3}{2}R - R = \frac{R}{2}$$

   $$Q = \mu C\Delta T = \mu\left(\frac{R}{2}\right)\Delta T = \text{Negative}$$

   For (C) :

   $$C = C_v + \frac{R}{1-\frac{4}{3}} = -\frac{3}{2}R \Rightarrow Q = \mu C\Delta T$$

   $$= -\mu\left(\frac{3}{2}R\right)\Delta T \equiv \text{Positive}$$

   For (D) :

   $P\uparrow, V\uparrow, T\uparrow$

   Work = Area under PV curve → positive

   ΔU → positive

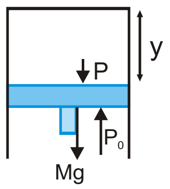
   Q → positive (given to system)

Comprehension #1

1. When the piston is pulled out slowly, the pressure drop produced inside the cylinder is almost instantaneously neutralised by the air entering from outside into the cylinder. Therefore the pressure inside is P_0.

2. $$Mg = (P_0 - P)\,\pi R^2 \Rightarrow P = P_0 - \frac{Mg}{\pi R^2}$$

   Since the cylinder is thermally conducting, the temperature remains the same.



$$P_0\,(2L \times \pi R^2) = P\,(y \times \pi R^2) \Rightarrow y = \left(\frac{P_0 \times \pi R^2}{P_0\pi R^2 - Mg}\right)(2L)$$

3. Equating pressures

   $$P_0 + \rho g(L_0 - H) = P = \frac{P_0L_0}{\left(L_0 - H\right)}$$

Comprehension #2

1. Force due to the pressure of liquid = The buoyancy force.

2. $T^{\gamma}P^{1-\gamma}$=constant $\Rightarrow T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$

$$=T_0\left(\frac{P_0+\rho_1 g(H-y)}{P_0+\rho_1 gH}\right)^{1-\frac{3}{5}} = T_0\left(\frac{P_0+\rho_1 g(H-y)}{P_0+\rho_1 gH}\right)^{\frac{2}{5}}$$

3. Buoyancy force $= V\rho_{\bullet}g = \left(\frac{nRT_2}{P_2}\right)\rho_1 g$

$$=\frac{nR\rho_1 gT_0}{P_0+\rho_1 g(H-y)}\left[\frac{P_0+\rho_1 g(H-y)}{P_0+\rho_1 gH}\right]^{\frac{2}{5}}$$

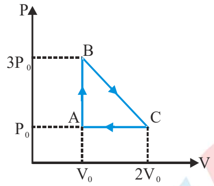
$$=\frac{\rho_1 nRgT_0}{(P_0+\rho_1 gH)^{\frac{2}{5}}(P_0+\rho_1 g(H-y))^{\frac{3}{5}}}$$

Comprehension #3

1. D **2.** D

Subjective Questions

1. **(a)** ABCA is a clockwise cyclic process.



$\therefore$ Work done by the gas

W = + Area of triangle ABC

$$W=\frac{1}{2}\text{ (base) (height)} = \frac{1}{2}(2V_0-V_0)(3P_0-P_0) = P_0V_0$$

(b) No. of moles n=1 and gas is monoatomic, therefore

$$C_V=\frac{3}{2}R \text{ and } C_P=\frac{5}{2}R \Rightarrow \frac{C_V}{R}=\frac{3}{2} \text{ and } \frac{C_P}{R}=\frac{5}{2}$$

(i) Heat rejected in path CA

(Process is isobaric)

$$\therefore\ Q_{CA}=C_P\Delta T=C_P(T_f-T_i)=C_P\left(\frac{P_fV_f}{R}-\frac{P_iV_i}{R}\right)$$

$$=\frac{C_P}{R}(P_fV_f-P_iV_i)$$

Substituting the values

$$Q_{CA}=\frac{5}{2}(P_0V_0-2P_0V_0)=-\frac{5}{2}P_0V_0$$

Therefore, heat rejected in the process CA is $\frac{5}{2}P_0V_0$.

(ii) Heat absorbed in path AB:

(process is isochoric)

$$\therefore\ Q_{AB}=C_V\Delta T=C_V(T_f-T_i)$$

$$=C_V\left(\frac{P_fV_f}{R}-\frac{P_iV_i}{R}\right)=\frac{C_V}{R}(P_fV_f-P_iV_i)$$

$$=\frac{3}{2}(P_fV_f-P_iV_i)=\frac{3}{2}(3P_0V_0-P_0V_0)=3P_0V_0$$

$\therefore$ Heat absorbed in the process AB is $3P_0V_0$.

(c) Let Q_{BC} be the heat absorbed in the process BC

Total heat absorbed

$$Q=Q_{CA}+Q_{AB}+Q_{BC}$$

$$Q=\left(-\frac{5}{2}P_0V_0\right)+(3P_0V_0)+Q_{BC}$$

$$Q=Q_{BC}+\frac{P_0V_0}{2}$$

Change in internal energy $\Delta U=0$

$$\therefore\ Q=W \qquad \therefore\ Q_{BC}+\frac{P_0V_0}{2}=P_0V_0$$

$$\Rightarrow\ \therefore\ Q_{BC}=\frac{P_0V_0}{2}$$

$\therefore$ Heat absorbed in the process BC is $\frac{P_0V_0}{2}$

(d) Maximum temperature of the gas will some where between B and C. Line BC is a straight line. Therefore, P–V equation for the process BC can be written as

$$P=-mV+c;\ (y=mx+c)$$

Here, $m=\frac{2P_0}{V_0}$ and $c=5P_0$ $\therefore P=-\left(\frac{2P_0}{V_0}\right)V+5P_0$

Multiplying the equation by V

$$PV=-\left(\frac{2P_0}{V_0}\right)V^2+5P_0V\ \ (PV=RT \text{ for } n=1)$$

$$RT=-\left(\frac{2P_0}{V_0}\right)V^2+5P_0V$$

$$\Rightarrow T=\frac{1}{R}\left[5P_0V-\frac{2P_0}{V_0}V^2\right] \qquad \text{...(i)}$$

For T to be maximum

$$\frac{dT}{dV}=0 \Rightarrow 5P_0-\frac{4P_0}{V_0},V=0 \Rightarrow V=\frac{5V_0}{4}$$

i.e., at $V = \frac{5V_0}{4}$ (on line BC), temperature of the gas is maximum

From Equation (i) this maximum temperature will be

$$T_{max} = \frac{1}{R}\left[5P_0\left(\frac{5V_0}{4}\right) - \frac{2P_0}{V_0}\left(\frac{5V_0}{4}\right)^2\right] = \frac{25}{8}\frac{P_0V_0}{R}$$

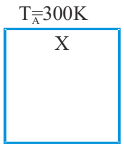
2. In the first part of the question ($t \le t_1$)

At $t = 0$, $T_X = T_0 = 400K$ and at $t = t_1$ $T_X = T_1 = 350K$

Temperature of atmosphere, $T_A = 300K$ (constant)

This cools down according to Newton's law of cooling.

Therefore, rate of cooling ∝ temperature difference.

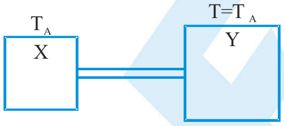


$$\therefore \left(-\frac{dT}{dt}\right) = k(T - T_A) \Rightarrow \frac{dT}{T - T_A} = -k.dt$$

$$\Rightarrow \int_{T_0}^{T_1}\frac{dT}{T - T_A} = -k\int_0^{t_1} dt \Rightarrow \ell n\left(\frac{T_1 - T_A}{T_0 - T_A}\right) = -kt_1$$

$$\Rightarrow kt_1 = -\ell n\left(\frac{350 - 300}{400 - 300}\right) \Rightarrow kt_1 = \ell n(2)$$

In the IInd part, body X cools by radiation (according to Newton's law) as well as by conduction ($t > t_1$).



Therefore, rate of cooling

= (cooling by radiation) + (cooling by conduction)

In conduction $\frac{dQ}{dt} = \frac{KA(T - T_A)}{L} = C\left(-\frac{dT}{dt}\right)$

$$\therefore \left(-\frac{dT}{dt}\right) = \frac{KA}{LC}(T - T_A)$$

where C = heat capacity of body X

$$\therefore \left(-\frac{dT}{dt}\right) = k(T - T_A) + \frac{KA}{CL}(T - T_A) \qquad ...(ii)$$

$$\left(-\frac{dT}{dt}\right) = \left(k + \frac{KA}{CL}\right)(T - T_A) \qquad ...(iii)$$

Let at $t = 3t_1$, temperature of X becomes T_2

Therefore, from Equation (iii)

$$\int_{T_1}^{T_2}\frac{dT}{T - T_A} = -\left(k + \frac{KA}{LC}\right)\int_{t_1}^{3t_1} dt$$

$$\Rightarrow \ell n\left(\frac{T_2 - T_A}{T_1 - T_A}\right) = -\left(k + \frac{KA}{LC}\right)(2t_1)$$

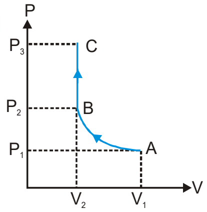
$$= -\left(2kt_1 + \frac{2KA}{LC}t_1\right)$$

$$\Rightarrow \ell n\left(\frac{T_2 - 300}{350 - 300}\right) = -2\ell n(2) - \frac{2KAt_1}{LC}$$

$\Rightarrow$ $kt_1 = \ell n2$ from Equation (i)

This equations gives $T_2 = \left(300 + 12.5e^{\frac{-2KAt_1}{CL}}\right)$ kelvin

3. The P–V diagram for the complete process will be as follows



Process A → B is adiabatic compression and

Process B → C is isochoric.

(b) **(i)** Total work done by the gas process A – B **:**

$$W_{AB} = \frac{P_AV_A - P_BV_B}{\gamma - 1} = \frac{P_iV_i - P_fV_f}{\gamma - 1} = \frac{P_1V_1 - P_2V_2}{\frac{5}{3} - 1}$$

$$= \frac{P_1V_1 - P_1\left(\frac{V_1}{V_2}\right)^{\gamma}V_2}{2/3} \quad \left[\begin{array}{c} P_1V_1^{\gamma} = P_2V_2^{\gamma} \\ \therefore P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} \end{array}\right]$$

$$= \frac{3}{2}P_1V_1\left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma - 1}\right] = -\frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{5/3-1} - 1\right]$$

$$= -\frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right]$$

Process B–C : $W_{BC} = 0$ (V= constant)

$$\therefore W_{Total} = W_{AB} + W_{BC} = -\frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right]$$

(ii) Total change in internal energy

Process A–B

$Q_{AB} = 0$ (Process is adiabatic)

$$\therefore \Delta U_{AB} = -W_{AB} = \frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right]$$

Process B–C

$W_{BC} = 0$

$\therefore \Delta U_{BC} = Q_{BC} = Q$ (Given)

$$\therefore \Delta U_{Total} = \Delta U_{AB} + \Delta U_{BC} = \frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right] + Q$$

(iii) Final temperature of the gas

$$\Delta U_{Total} = nC_V\Delta T = 2\left(\frac{R}{\gamma - 1}\right)(T_C - T_A)$$

$$\therefore \frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right] + Q = \frac{2R}{5/3 - 1}\left(T_C - \frac{P_AV_A}{2R}\right)$$

$$\Rightarrow \frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right] + Q = 3R\left(T_C - \frac{P_1V_1}{2R}\right)$$

$$\therefore T_C = \frac{Q}{3R} + \frac{P_1V_1}{2R}\left(\frac{V_1}{V_2}\right)^{2/3} = T_{final}$$

4. **(i)** Number of moles

$n=2$, $T_1 = 300K$

During the process $A \to B$

PT = constant or P^2V = constant = K(say)

$$\therefore \quad P = \frac{\sqrt{K}}{\sqrt{V}}$$

$$\therefore \quad W_{A\to B} = \int_{V_A}^{V_B} P.dV = \int_{V_A}^{V_B} \frac{\sqrt{K}}{\sqrt{V}}dV$$

$$= 2\sqrt{K}[\sqrt{V_B} - \sqrt{V_A}] = 2[\sqrt{KV_B} - \sqrt{KV_A}]$$

$$= 2\left[\sqrt{(P_B^2V_B)V_B} - \sqrt{(P_A^2V_A)V_A}\right] \quad (K = P^2V)$$

$$= 2[P_BV_B - P_AV_A] = 2[nRT_B - nRT_A]$$

$$= 2nR[T_1 - 2T_1] = (2)(2)(R)[300 - 600] = -1200R$$

$\therefore$ Work done on the gas in the process AB is 1200R.

(ii) Heat absorbed/released in different processes. Since, the gas is monoatomic.

Therefore, $C_V = \frac{3}{2}R$ and $C_P = \frac{5}{2}R$ and $\gamma = \frac{5}{3}$

Process A–B :

$$\Delta U = nC_V\Delta T = (2)\left(\frac{3}{2}R\right)(T_B - T_A) = (2)\left(\frac{3}{2}R\right)$$

$(300–600) = -900R$

$$\therefore \quad Q_{A\to B} = W_{A\to B} + \Delta U = (-1200R) - (900\,R)$$

$$Q_{A\to B} = -2100R \text{(Released)}$$

Process B–C :

Process is isobaric

$$\therefore \quad Q_{B\to C} = nC_P\Delta T$$

$$= (2)\left(\frac{5}{2}R\right)(T_C - T_B) = 2\left(\frac{5}{2}R\right)(2T_1 - T_1)$$

$$= (5R)(600–300)$$

$$Q_{B\to C} = 1500\,R \text{(absorbed)}$$

Process C–A :

Process is isothermal

$$\therefore \quad \Delta U = 0 \text{ and } Q_{C\to A} = W_{C\to A} = nRT_C \ell n\left(\frac{P_C}{P_A}\right)$$

$$= nR(2T_1)\ell n\left(\frac{2P_1}{P_1}\right) = (2)(R)(600)\ell n(2)$$

$$Q_{C\to A} = 831.6\,R \text{ (absorbed)}$$

5. Let m be the mass of the container. Initial temperature of container, $T_i = (227 + 273) = 500$ K and final temperature of container,

$$T_f = (27 + 273) = 300\,K$$

Now, heat gained by the ice cube = heat lost by the container i.e., (mass of ice) (latent heat of fusion of ice) + (mass of ice) (specific heat of water)

$$T_i = (227 + 273) = 500\,K$$

$$(300\,K - 273\,K) = -m\int_{T_i}^{T_f} S.dT$$

Substituting the values, we have

$(0.1)(8 \times 10^4) + (0.1)(10^3)(27)$

$$= -m\int_{500}^{300}(A + BT)dT \text{ of } 10700 = -m\left[AT + \frac{BT^2}{2}\right]_{500}^{300}$$

After substituting the values of A and B and the proper limits

we get $m = 0.495$ kg.

6. Given :

No. of moles, n=2

$C_V = \frac{3}{2}R \;\&\; C_P = \frac{5}{2}R$

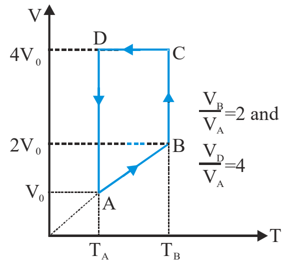
(Monoatomic)

$T_A = 27°C = 300\,K$

Let $V_A = V_0$

then $V_B = 2V_0$

and $V_D = V_C = 4V_0$



(i) Process A → B :

$$V \propto T \Rightarrow \frac{T_B}{T_A} = \frac{V_B}{V_A}$$

$$\therefore \quad T_B = T_A\left(\frac{V_B}{V_A}\right) = (300)(2) = 600K$$

$$\therefore \quad T_B = 600\,K$$

(ii) Process A→ B :

$V \propto T \Rightarrow P = \text{constant}$

$\therefore \quad Q_{AB} = nC_PdT = nC_P(T_B - T_A)$

$$= (2)\left(\frac{5}{2}R\right)(600 - 300)$$

$\therefore \quad Q_{AB} = 1500R$ (absorbed)

Process B → C :

T = constant $\therefore$ dU =0

$$\therefore Q_{BC} = W_{BC} = nRT_B \bullet n\left(\frac{V_C}{V_B}\right) = (2)(R)(600)\bullet n\left(\frac{4V_0}{2V_0}\right)$$

$$= (1200\,R)\bullet n(2) = (1200\,R)(0.693)$$

$\Rightarrow Q_{BC} \approx 831.6\,R$ (absorbed)

Process C → D

V = constant

$\therefore Q_{CD} = nC_VdT = nC_V(T_D - T_C)$

$$= n\left(\frac{3}{2}R\right)(T_A - T_B)\;(T_D = T_A \text{ and } T_C = T_B)$$

$$= (2)\left(\frac{3}{2}R\right)(300 - 600)$$

$\Rightarrow Q_{CD} = -900\,R$ (released)

Process D → A :

T = constant $\Rightarrow$ dU = 0

$$\therefore \quad Q_{DA} = W_{DA} = nRT_D \bullet n\left(\frac{V_A}{V_D}\right)$$

$$= (2)(R)(300)\bullet n\left(\frac{V_0}{4V_0}\right) = 600R\bullet n\left(\frac{1}{4}\right)$$

$Q_{DA} \approx -831.6\,R$ (Released)

(iii) In the complete cycle: dU = 0

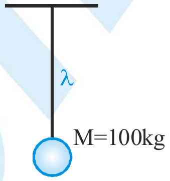
Therefore, from conservation of energy

$W_{net} = Q_{AB} + Q_{BC} + Q_{CD} + Q_{DA}$

$W_{net} = 1500R + 831.6R - 900\,R - 831.6\,R$

$\Rightarrow \quad W_{net} = W_{total} = 600\,R$

7. Given



Length of the wire ●=5m

Radius of the wire $r = 2 \times 10^{-3}$m

Density of wire $\rho = 7860\,kg/m^3$

Young's, modulus

$Y = 2.1 \times 10^{11}\,N/m^2$ and specific heat

$S = 420\,J/kg–K$

Mass of wire, m = (density) (volume)

$= (\rho)(\pi r^2\bullet) = (7860)(\pi)(2 \times 10^{-3})^2(5)\,kg = 0.494\,kg$

Elastic potential energy stored in the wire,

$$U = \frac{1}{2}\text{(stress) (strain)} \times \text{(volume)}$$

$$\Rightarrow \quad U = \frac{1}{2}\left(\frac{Mg}{\pi r^2}\right)\left(\frac{\Delta l}{1}\right)(\pi r^2 1) = \frac{1}{2}(Mg).\Delta\bullet$$

$$✈ \quad \left(\Delta l = \frac{Fl}{AY}\right) = \frac{1}{2}(Mg)\frac{(Mgl)}{(\pi r^2)Y} = \frac{1}{2}\frac{M^2g^21}{\pi r^2 Y}$$

Substituting the values, we have

$$U = \frac{1}{2}\frac{(100)^2(10)^2(5)}{(3.14)(2 \times 10^{-3})^2(2.1 \times 10^{11})}J = 0.9478\,J$$

When the bob gets snapped, this energy is utilised in raising the temperature of the wire.

So, $U = ms\Delta\theta$

$$\therefore \quad \Delta\theta = \frac{U}{ms} = \frac{0.9478}{0.494(420)}°C \text{ or } K$$

$\Rightarrow \quad \Delta\theta = 4.568 \times 10^{-3}°C$

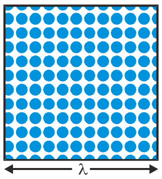
8. Volume of the box = $1m^3$

Pressure of the gas = $100N/m^2$

Let T be the temperature of the gas.

Then

(i) Time between two consecutive collisions with one wall = $\frac{1}{500}$ s.



This time should be equal to $\frac{2●}{v_{rms}}$

where ● is the side of the cube.

$$\Rightarrow \quad \frac{2●}{v_{rms}} = \frac{1}{500} \Rightarrow v_{rms} = 1000m/s \text{ (as } ● = 1m)$$

$$\Rightarrow \sqrt{\frac{3RT}{M}} = 1000$$

$$\therefore \quad T = \frac{(1000)^2 M}{3R} = \frac{(10)^6 (4 \times 10^{-3})}{3(25/3)} = 160 K$$

(ii) Average kinetic energy per atom $= \frac{3}{2} kT$

$$= \frac{3}{2}(1.38 \times 10^{-23})(160)\,J = 3.312 \times 10^{-21} J$$

(iii) From $PV = nRT = \frac{m}{M} RT$

We get mass of helium gas in the box, $m = \frac{PVM}{RT}$

Substituting the values we get

$$m = \frac{(100)(1)(4)}{(25/3)(160)} = 0.3\,g$$

9. Decrease in kinetic energy = increase in internal energy of the gas

$$\therefore \frac{1}{2} m v_0^2 = n C_V \Delta T = \left(\frac{m}{M}\right)\left(\frac{3}{2} R\right) \Delta T \;\therefore\; \Delta T = \frac{M v_0^2}{3R}$$

10. **(i)** Rate of heat loss per unit area due to radiation

$$I = e\sigma(T^4 - T_0^4)$$

Here. $T = 127 + 273 = 400\,K$

and $T_0 = 27 + 273 = 300\,K$

$$\therefore \quad I = 0.6 \times \frac{17}{3} \times 10^{-8}[(400)^4 - (300)^4] = 595\ W/m^2$$

(ii) Let θ be the temperature of the oil.

Then, rate of heat flow through conduction = rate of heat loss due to radiation

$$\therefore \quad \frac{\text{temperature difference}}{\text{thermal resistance}} = (595)A$$

$$\Rightarrow \frac{(\theta - 127)}{\left(\frac{1}{KA}\right)} = (595)A$$

Here, A = area of disc; K = thermal conductivity and ● = thickness (or length) of disc

$$\therefore \quad (\theta - 127)\frac{K}{l} = 595$$

$$\therefore \quad \theta = 595\left(\frac{l}{K}\right) + 127 = \frac{595 \times 10^{-2}}{0.167} + 127 = 162.6°C$$

11. At constant pressure

$$V \propto T \Rightarrow \frac{V_2}{V_1} = \frac{T_2}{T_1} \Rightarrow \frac{Ah_2}{Ah_1} = \frac{T_2}{T_1}$$

$$\therefore h_2 = h_1\left(\frac{T_2}{T_1}\right) = (1.0)\left(\frac{400}{300}\right) m = \frac{4}{3} m$$

As there is no heat loss, process is adiabatic.

For adiabatic process $T_f V_f^{\gamma-1} = T_i V_i^{\gamma-1}$

$$\therefore T_f = T_i\left(\frac{V_i}{V_f}\right)^{\gamma-1} = (400)\left(\frac{h_i}{h_f}\right)^{1.4-1} = 400\left(\frac{4}{3}\right)^{0.4}$$

12. When the temperature is increased, volume of the cube will increase while density of liquid will decrease. The depth upto which the cube is submerged in the liquid remains the same, hence the upthrust will not change.

$F = F' \qquad \therefore\; V_i \rho_L g = V_i' \rho'_L g$

(V_i = volume immersed)

$$\therefore \quad (Ah_i)(\rho_L)(g) = A(1 + 2\alpha_s \Delta T)(h_i)\left(\frac{\rho_L}{1 + \gamma_l \Delta T}\right) g$$

Solving this equation, we get $\gamma_l = 2\alpha_s$

13. Rate of heat conduction through rod= rate of the heat lost from right end of the rod.

$$\therefore \frac{KA(T_1 - T_2)}{L} = eA\sigma(T_2^4 - T_s^4) \qquad \text{...(i)}$$

Given that $T_2 = T_s + \Delta T$

$$\therefore \; T_2^4 = (T_s + \Delta T)^4 = T_s^4\left(1 + \frac{\Delta T}{T_s}\right)^4$$

Using binomial expansion, we have

$$T_2^4 = T_s^4\left(1 + 4\frac{\Delta T}{T_s}\right) \text{ (as } \Delta T << T_s)$$

$$\therefore \; T_2^4 - T_s^4 = 4(\Delta T)(T_s^3)$$

Substituting in Eq.(i), we have

$$\frac{K(T_1 - T_s - \Delta T)}{L} = 4e\sigma T_s^3.\Delta T$$

$$\Rightarrow \frac{K(T_1 - T_s)}{L} = \left(4e\sigma T_s^3 + \frac{K}{L}\right)\Delta T$$

$$\therefore \quad \Delta T = \frac{K(T_1 - T_s)}{(4e\sigma L T_s^3 + K)}$$

Comparing with the given relation, proportionality

$$\text{constant} = \frac{K}{4e\sigma L T_s^3 + K}$$

14. **(a)** From $\Delta Q = ms\Delta T$

$$\Delta T = \frac{\Delta Q}{ms} = \frac{20000}{1 \times 400} = 50°C$$

(b) $\Delta V = V\gamma\Delta T = \left(\frac{1}{9000}\right)(8 \times 10^{-5})(50)$

$$= 5 \times 10^{-7}\ m^3$$

$\therefore W = P.\Delta V = (10^5)(5 \times 10^{-7}) = 0.05$ J

(c) $\Delta U = \Delta Q - W = (20000 - 0.05)$ J $= 19999.95$ J

15. 0.05 kg steam at 373 K $\xrightarrow{Q_1}$ 0.05 kg water at 373 K

0.05 kg water at 373 K $\xrightarrow{Q_2}$ 0.05kg water at 273 K

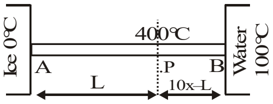
0.45 kg ice at 253 K $\xrightarrow{Q_3}$ 0.45 kg ice at 273 K

0.45 kg ice at 273 K $\xrightarrow{Q_4}$ 0.45 kg water at 273 K

$Q_1 = (50)(540) = 27{,}000$ cal $= 27$ kcal
$Q_2 = (50)(1)(100) = 5000$ cal $= 5$ kcal
$Q_3 = (450)(0.5)(20) = 4500$ cal $= 4.5$ kcal
$Q_4 = (450)(80) = 36000$ cal $= 36$ kcal

Now since $Q_1 + Q_2 > Q_3$ but $Q_1 + Q_2 < Q_3 + Q_4$ ice will come to 273K from 253 K, but whole ice will not melt. Therefore, temperature of the mixture is 273K.

16.

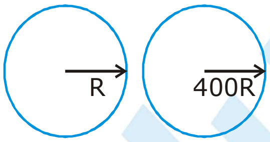


$$\frac{k(400 - 0)A}{L} = m(80) \qquad ...(i)$$

$$\frac{kA(400 - 100)}{(10x - L)} = m(540) \qquad ...(ii)$$

Divide (i) by (ii) $1080x = 120L$ ✈ $L = \lambda x \therefore \lambda = 9$

17.



$$\frac{\lambda_A}{\lambda_B} = \frac{T_B}{T_A}$$

$P = \sigma eA\ T_4$
$P_A = \sigma e.\ 4\pi(400\ R)^2 \times T_A{}^4$
$P_B = \sigma e.\ 4pR^2 \times T_B{}^4$
$(400R)^2 \times T_A{}^4 = 10^4 \times T_B{}^4$
$16 \times 10^4 \times T_A{}^4 = 10^4 \times T_B{}^4$

$$\frac{T_B}{T_A} = 2$$

18. 2 **19.** 9 **20.** 3

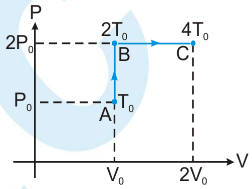
MOCK TEST : BASIC MATHS

1. Let initial pressure, volume, temperature be P_0, V_0, T_0 indicated by state A in P-V diagram. The gas is then isochorically taken to state B $(2P_0, V_0, 2T_0)$ and then taken from state B to state C $(2P_0, 2V_0, 4T_0)$ isobarically. Total heat absorbed by 1 mole of gas

$$\Delta Q = C_v(2T_0 - T_0) + C_P(4T_0 - 2T_0)$$

$$= \frac{5}{2}RT_0 + \frac{7}{2}R \times 2T_0 = \frac{19}{2}RT_0$$

Total change in temperature from state A to C is $\Delta T = 3T_0$



$\therefore$ Molar heat capacity

$$= \frac{\Delta Q}{\Delta T} = \frac{\frac{19}{2}RT_0}{3T_0} = \frac{19}{6}R.$$

2. In an ideal gas internal energy $= \frac{f}{2}nRT$

$$U = \frac{5}{2} \times 2 \times RT + 4 \times \frac{3}{2}RT = 11\ RT.$$

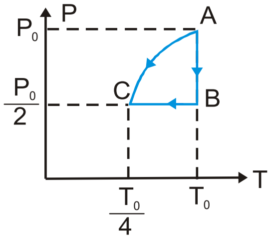
3. Heat absorbed by gas in three processes is given by
$Q_{ACB} = \Delta U + W_{ACB}$
$Q_{ADB} = \Delta U$
$Q_{AEB} = \Delta U + W_{AEB}$
The change in internal energy in all the three cases is same. And W_{ACB} is +ve, W_{AEB} is –ve.
Hence $Q_{ACB} > Q_{ADB} > Q_{AEB}$

4. In an adiabatic expansion, internal energy decreases and hence temperature decreases.
$\therefore$ from equation of state of ideal gas
$PV = nRT \Rightarrow$ The product of P and V decreases.

5. Process AB is isothermal expansion, BC is isobaric compression

In process CA $P \propto \frac{nRT}{P}$

$\Rightarrow P^2 \propto T.$



6. Higher is the temperature greater is the most probable speed.

7. The rate of heat loss by a thin hollow sphere of thickness 'Δx', mean radius 'r' and made of density 'ρ' is given by

$$mS\frac{dT}{dt} = -\varepsilon\sigma A(T^4 - T_0^4)$$

$$(\rho\, 4\pi r^2 \Delta x)\ S\frac{dT}{dt} = -\varepsilon\sigma\, 4\pi r^2\, (T^4 - T_0^4)$$

$\Rightarrow \dfrac{dT}{dt} = -\dfrac{\varepsilon\sigma(T^4 - T_0^4)}{S\Delta x}$ is independent of radius

Hence rate of cooling is same for both spheres.

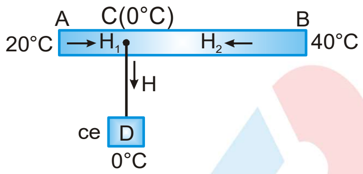
8. Thermal resistance of AC $\left(= \dfrac{L}{KA}\right)$

$$= \frac{0.1}{336 \times 1 \times 10^{-4}} = \frac{10^3}{336} = R \text{ (suppose)}$$

thermal resistance of BC $= \dfrac{0.2}{336 \times 10^{-4}} = 2R$

temperature of point C

$$\therefore H_1 = \frac{20}{R}\ ;\ H_2 = \frac{40}{2R} = \frac{20}{R}$$



$$\therefore H = H_1 + H_2 = \frac{40}{R} = \frac{40 \times 336}{10^3} = \frac{13440}{10^3}$$

$$= 13.44 \text{ watt}$$

Rate of melting of ice $= \dfrac{H}{L_f} = \dfrac{13.44/4.2}{80}$ g/s $= 40$ mg/s

9. Since tension is the two rods will be same, hence

$A_1Y_1\alpha_1\,\Delta\theta = A_2Y_2\alpha_2\,\Delta\theta \quad \Rightarrow \quad A_1Y_1\alpha_1 = A_2Y_2\alpha_2$

10. $V_{r.m.s.} = \sqrt{\dfrac{1^2 + 0^2 + 2^2 + 3^2}{4}} = \sqrt{3.5}$.

11. We have $\rho = \dfrac{PM}{RT}$

$$\frac{P_1M}{RT_1} = \frac{P_2M}{RT_2} \qquad \frac{P_1}{T_1} = \frac{P_2}{2T_1}$$

$P_2 = 2P_1$ i.e., change in pressure is 100%.

12. Strain developed :

$\varepsilon = \alpha\,\Delta T = (12 \times 10^{-6})\,(50) = 6 \times 10^{-4}$

Strain will be **negative**, as the rod is in a compressed state.

13. Heat current : $\quad i = -kA\dfrac{dT}{dx}$

$$idx = -kA\, dT$$

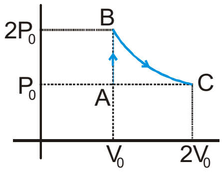
$$i\int_0^1 dx = -A\alpha\int_{T_1}^{T_2} T\, dT \Rightarrow i\bullet = -A\alpha\,\frac{(T_2^2 - T_1^2)}{2}$$

$$\Rightarrow i = \frac{A\,\alpha\,(T_1^2 - T_2^2)}{2\,1}$$

14. BC is isochoric. $V_B > V_A$, $V_B = V_C$, $V_D > V_C$

15. $Q_{AB} = \Delta U_{AB} + W_{AB}$

$W_{AB} = 0$



$$\Delta U_{AB} = \frac{f}{2} nR\,\Delta T$$

$\Rightarrow \dfrac{f}{2}(\Delta PV)\ \Delta U_{AB} = \dfrac{5}{2}(\Delta PV) \qquad Q_{AB} = 2.5\, P_0V_0$

Process BC $\quad Q_{BC} = \Delta U_{BC} + W_{BC}$

$Q_{BC} = 0 + 2P_0V_0 \log 2 = 1.4\, P_0V_0$

$Q_{net} = Q_{AB} + Q_{BC} = 3.9\, P_0V_0$

16. $\dfrac{X - (-125)}{500} = \dfrac{Y - (-70)}{40} \qquad$ For $\quad Y = 50$

$X = 1375.0°X$

17. Rate of radiation per unit area is proportional to (T^4)

$\therefore \quad P \propto AT^4 \Rightarrow P \propto r^2$.

Also $\quad ms\dfrac{dT}{dt} \propto AT^4 \qquad \therefore \quad \dfrac{dT}{dt} = R \propto \dfrac{1}{r}$

(because $\ m = (V\rho) \propto r^3$ and $A \propto r^2$)

$\therefore \quad PR \propto r$

18. For a block body, wavelength for maximum intensity :

$\lambda \propto \dfrac{1}{T}$ & $P \propto T^4 \Rightarrow P \propto \dfrac{1}{\lambda^4} \Rightarrow P' = 16\,P$.

$\therefore \quad P'\,T' = 32PT$

19. Since, $e = a = 0.2$ (Since, $a = (1 - r - t) = 0.2$ for the body B)

$E = (100)\,(0.2) = 20\ \text{W/m}^2$

20. Thermal equilibrium means same temperature.

21. $\frac{C}{5} = \frac{F-32}{9} \Rightarrow \frac{\Delta C}{5} = \frac{\Delta F}{9}$

$\Delta C = \frac{5}{9}\Delta F \Rightarrow \Delta C = \Delta K$

22. PV = RT for 1 mole

$W = \int PdV = \int \frac{RT}{V} dV \Rightarrow V = CT^{2/3}$

$\therefore\ dV = \frac{2}{3} CT^{-1/3}\, dT$ or $\frac{dV}{V} = \frac{2}{3}\frac{dT}{T}$

$\therefore\ W = \int_{T_1}^{T_2} RT\left(\frac{2}{3}\right)\frac{dT}{T} = \frac{2}{3}R(T_2 - T_1) = 166.2\ J$

23. $\Delta s \Delta U = \frac{nfR}{2}\Delta T$

$\Delta U \propto \Delta T$;

Since volume is same in all three process therefore temperature will be least having least pressure.

24. log P = m log V where m is slope

$m = \frac{2.38 - 2.10}{1.1 - 1.3} = -1.4$

$\log P = -1.4 \log V$

$\log PV^{1.4} = 0$

$PV^{1.4} = k$

25. Rate of heat loss = $\sigma\, eA\,(T^4 - T_s^{\,4})$

$-ms\frac{dT}{dt} = \sigma\, eA\,(T^4 - T_s^{\,4})$

$-\frac{dT}{dt} = \frac{5.8\times 10^{-4} \times i \times T(0.08)^2((500)^4(300)^4)}{10\times 4.2 \times 90}$

$\Rightarrow \frac{-dT}{dt} = 0.066\ ^{o}C/sec.$

26. In the equilibrium position the net force on the partition will be zero.

Hence pressure on both sides are same.

Hence, (A) is correct.

Initially, PV = nRT

$n_1 = \frac{P_1V_1}{RT_1} = \frac{PV}{RT}$ & $n_2 = \frac{(2P)(2V)}{RT} = 4\frac{PV}{RT}$

$\Rightarrow n_2 = 4n_1$

Moles remains conserved.

Finally, pressure becomes equal in both parts.

Using, $P_1V_1 = n_1RT_1 \Rightarrow P_2V_2 = n_2RT_2$

✈ $P_1 = P_2$ & $T_1 = T_2$

$\therefore\ \frac{V_1}{V_2} = \frac{n_1}{n_2} = \frac{1}{4} \Rightarrow V_2 = 4V_1$

Also $V_1 + V_2 = 3V \Rightarrow V_1 + 4V_1 = 3V$

$\Rightarrow V_1 = \frac{3}{5}V$ And $V_2 = \frac{12}{5}V$

Hence (B) and (C) are correct.

In compartment (I) :

$P_1'V_1 = n_1RT_1$

$P_1'\left(\frac{3V}{5}\right) = \left(\frac{PV}{RT}\right)R(T)$

$P_1' = \frac{5PV}{3V} = \frac{5}{3}P$

Hence (D) is also correct.

27. $\frac{P^2}{\rho} = k \Rightarrow \frac{P^2RT}{PM} = k$

$\Rightarrow PT = \left(\frac{kM}{R}\right)$ ....(i)

$\frac{P^2}{\rho} = \frac{P'^2}{\rho/2} \Rightarrow P' = \frac{P}{\sqrt{2}}$

Hence from (i) T' = $T\sqrt{2}$. PT = constant hence P – T curve is a hyperabola.

28. $V_{r.m.s.} = \sqrt{\frac{3kT}{m}}$

Since PV = nRT therefore P and V both can change simultaneously keeping temperature constant.

29. Slope of graph is smaller in the solid state i.e., temperature is rising slower, hence higher heat capacity.

The transition from solid to liquid state takes lesser time, hence latent heat is smaller.

30. Initial state is same for all three processes (say initial internal energy = E_0)

In the final state, $V_A = V_B = V_C$

and $P_A > P_B > P_C$

$\Rightarrow P_AV_A > P_BV_B > P_CV_C \Rightarrow E_A > E_B > E_C$

if $T_1 > T_2$

then $E_0 > E_f$ for all three processes

and hence $(E_0 - E_A) < (E_0 - E_B) < (E_0 - E_C)$

$\Rightarrow |\Delta E_A| < |\Delta E_B| < |\Delta E_C|$

If $T_1 < T_2$, then $E_0 < E_f$ for all three processes

and hence $(E_A - E_0) > (E_B - E_0) > (E_C - E_0)$

$\Rightarrow |\Delta E_A| > |\Delta E_B| > |\Delta E_C|$

31. $\frac{\Delta A}{A} \times 100 = 2\left(\frac{\Delta l}{l}\right) \times 100$

$\Rightarrow$ % increase in Area $= 2 \times 0.2 = 0.4$

$\frac{\Delta V}{V} \times 100 = 3 \times 0.2 = 0.6\,\%$

Since $\Delta l = l\,\alpha\,\Delta T$

$\frac{\Delta\lambda}{\lambda} \times 100 = \alpha\,\Delta T \times 100 = 0.2 \Rightarrow \alpha = 0.25 \times 10^{-4}\ /°C$

32. $\Delta V_L = \Delta V_V \Rightarrow Y_L V_L = Y_V V_V$ or $\frac{Y_L}{Y_V} = \frac{V_V}{V_L}$

but $V_V > V_L \Rightarrow Y_L > Y_V$

33. Every object emit and absorb the radiations simultaneously, if energy emitted is more than energy absorbed temperature falls and vice versa.

34. Equivalent thermal conductivity of two identical rods in series is given by

$\frac{2}{K} = \frac{1}{K_1} + \frac{1}{K_2}$

If $K_1 < K_2$, then $K_1 < K < K_2$. Hence statement 1 is false.

35. From Wein's law $\lambda_m T$ = constant i.e., peak emission wavelength $\lambda_m \propto \frac{1}{T}$. Hence as T increase λ_m decreases.

36. If the rate at which molecules of same mass having same rms velocity striking a wall decreases, then the rate at which momentum is imparted to the wall decreases. This results in lowering of pressure. Hence statement-2 is correct.

In statement-1 the rms velocity of gas remains same on increasing the volume of container by piston, since the given process is isothermal. Now the piston is at a greater distance from opposite wall and hence time taken by gas molecules from near the opposite wall to reach the piston will be more. Thus rate of molecules striking the piston decreases. Hence statement-1 is correct and statement-2 is correct explanation.

37. Heat given : $\Delta Q = n_1 C_{V_1} \Delta T \rightarrow$ For gas A & for Gas B $\rightarrow \Delta Q = n_2 C_{V_2} \Delta T$

($\because$ For same heat given, temperature rises by same value for both the gases.)

$\Rightarrow \quad n_1 C_{V_1} = n_2 C_{V_2}$ ....(1)

Also, $(\Delta P_B)V = n_2 R \Delta T$ and $(\Delta P_A)V = n_1 R \Delta T$

$\Rightarrow \quad \frac{n_1}{n_2} = \frac{\Delta P_A}{\Delta P_B} = \frac{2.5}{1.5} = \frac{5}{3} \Rightarrow n_1 = \frac{5}{3} n_2$

Substituting in (1)

$\frac{5}{3} n_2\ C_{V_1} = n_2 C_{v_2} \Rightarrow \frac{C_{v_2}}{C_{v_1}} = \frac{5}{3} = \frac{(\frac{5}{2}R)}{(\frac{3}{2}R)}$

Hence, Gas B is diatomic and Gas A is monoatomic.

38. Since $n_1 = \frac{5}{3} n_2$

Therefore $\frac{125}{M_A} = \frac{5}{3}\left(\frac{60}{M_B}\right)$

(From experiment 1 : $W_A = 25$ gm & $W_B = 60$ gm)

$\Rightarrow 5M_B = 4M_A$

The above relation holds for the pair–Gas A : Ar and Gas B : O_2.

39. $n_A C_{V_A} \times 300 + n_B C_{V_B} \times 300 = n_A C_{V_A} T + n_B C_{V_B} T$

(number of moles remains same)

$\Rightarrow T = 300$ K

(It could also be seen directly that temperature finally will be 300 K, since no heat exchange takes place between those gases as their initial temperatures are same)

Since, volume remains same but number of moles increases.

Therefore, pressure increases.

40. We have $\theta - \theta_s = (\theta_0 - \theta_s)\,e^{-kt}$

where θ_0 = Initial temperature of body = 40°C

θ = temperature of body after time t.

Since body cools from 40 to 38 in 10min, we have

$38 - 30 = (40 - 30)\,e^{-k\,10}$ .... (1)

Let after 10 min, The body temp. be θ

$\theta - 30 = (38 - 30)\,e^{-k\,10}$ .... (2)

$\frac{(1)}{(2)}$ gives $\frac{8}{\theta - 30} = \frac{10}{8}$, $\theta - 30 = 6.4$

$\Rightarrow \theta = 36.4$ °C

41. Temperature will decrease exponentially

42. During heating process from 38 to 40 in 10 min. The body will lose heat in the surrounding which will be exactly equal to the heat lost when it cooled from 40 to 38 in 10 min, which is equal to $ms\,\Delta\theta = 2 \times 2 = 4$ J.

During heating process heat required by the body = $m\,s\,\Delta\theta = 4$ J.

$\therefore$ Total heat required = 8 J.

43. **(A)** If $P = 2V^2$, from ideal gas equation we get $2V^3 = nRT$

$\therefore$ with increase in volume

(A) Temperature increases implies $dU = +ve$

$\therefore$ $dW = +ve$

Hence $dQ = dU + W = +ve$

(B) If $PV^2 = $ constant, from ideal gas equation we get $VT = K$ (constant)

On decreasing temperature, as volume of an ideal gas increases

$\therefore$ $dW = +ve$

Now $dQ = dU + PdV = nC_v dT - \frac{PK}{T^2} dT$ [✈ $dV = -\frac{K}{T^2} dT$]

$$= nC_v dT - \frac{PV}{T} dT = n(C_v - R)\, dT$$

$\therefore$ with increase in temperature $dT = +ve$

and since $C_v > R$ for monoatomic gas. Hence $dQ = +ve$ as temperature is increased

(C) $dQ = nC\,dT = nC_v\,dT + PdV$

$\Rightarrow$ $n(C_v + 2R)\,dT = nC_v dT + PdV$

$\therefore 2nRdT = PdV \quad \therefore \frac{dV}{dT} = +ve$

Hence with increase in temperature volume increases and vice versa.

$\therefore dQ = dU + W = +ve$

(D) $dQ = nC\,dT = nC_v\,dT + PdV$

or $n(C_v - 2R)dT = nC_r dT + PdV$

or $-2nRdT = PdV \quad \therefore \frac{dV}{dT} = -ve$

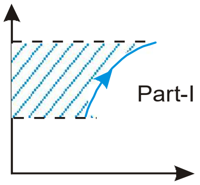
On decreasing temperature, as volume of an ideal gas increases

$\therefore$ $dW = +ve$

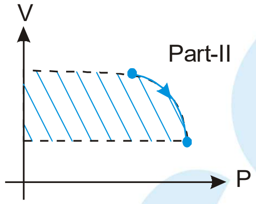
Also $dQ = n(C_v - 2R)dT$

with increase in temperature $dT = +ve$ but $C_v < 2R$ for monoatomic gas. Therefore $dQ = -ve$ with increase in temperature.

44. in (A), V is on vertical axis.



As V is icreasing, W is positive.



V is decreasing, W is negative.

As negative work in part-II is greater than positive work in part-I, net work during the process is negative.

Using $PV = nRT$ and as $V_{remains}$ same for initial and final points of the process, it is obvious that final temp. is greater than initial temperature as pressure has increased. Therefore dU is positive. Hence option (S) is connected with (A).

As $T = \frac{PV}{nR}$

$\therefore$ From graph we can say

$T_{final} < T_{initial}$ in part B,C & D

Similar arguments can be applied to other graphs.

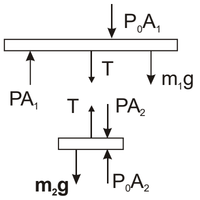
45. Due to the heating pressure inside is not changed. Let inside pressure be ρ. Then for equilibrium of the system :

$$P(A_1 - A_2) = P_0(A_1 - A_2) + (m_1 + m_2)g$$

$\Rightarrow$ $P\Delta V = (P_0\Delta A + mg)$●

● is displacement of the piston.

$P \,.\, \Delta V = nR\Delta T.$



$$\Delta T = \frac{P\Delta V}{nR}$$

$$= \frac{(P_0\Delta A + mg)\lambda}{nR}$$

$$= \frac{(10^5 P_a \text{ x } 10^{-3} m^2 + 5 \text{ x } 10)(50 \times 10^{-2})}{1 \text{ x } R}$$

$$\Delta T = \frac{75}{R} \text{ K.}$$

46. Change in internal energy for cyclic process (ΔU) = 0

for process a → b, (P – constant)

$$W_{a\to b} = P.\Delta V = nR\Delta T = -400\,R$$

for process b → c (T – constant)

$$W_{b\to c} = -2R((300)\bullet n2$$

for process c → d (P – constant)

$$W_{c\to d} = +400\,R$$

for process d → a (T – constant)

$$W_{d\to a} = +2R\,(500)\bullet n2$$

Net work (ΔW) = $W_{a\to b} + W_{b\to c} + W_{c\to d} + W_{d\to a}$

$$\Delta W = 400\,R\bullet n2$$

$\therefore$ $dQ = dU + W$, first law of thermady names.

$\therefore$ $dQ = 400\,R\bullet n2.$

47. Energy supply by resistance

$$= i^2.R$$

By first law of thermodynamics

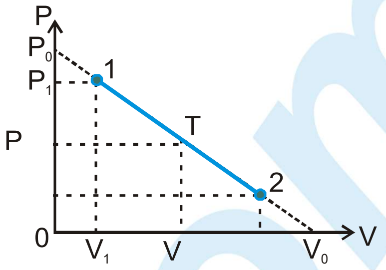
$\Delta Q = \Delta U + \Delta W$

$\Delta U = 0$

$$\therefore\ i^2R = mg\left(\frac{dx}{dt}\right) \Rightarrow v = \frac{F^2R}{mg} = \frac{2\times2\times10}{1\times10}$$

$$v = 4\ \text{m/s}.$$

48. $Q = \Delta U + W$



where ΔU is the change in the internal energy of the gas; and W is work, done by the gas. For one mole of the monatomic ideal gas $\Delta U = 3/2 R\,\Delta T$. Work equals the area under the graph

P vs. V

Therefore, for the process from the initial state with $P_1V_1 = 3/2\,RT_1$ to the state with P,V,T the heat given to system is

$$Q = (3/2)\,R\,(T - T_1) + (1/2)\,(P + P_1\,(V - V_1)$$

$$= \frac{3}{2}\,(PV - P_1V_1) + \frac{1}{2}(PV + P_1V + PV_1 - P_1V_1) \quad \text{....}\ (3)$$

$$= 2PV + \frac{1}{2}\,P_1V - \frac{1}{2}PV_1 - 2P_1V_1$$

from equation 1 and 3 we get

$$Q = 2\frac{P_0}{V_0}V^2 + \frac{5}{2}P_0V - 2P_0V_1\left(\frac{5}{4} - \frac{V_1}{V_0}\right)$$

The process switches from endothermic to exothermic as $\frac{dQ}{dV}$ changes from positive to negative, that is at

$\frac{dQ}{dV} = 0$. Solving we get

$$V = \frac{5}{8}V_0$$