Heat & Thermo

Conceptual Problem Set-I Solution

1. (D) does not depend

2. (A) particles will come closer, & moment of Inertia will decrease. $L = I\omega \rightarrow \omega$ will Increase.

3. (D) $L = L_0(1+\alpha\Delta T) = 10 \times (1 + 10^{-5} \times 35) = 10.0035$

4. (A) length of Iron $= L_1$

'' '' Copper $= L_2$

given $|L_2 - L_1| = 10$ cm. — ①

as change is independent of temp,

$\Delta L_2 - \Delta L_1 = 0 \Rightarrow L_1\alpha_1 \cancel{\Delta T} = L_2\alpha_2 \cancel{\Delta T}$

$L_1 \times 11 = L_2 17$ — ②

$\left| \frac{L_1 \times 11}{17} - L_1 \right| = 10$

$\Rightarrow L_1 = 28.33$ cm

$L_2 = 18.33$ cm.

5. (B)

time ~~lost~~ gain in one day (at 15°c) $= \left[\frac{1}{2}\alpha\Delta\theta_1\right]$ 24 hours $= 5$ se. — ①

time loss in one day (at 30°c) $= \left[\frac{1}{2}\alpha\Delta\theta_2\right]$ 24 hours $= 10$ se. — ②

$\frac{①}{②} = \frac{\Delta\theta_1}{\Delta\theta_2} = \frac{1}{2}$

$2\Delta\theta_1 = \Delta\theta_2$

$2(\theta - 15) = 30 - \theta$

Calibrated temp. would be b/w $15° < \theta < 3$

using ① $\frac{1}{2}\alpha \times 5 \times 24 \times 60 \times 60 = 5$

$\alpha = 2.314 \times 10^{-5}$

6. (B) $Y = E = \dfrac{\frac{F}{A}}{\frac{\alpha L_0 \Delta T}{L_0(1+\alpha \Delta T)}}$

$\Rightarrow F = \dfrac{EA\alpha t}{1+\alpha t}$

6.

~~$L = L_0(1+\alpha\Delta T)$~~

~~$= 10'(1+1\times10^{-5}\times 35)$~~

7.

~~Fx~~ $\dfrac{\Delta l}{L_0} = \dfrac{L_0 \alpha \Delta T}{L_0} = 1.2\times10^{-5}\times 30$

$= 36\times10^{-5}$

8.

(a) already compressed by ΔL

new strain $= \Delta l + \alpha\theta$

(b)

decreased temp.

new strain $= \Delta l - \alpha\theta$

9.

$(t - t_0) = \left(\frac{1}{2}\alpha\Delta\theta\right)t_0$

$15 = \frac{1}{2}\times\alpha\, 20\times24\times60\times60$

$\alpha = 1.73\times10^{-5}\,/^\circ C$

10.

$\rho = \dfrac{\rho_0}{1+\gamma\Delta T}$

1.900

Conceptual problem set-2 Answer Key.

1. $K.E = \frac{1}{2} \times \frac{10}{1000} \times 400 \times 400 \ J$

$= 800\ J = \frac{800}{4.2}\ Cal = 190.5\ Cal.$

2. $\boxed{100^\circ c} \xrightarrow{\theta_1} \boxed{100^\circ c} \xrightarrow{\theta_2} \boxed{20^\circ c}$

steam $\quad$ water $\quad$ water

$Q = \theta_1 + \theta_2 = 1 \times 540 \times 10^{3} + 1 \times 1 \times 80 \times 10^{3}$

$= 620 \times 10^{3}\ Cal/gm.$

3. $Q = ms\Delta T = 1 \times 1 \times 1 = 1\ Cal/.$

4. $Q = 420\ J = \frac{420}{4.2}\ Cal = 100\ Cal$

$= ms\Delta T$

$\Delta T = \frac{100}{10 \times 1} = 10^\circ C$

5. thermal Capacity $= C = ms$

thermal Capacity Per Unit Volume $= \frac{ms}{V} = \rho s$

Ration $= \frac{\rho_1 s_1}{\rho_2 s_2} = \frac{3}{4} \times \frac{4}{3} = 1$

6. $Q = ms\Delta T = 200 \times 1 \times 20 = 4000\ Cal.$

7. $\boxed{10^\circ C}$ $\quad = 10 \times 10^3$ $\quad \boxed{100^\circ c}$

$Q = 1 \times 1 \times 100 \times 10^3$

from the flow chart we can say all ice will melt. suppose final temp. is 'T'

Heat lost by water = Heat gain by ice

$$1\times\cancel{10^3}\times 1\times(100-T) = 1\times .5\times 10\,\cancel{\times 10^3} + 1\times 80\times\cancel{10^3}$$

$$+\,1\times\cancel{10^3}\times 1\times T$$

$$100 - T = 5 + 80 + T$$

$$2T = 15 \Rightarrow T = 7.5^\circ C$$

8. from the flow chart of above problem, we can say, all ice would not melt.

therefore, equilibrium temp $= 0^\circ C$

9.

A	B	C
m	m	m
15	20	30°
S_A	S_B	S_C

A + C = ?

A, B → $18^\circ C$ B, C → $22^\circ C$

$$\cancel{m} S_A \times 3 = \cancel{m}\, S_B\, 2 \qquad m S_B 2 = m S_C 8$$

$$3S_A = 2S_B \qquad S_B = 4S_C$$

$$3S_A = 8S_C$$

10.

A	B
m	m
S_A	S_B
32°	24°

$28^\circ C$

$$m S_A (32 - 28) = m S_B (28 - 24)$$

$$S_A = S_B \Rightarrow \frac{S_A}{S_B} = 1:1$$

Conceptual problem set - 3 (KTG)

1. (C) $\Delta t = \frac{2L}{V}$ as length decreases

$P = \frac{F}{A} = \frac{\Delta P}{A \Delta t}$ Succesive Collision time decreas pressure increased

2. (C) [With collision speed changes, but average speed remain const.]

3. (C), (d)

4. (b) (Vector quantity)

5. (d) (None, average momentum always zero if Container is at rest]

6. (a) $V_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow \frac{V_1}{V_2} = 1 \Rightarrow \sqrt{\frac{T_1}{m_1}} = \sqrt{\frac{T_2}{m_2}}$ $T_{O_2} = 426.5$ K

7. (C) $V_0 = \sqrt{\frac{3KT}{m}} = \cancel{\sqrt{3}}$ $V_{new} = \sqrt{\frac{3K(2T)}{m/2}} = 2V_0$

8. (a)

9. (a)

10. (d) $PV = \frac{m}{M} RT \Rightarrow \frac{mRT}{PV} = M$

M = molecular mass

$PV = \frac{N_A}{M}$

M KT

$nR = N_A k$

Solution of Conceptual Problem Set for Thermodynamic

(4)

1. (d)

2. (b) $T_B < T_A$ $\qquad V = \dfrac{nRT}{P}$

$P_B > P_A$ $\qquad \Rightarrow V \downarrow$

3. $A \rightarrow B$ $\qquad P_A = P_B$

but $V_B > V_A \Rightarrow T_B > T_A$

$\Rightarrow U_B > U_A$ $\qquad$ (A)

4. $W = \int P\,dV$ = always increasing

(a)

5. we can't predict temp is continuously increasing or Not. ~~as curve is n~~

as equation of curve is not mentioned.

so only (C)

6. (A) $Q = -ve$ $\qquad T = \text{Const} \Rightarrow \Delta U = 0$

$Q = \Delta W \Rightarrow W = -ve$

Work done by the gas = $-ve$

$\Rightarrow$ work done on the gas = $+ve$

$PV = nRT$

$nR\Delta T = Q$

now Heat Supplied $\Rightarrow nC_p\Delta T$

$= n\frac{7R}{2}\Delta T$

(d) $= \frac{7}{2}Q$

8. (A) $\frac{dw}{dQ} = 1 \Rightarrow \Delta U = 0$ isothermal process.

9. $W = P\Delta V = nR\Delta T = 1 \times \frac{25}{3} \times 12 = 100 J$

(A)

10. $\Delta U = nC_v\Delta T = 10 \times \frac{R}{\gamma - 1} \times 30$

(d) $= 10 \times \frac{R \times 30}{\cancel{}.5} = 600R$

Conceptual problem set - 5

1. (d)

2. (b)

3. (c) steady state $\Rightarrow T = \text{Const.}$

4. (c) 〃 〃

5. (a) more than 10 mins.

as $\frac{dT}{dt} \propto (T - T_s)$ so rate of cooling decreases as Temp. of body decreases. it takes more time.

6. $\left(\frac{dT_1}{dt}\right) > \left(\frac{dT_2}{dt}\right)$

$\frac{70-60}{10} > \frac{60-T}{10} \Rightarrow T > 50^\circ C$

only 6 possible

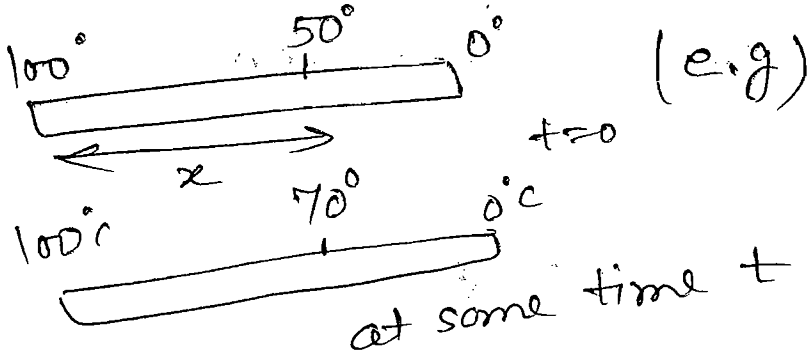
7. $\frac{dT}{dt} = \frac{\sigma A T^4}{ms}$ but as we know, for the same mass, sphere has lowest surface area.

So cooling rate of sphere is lowest

$\Rightarrow$ (a)

8. (d)

9. decreases 10. $i = \frac{dQ}{dt} = \frac{KA}{L}\frac{dT}{dx}$



$$\left(\frac{dT}{dx}\right)_{\text{initially}} = \frac{50}{x}$$

$$\left(\frac{dT}{dx}\right)_{\text{finally}} = \frac{30}{x}$$ so i decreases.

Exercise - 1

1. Suppose wood length = l_0

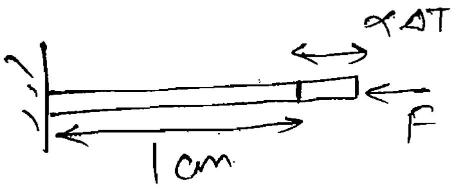
Reading at $0^\circ c = \dfrac{L_0}{(1-\alpha_s \Delta T)}$ at $0^\circ c$ gap will become $1(1-\alpha_s \Delta T)$

$$25 = \frac{L_0}{(1-\alpha_s \Delta T)} \Rightarrow L_0 = 25(1-\alpha_s \Delta T)$$

So $L_0 < 25$

(B)

2.



$$Y = E = \frac{F/A}{\frac{\alpha \Delta T}{(1+\alpha \Delta T)}}$$

Rod is Compressed from $(1+\alpha \Delta T)$ to $\rightarrow$ 1 cm $\Rightarrow$ $F = \dfrac{EA\alpha \Delta T}{1+\alpha \Delta T}$

therefore original length = $1+\alpha \Delta T$

(B)

3. Suppose Weight of ball in air = W_0 (Volume V_0 density ρ_0)

at $0^\circ c \Rightarrow W_1 = W_0 - B_{0^\circ c}$ (B $\rightarrow$ Buoyancy force)

$W_2 = W_0 - B_{50^\circ c}$

$B = \rho_{Liquid} V_{Inside}\, g$ $B_{0^\circ c} = \rho_{L0} V_0 g$

$$B_{50^\circ c} = \frac{\rho_{L0}}{1+\gamma_{AL} 50} \times V_0 (1+\gamma_m 50)$$

$$B_{50^\circ c} = B_{0^\circ c} \times (1+(\gamma_m - \gamma_{AL})50)$$

as $\gamma_m < \gamma_{AL} \Rightarrow B_{50^\circ c} < B_{0^\circ c}$

$\Rightarrow W_2 > W_1$ (C)

4. $\gamma_{ap} = \gamma_L - \gamma_V \Rightarrow$

$$C = \gamma_L - \gamma_C \quad -(1)$$
$$S = \gamma_L - \gamma_S \quad -(2)$$

$\gamma_s = 3\alpha$

Solving (1) & (2) $\Rightarrow$

$$\gamma_s = C - S + \gamma_C$$
$$\alpha_s = \frac{C - S + \gamma_C}{3} \quad (C)$$

5. $$\frac{t - t_0}{t_0} = \frac{1}{2}\alpha\Delta T$$

So change $(t - t_0) = \frac{1}{2}\alpha t_0 \Delta T$

(A)

$$T = 2\pi\sqrt{\frac{\left(\frac{k^2}{l} + l\right)}{g}}$$

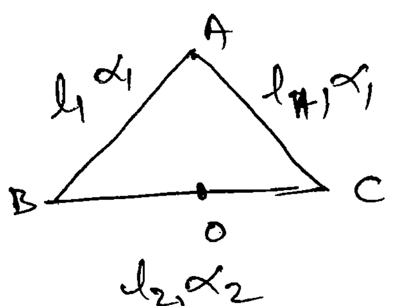
as we can see, from dimension, variation would be same as variation in simple pendulum.

6. difference would remain constant only if increase in length for both rods will be same

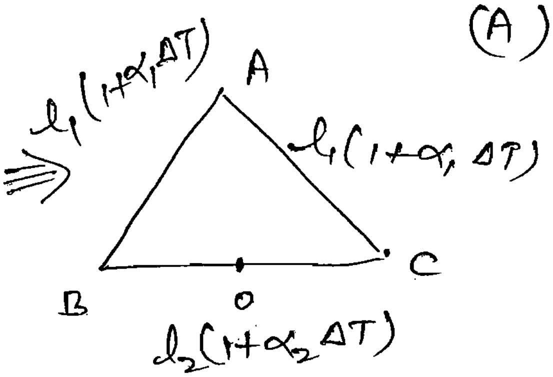
$\Rightarrow \quad l_1\alpha_1\Delta T = l_2\alpha_2\Delta T \quad \Rightarrow \quad l_1\alpha_1 = l_2\alpha_2$

(A)

7.



$\Rightarrow$



initial $d(AO)$ = final $d(AO)$

$$\sqrt{l_1^2 - \frac{l_2^2}{4}} = \sqrt{l_1^2(1+\alpha_1\Delta T)^2 - \frac{l_2^2(1+\alpha_2\Delta T)^2}{4}}$$

$$l_1^2 - \frac{l_2^2}{4} = l_1^2(1+\alpha_1\Delta T)^2 - \frac{l_2^2(1+\alpha_2\Delta T)^2}{4}$$

$$l_2^2((1+\alpha_2\Delta T)^2 - 1) = l_1^2((1+\alpha_1\Delta T)^2 - 1)$$

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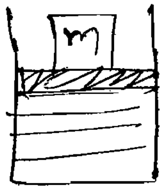
$$\frac{l_2^2}{4}\alpha_2 = l_1^2\alpha_1 \Rightarrow \frac{l_1^2}{l_2^2} = \frac{\alpha_2}{4\alpha_1} \Rightarrow \frac{l_1}{l_2} = \frac{1}{2}\sqrt{\frac{\alpha_2}{\alpha_1}}$$

(d)

8.



increase in pressure $\Delta p = \frac{mg}{A}$

$$V = \frac{4}{3}\pi R^3$$

$$dV = \frac{4}{3}\pi\, 3R^2 dR \Rightarrow 4\pi R^2 dR$$

$$\frac{dV}{V} = -\frac{4\pi R^2\, dR}{\frac{4}{3}\pi R^3} = -\frac{3\,dR}{R}$$

as Radius is decreasing

Bulk modulus $K = \frac{\Delta P}{-\frac{\Delta V}{V}} = \frac{mg/A}{3\,dR/R}$

$$\Rightarrow \frac{dR}{R} = \frac{mg}{3KA}$$

(B)

9. loss in weight = Buoyancy force

$B_{0^\circ C} = W_0$ $\qquad B_t = W$ $\qquad B = \rho_{Liquid} V_{in}\, g$

$W_0 = \rho_{L_0} V_0\, g$

$$B_t = W = \left(\frac{\rho_{L_0}}{1+\gamma_L \Delta T}\right) V_0 (1+\gamma_s \Delta T)\, g$$

$$W = W_0\left(1+(\gamma_s-\gamma_L)\Delta T\right)$$

$$W = W_0\left[1-(\gamma_L-\gamma_s)t\right]$$

10. $P = \frac{F}{A}$ where $F = mg$ (m = mass of Benzene) (B)

as mass will not change with temp. F = Constant

$P_0 = \frac{F}{A_0}$ $\qquad P = \frac{F}{A} = \frac{F}{A_0(1+2\alpha\Delta T)}$

% change $\frac{P-P_0}{P_0}\times 100 = \left(\frac{P}{P_0}-1\right) = \left(\frac{1}{1+2\alpha\Delta T}-1\right)\times 100 = -2\alpha\Delta T\times 100$

(11) Both has same coefficient of Volume expansion. So liquid will not spill out. (D)

$\Rightarrow$ mass Contain will remain same but now Volume is increased (D)

(12) $\alpha_s = 12\times10^{-6}$ Reading at $40^\circ C$ 100 mm.

$\alpha_m = 2\times10^{-6}$

Calibration at $0^\circ c$, suppose actual length = l

measured value = Calibrated value $\times [1+(\alpha_0-\alpha_s)\Delta T)$

$100 = l_0[1+(2-12)\times10^{-6}\Delta T)$

$100 = L_0(1-10\times10^{-6}\Delta T)$

So $L_0 > 100$ mm (A)

13. Variation $l_0 \pm |l_0\alpha\Delta T|$

So $l_0\alpha\,\Delta T \le 6\times10^{-5}$ mm

$(1mm)(12\times10^{-6})\,\Delta T \le 6\times10^{-5}$

$\Delta T \le \frac{1}{2}\times10 = 5^\circ C$

(C)

14. $I_0 = mk^2$ (k = Radius of gyration dimension length)

Change in (I)

$= I - I_0 = mk^2(1+\alpha\Delta T)^2 - mk^2$

$= mk^2(2\alpha\Delta T)$

$= 2\alpha I\Delta T$ (C)

(15) % in $d_2 \Rightarrow \left(\frac{d_2(1+\alpha\Delta T)-d_2}{d_2}\right)\times100 = .3$

$\therefore$ % in $d_1 \Rightarrow \dfrac{d_1(1+\alpha\Delta T) - d_1}{d_1} \times 100 = \alpha \Delta T \times 100 = .3\%$

(d)

16. Suppose body Volume = V

$B = W$

$\rho_{L_0}(.98V)g = \rho_{B_0} V g \Rightarrow .98\rho_{L_0} = \rho_{B_0}$

body will combletly immersed in water

when $\rho_L = \rho_B$

$\dfrac{\rho_{L_0}}{1+\gamma_L \Delta T} = \rho_{B_0}$ (Body not expanding)

$1-\gamma_L\Delta$

$.2$

$\dfrac{1}{1+\gamma_L \Delta T} = .98$

$\dfrac{\left(\frac{1}{.98} - 1\right)}{\gamma_L} = \Delta T \Rightarrow \Delta T = 60.6$

$T = 64.6°C$ (B)

17. $\rho_{35} = \dfrac{266.5}{\frac{4}{3}\pi(3.5)^3} = 1.484\ g\ cm^{-3}$

$\dfrac{\rho_\theta}{\rho_0} = \dfrac{V_0}{V_\theta} = \dfrac{1}{1+\gamma\theta} \Rightarrow \rho_\theta = \dfrac{\rho_0}{1+\gamma\theta}$

$\gamma = \dfrac{\rho_0 - \rho_{35}}{\rho_{35}(35)} = 8.28 \times 10^{-4}$

(A)

18. from the options $T > 0°c$ (T = final temp.)

Heat lost = Heat gain

$4.4\,kg\,(1)(30-T) = 1 \times .5(10) + 1 \times 80 + 1 \times 1 \times (T-0)$

$4.4 \times 30 - 4.4 \times T = 5 + 80 + T$

19. Suppose final temp. $= T$

$$20\times 80 + 20\times 1\times T = 50 \times \cancel{\ \ } \times .6\times(25-T) + 50\times 1\times 1\times(25-T)$$

$$1600 + 20T = \cancel{1874.75}\ \cancel{2000} = 2000 - 80T$$

~~T = 8.9°C~~

$$\boxed{T = 4^\circ C}$$

(C)

(20)

A	B	C
m	m	m
s_1	s_2	s_3

When A & B mixed $12^\circ C < T_{mix} < 19^\circ C$

So only (a) option possible.

(21) Energy consumed by container

$= 10\times 1\times(100-0) = 1000$ c

" , by ice $= 10\times 80 + 10\times 1\times 100 + 10\times 540$

$= 7200$ cal

total $Q = 8200$ Cal (D)

22. $\frac{dQ}{dt} = \frac{d}{dt}(ms\,\Delta T) = \frac{dm}{dt}\times s\times \Delta T$

$$2100 = 20\times 10^{-3}\times 4200\times \Delta T$$

$$\Delta T = \frac{1000}{40} = 25^\circ C$$

$$T = 35^\circ C \quad (C)$$

23.

from the graph at the time of Vapourization

(~~20 → 30~~) (20 → 30) min

Heat Supplied = 42 × 10 = 420 KJ

$mL = 420$ KJ

$L = \frac{420}{5} = 84$ KJ/kg. (C)

24.

Suppose mass of steam = m

Heat lost by steam = $m \times 540 + m \times 1 \times 20$

Heat gain by (water + Calorimeter)

$= 1.12 \times 1 \times 65$

$\Rightarrow$ $1.12 \times 65 = m(560)$

$m = \frac{1.12 \times 65}{560} = .13$ (A)

25.

efficiency $= \eta = \frac{\text{work done}}{Q_{in}} = \frac{W}{100\,\text{kcal}} = .28$

$\omega = 28$ Kcal.

$= 28 \times 4.2$ KJ

Work done in climbing = $mgh = 28 \times 4.2$

$60 \times 10 \times h = 28 \times 4.2 \times 10^3$ J

$h = 196$ m

(B)

26.

Suppose ~~mass~~ amount of ~~ice~~ water Converted to ice $= x$ & Vapourize $= y$

Heat Lost = Heat gain

$x \times \cancel{3.21 \times 10^5} =$

$$x \times 3.36 \times 10^5 = y \times 21 \times 10^5$$

$$x = \frac{21}{3.36} y$$

$$\% = \frac{x}{x+y} \times 100 = \frac{x}{x + \frac{3.36}{21} x} \times 100 = \frac{21}{24.36} \times 100$$

$$= 86.2\%$$

(A)

27.

Suppose latent heat of fusion = L & water equivalent of flask is ω

Case (i)

$$50 \times L + 50 \times 1 \times 40 = (200 + \omega) \times 1 \times 30$$

$$50L + 2000 = 6000 + 30\omega$$

$$50L = 4000 + 30\omega$$

$$5L = 400 + 3\omega \quad \text{--- (1)}$$

Case (ii)

$$80L + 80 \times 1 \times 10 = (250 + \omega) \times 1 \times 30$$

$$80L + 800 = 7500 + 30\omega$$

$$80L = 6700 + 30\omega$$

$$8L = 670 + 3\omega \quad \text{--- (2)}$$

(2) − (1) $\Rightarrow$ $3L = 270$

$L = 90$ cal/gm

KTG

28. ~~29~~. density should be very low ∴ $P = \frac{\rho}{M} RT$

$\Rightarrow$ low pressure, high temp. $\rho = \frac{MP}{RT}$

29. ~~30~~. only (A)

30 ~~31~~. elastic collision. A not possible

obey. NLM B " "

$P \propto V_{rms}^2$ C " "

$KE \propto T$ (D) Ans.

31. metal Cylinder (conducting) + slowly pushing (sufficient time for Heat transfer

$\Downarrow$

T = Constant

PV = Const

$V \downarrow$ $P \uparrow$ (Correct)

B also Correct as $V \downarrow$

as T is const. ~~Vrms same~~ V_{av} remains Const. C (incorrect)

(C)

$\text{frequency} = \frac{1}{t} = \frac{V}{2L}$

as Length $L \downarrow$ frequency $f \uparrow$

32.

mean speed $= \dfrac{2U + 10U + 11U}{3} = \dfrac{23}{3}U \approx 7.66\,U$

rms. $= \sqrt{\dfrac{4+100+121}{3}} = \sqrt{\dfrac{225}{3}U} = \sqrt{75U} = 5\sqrt{3}$
$= 8.66$

only (A)

33.

$PV = nRT$

$1.3\times10^{5} \times 7\times10^{-3} = n \times 8.314 \times 273$

$n = .4$

1 mole contain N_A no. of molecules.

So total molecules $= n N_A$

$= .4 \times 6.023\times10^{23}$

$= 2.4 \times 10^{23}$

(A)

34.

$2\times10^{5} \times .02 = n \times 8.314 \times 293$

$n = 1.642$ suppose x gm H_2, $5-x$ He

So $\dfrac{x}{2} + \dfrac{5-x}{4} = 1.642$

$x + 5 = 1.642 \times 4$

(A)

$x = 1.642 \times 4 - 5 = 1.568$

ratio $\dfrac{x}{5-x} = \dfrac{1.568}{3.431} = .456 \approx 1:2$

35.

Velocity $\Rightarrow$ vector quantity

36. gas is isotropic ⇒ it has same property in every direction. (B)

37. mono atomic gas

$$\text{average K.E} = \frac{f\cancel{R}^{K}T}{2} = \cancel{\frac{3}{2}\times 8.314}$$

$$= \frac{3}{2}\times 1.38\times10^{-23}\times 273$$

$$= 5.65\times10^{-21}\,J \quad (C)$$

38. ~~$PV = nRT$~~

~~$1V = nR\,300$~~ ~~$V_{rms} = \sqrt{\;}$~~

as T is const. $V_{rms} = 900\ m/s$ (C)

39. $V = \sqrt{\frac{3kT}{m}}$ here m = mass of single O_2 molecule

$$V_{new} = \sqrt{\frac{3k\,2T}{m/2}} = 2V \quad (B)$$

40. $PT = K$ $\quad PV = nRT$

$P^2V = K_1 \Leftarrow T \Rightarrow \frac{PV}{nR}$

$P = \frac{k_2}{\sqrt{V}}$ $\quad \frac{dP}{dV} = -\frac{1}{2}\frac{k_2}{V^{3/2}}$ slope −ve

$V\uparrow\ P\downarrow \Rightarrow \frac{d^2P}{dV^2} = +ve$ means minima.

so option (C)

41. $1V = \frac{2}{M_A}R(298)$ —①

$1.5V = \left(\frac{2}{M_A}+\frac{3}{M_B}\right)R(298)$ —②

$\frac{①}{②} \Rightarrow$ 1 ... 2 ... 3 ... (A)

42.

$v^2 = \frac{3KT}{2m}$ Now $\omega^2 = \frac{V_{rms}^2}{3} = \frac{3KT}{3m}$

$\omega^2 = \frac{KT}{m}$

$v^2 = \frac{3}{2}\omega^2 \Rightarrow \frac{\omega^2}{v^2} = \frac{2}{3}$ (D)

43.

$V_{rms} = \sqrt{\frac{3K(T+273)}{m}}$ $T\,^{\circ}C$

Now $2T^{\circ}$ $(T+273)\,2$ K

$\Rightarrow (2T+273)$

as temp. in Kelvin $[2(T+273)]$

> temp. in °C

So V_{rms} in Kelvin is high.

(A)

44.

$PV = nRT$ P, n, R Const.

$V = kT$

$\frac{dV}{dt} = k$ now $k = \frac{nR}{P}$ pressure is doublee & mass also. So slope will ~~become~~ remain same.

(B)

(A) (C) option line

45.

$PV = 1RT$

$P_1 V = 1R\,2T$

$P_1 = 2P$ (C)

46. $V_{rms} = \sqrt{\frac{3kT}{m}}$ now $m_{O_2} > m_{H_2}$

47.

$\cancel{as}$ $PV^{2/3} = K$

$\frac{PV}{V^{1/3}} = K \Rightarrow nRT = V^{1/3}$

$V \uparrow$ so $T \uparrow$ (A)

48.

$6V = \frac{35kg}{28gm} RT$

$9V = \left(\frac{35kg}{28gm} + \frac{m}{32gm}\right) RT$

$\frac{3}{2} = \frac{9}{6} = \frac{\frac{35kg}{28gm} + \frac{m}{32gm}}{\frac{35kg}{28gm}}$

$\Rightarrow \frac{35kg}{28gm} = \frac{2m}{32gm} \Rightarrow m = \frac{\cancel{32}^{4} \times \cancel{35}^{5}}{\cancel{28}_{4} \times \cancel{2}} = 20kg$

(C)

49.

$PV = nRT$

$P = \left(\frac{nR}{V}\right) T$

(D)

So $P_{V/s}T$ curve would be straight line. with different slopes. as Volume is different.

50.

at STP 1 mole contain 22.4 ltr

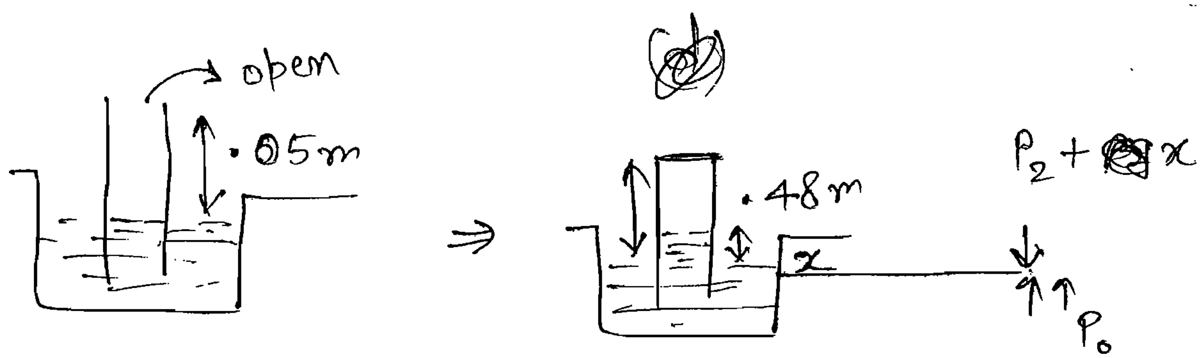
therefore $M =$ density $\times$ Volume

$= 1.3 \times 22.4$

now $\cancel{P\,\text{each}}$ $PV = \frac{m}{M} RT$

(d) $\Rightarrow$ $\Delta m = 30.2$ gms.

51.



Suppose cross-sectional area = A

$PV = nRT$ (as T is Const.)

$P_1V_1 = P_2V_2$

$(76) A (.05) = nRT = P_2 A (.48 - x)$

$$P_2 = \frac{76 \times .05}{(.48 - x)} \text{ mm.}$$

$$P_2 + x = 76$$

$$\frac{.76 \times .05}{(.48 - x)} + x = .76$$

$$.76 \times .05 = (.76 - x)(.48 - x)$$

.96 $\quad$ ~~$.03.8 = 36.48 - 76.48x + x^2$~~

$x^2 - 76.48x + 32.68 = 0$

$$.038 = .3648 - 1.24x + x^2$$

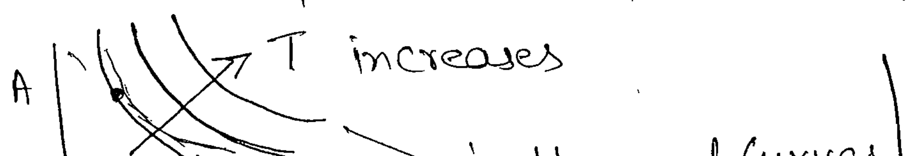
$$x^2 - 1.24x + .3268 = 0$$

$x = .86$ (not possible), $x = .38$ m

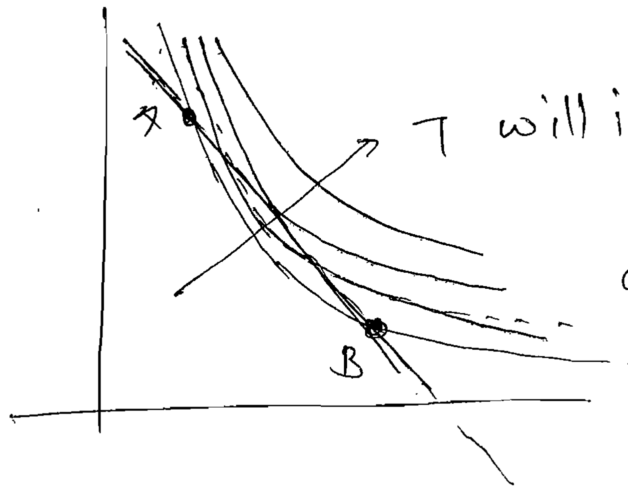
length of air $= .48 - .38 = .1$ m

(c)

52. A & B point lie on isothermal Curve



So temp. will increase then



53.

change in height of mercury = 25 cm

now $75\text{ cm} \longrightarrow 1\text{ atm} = 10^5\text{ pa}$

$25\text{ cm} \longrightarrow \frac{10^5}{3}\text{ pa} = 33.3\text{ KPa}$

54.

$PV = nR\,(60+273)$ (A)

$PV = \frac{3}{4}n\,(T)$ Remaing moles $\frac{3}{4}n$

$\frac{3}{4}T = 60 + 273 = 333$

$T = 444\text{ K} \Rightarrow 171^{\circ}C$ (B)

55.

$\frac{1}{n} = \frac{RT}{PV} = \frac{8.314 \times 330}{10 \times 10^5\, V} = 1 \quad n = \frac{28}{28} = 1$

now Suppose remain moles n_1

$\frac{1}{n_1} = \frac{8.314 \times 300}{5 \times 10^5 \times V} = \frac{8.314 \times 300}{\cancel{5 \times 10^5} \times \cancel{8.314} \times 330} \times \frac{10 \times \cancel{10^5}}{}\, 2$

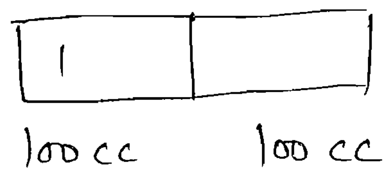
$\frac{1}{n_1} = \frac{600}{330} = \frac{20}{11} \quad n_1 = \frac{11}{20}$

moles leaked out $=$

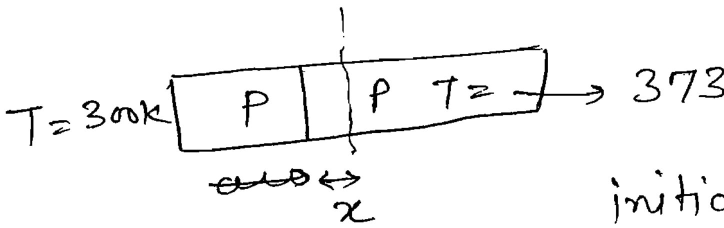
$1 - \frac{11}{20} = \frac{9}{20}$ moles

$T = 27^\circ C = 300 K$

56.



$A = 10.85 \ cm^2$



for 1^{st} Compartme

initially $P \times 100cc = nR\,300$

finally $P_1 (100 - Ax) = nR\,300$ — ①

for 2nd

$P_1 (100 + Ax) = nR\,373$ — ②

100

$\frac{①}{②} \Rightarrow \frac{100 - Ax}{100 + Ax} = \frac{300}{373}$

$\frac{200}{2Ax} = \frac{673}{73}$

$Ax = \frac{7300}{673}$

$\Rightarrow x = \frac{7300}{673 \times 10.85} = 1 \ cm$

(A)

57.

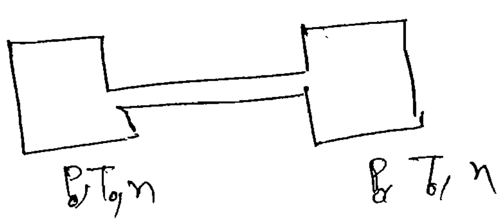
$P = \frac{\rho R T}{M}$ as P is Constant

$\rho_1 T_1 = \rho_2 T_2$

$\frac{\cancel{12}\,2}{\cancel{4} \times 10^{-3}} \times \cancel{280}\,70 = \cancel{6} \times 10^{-4}\, T_2$

$T_2 = 1400 K$ (B)

58.



Initially $P_0 V_0 = n R T_0$

finally $P V_0 = (n+x) R T_0$ — ① & $P V_0 = (n-x) R \cdot 2T_0$ — ②

Compare ① & ②

$$(n+x) T_0 = (n-x) 2 T_0$$
$$n + x = 2n - 2x$$
$$3x = n$$
$$x = \frac{n}{3}$$

So $P V_0 = \frac{4n}{3} R T_0$

also, $P_0 V_0 = n R T_0$

$$\frac{P}{P_0} = \frac{4}{3} \Rightarrow P = \frac{4}{3} P_0 \quad (B)$$

(59) in $2T_0$ container

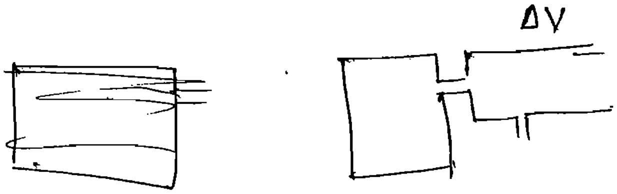
$$\text{moles} = n - \frac{n}{3} = \frac{2n}{3} = \frac{2}{3} \frac{P_0 V_0}{R T_0}$$

(C)

(60)
$$P = \frac{\rho R T}{M}$$
$$\frac{dP}{d\rho} = \frac{RT}{M} \quad \text{so} \quad T_1 > T_2 \quad (\text{chk slope})$$

(A)

(61)



before T remain Constant

$$P_1 V_1 = P_2 V_2$$
$$P V = P_1 (V + \Delta V) \Rightarrow P_1 = P\left(\frac{V}{V + \Delta V}\right)$$

62.

$P_1V = n_1RT_1$

$P_2V = n_2RT_2$

finally $P(2V) = (n_1+n_2)RT$

$$2P\cancel{V} = \left(\frac{P_1\cancel{V}}{\cancel{R}T_1} + \frac{P_2\cancel{V}}{\cancel{R}T_2}\right)\cancel{R}T$$

$$\frac{P}{T} = \cancel{\frac{P_1T_2 + P_2T_1}{T_1}}\ \frac{1}{2}\left(\frac{P_1}{T_1} + \frac{P_2}{T_2}\right)$$

(B)

63.

$$V_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$$

as V_{rms} is same

$$\frac{T_1}{M_1} = \frac{T_2}{M_2}$$

(A)

64.

$U_1 = n_1C_vT_1$

$U_2 = n_2C_vT_2$

mixture $U = (n_1+n_2)C_vT$

energy Conservation

$$(n_1+n_2)C_vT = (n_1T_1 + n_2T_2)C_v$$

$$T = \frac{n_1T_1 + n_2T_2}{n_1+n_2}$$

(D)

Thermodynamics

65. as average velocity $= 0$ (for any gas in steady state)

(B)

66. adiabatic process

$C = 0$ (D)

67. cyclic process $\Delta Q = \Delta W$

as $\Delta W = \frac{1}{2} \times V_0 \times P_0$

$\therefore \Delta Q \neq 0$ (C)

68. isobaric expansion $\Rightarrow P =$ Constant

$PV = nRT$

$P \frac{dV}{dT} = nR \Rightarrow \frac{dV}{dT} = \frac{nR}{P}$

$\frac{d^2V}{dT^2} = 0$

(D)

69. adiabatic process now $P.V^{3/2} =$ Const.

$\Rightarrow \gamma = \frac{3}{2}$

$\frac{T\,V^{3/2}}{V} = K_1$ $\quad \left| P = \frac{nRT}{V} \right.$

$T_1 V_1^{1/2} = T_2 V_2^{1/2}$ $\quad T V^{1/2} = K_1$

$V_2 = V_1/2 \Rightarrow T_1 V_1^{1/2} = T_2 \left(\frac{V_1}{2}\right)^{1/2}$

$\frac{T_1}{T_2} = \frac{1}{\sqrt{2}} \Rightarrow T_2 = \sqrt{2}\,T$

(C)

70. $Q = -30\,J$

$W = -18\,J$

So $Q = W + \Delta U$

$30 = -18 + \Delta U$

71. $Q = \omega + \Delta U$

$1 \times 2250 = 10^5 \times (1841 - 1) \times 10^{-6} + \Delta U$

$2250 = 184 + \Delta U \Rightarrow \Delta U = 2066\ J$

(C)

72. $A \to B$ P Const. $V \uparrow$ $T \uparrow$

B → rejected

$B \to C$ V Const. $T \downarrow$ $P \downarrow$

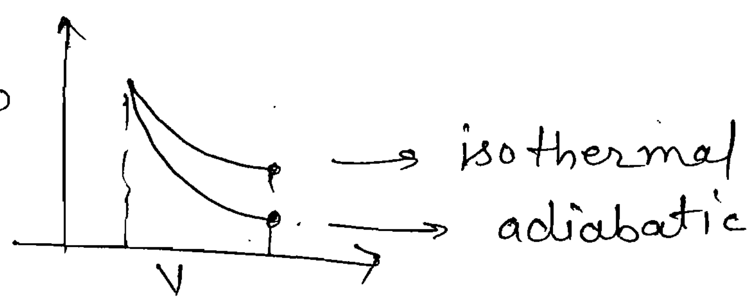
C, D → rejected

so only A possible.

$C \to A$ T Const. $V \downarrow$ $P \uparrow$ isothermal Curve.

So option (A)

73.



for same Compression

|Area Under isothermal| > |Area Under adiabatic|

$|\omega_1| > |\omega_2|$

but as it is −ve (compression)

$\Rightarrow \omega_2 > \omega_1$ (C)

74. $P = KV^n$ $\Rightarrow PV^{-n} = K$ $n = +ve$

75. as $P \propto T$ line passes through origin.

$P = KT$

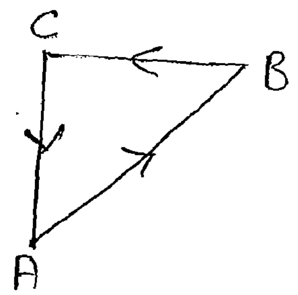
$\Rightarrow V =$ Constant. Work done $= 0$

(A)

76. $C \rightarrow A$ $T =$ Const.

isothermal curve.

$P \downarrow \Rightarrow V \uparrow$



~~C→B~~ $B \rightarrow C$ (So B or C possible)

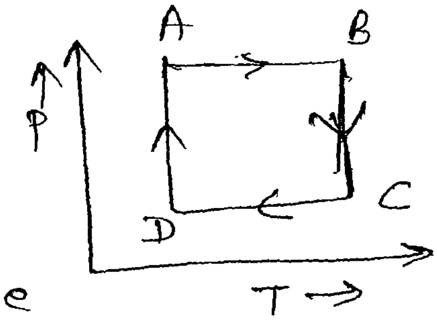
$P =$ Const. $T \downarrow \Rightarrow V \downarrow$

Only B possible.

77. $A \rightarrow B$

$P =$ constant

$T \uparrow \Rightarrow V \uparrow$



So only C & d possible

$B \rightarrow C$ $T =$ Const.

only (C) possible.

78. at Constant pressure

$Q = n C_p \Delta T = 70$ ~~= W + n C_v ΔT~~

$C_p = \frac{70}{2 \times 5} = 7 \Rightarrow C_p = 5$ ~~ΔT = 70/(2 C_p)~~ $\Rightarrow$ ~~nRΔT = 70~~

79. W = Area Under Curve

$= 2P \times 2V = 4PV$

80.

$\cancel{Q = nC\Delta T}$

$C \rightarrow D \Rightarrow$ Volume const.

$P\downarrow \quad T\downarrow$ only B & D possible

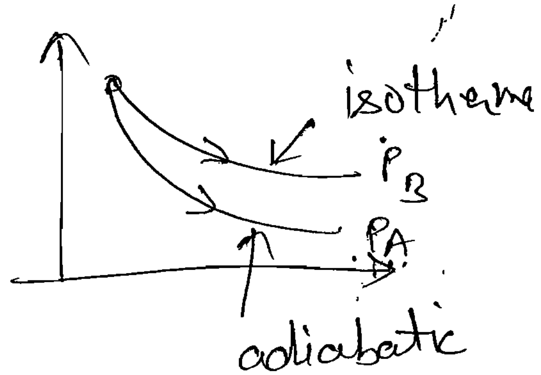
$A \rightarrow B \quad P =$ const.

$V\uparrow \Rightarrow T\uparrow$ So only (B)

81. from figure

$P_A < P_B$

(C)



82. Slope is $\frac{dP}{dV} = -\frac{\gamma P}{V} = -\frac{1.4 \times .7 \times 10^5}{.0049}$

(C) $= -2 \times 10^7\ Nm^{-5}$

83. Const. Volume

$6300 = n C_v\, 150$

Const. pressure

$8800 = n C_p\, 150$

now $Q \cancel{=} \Delta U = n C_v \Delta T = \frac{6300}{\cancel{150}} \times \overset{2}{\cancel{300}}$

$= 12600\ J$

(B)

84. $f = 6$

$Q = W + \Delta U$

$nC_p \Delta T = W + nC_v \Delta T$

$Q = nC_p \Delta T$

$= \frac{25}{R} \times 4R = 100 J$

$nR\Delta T = 25 J$

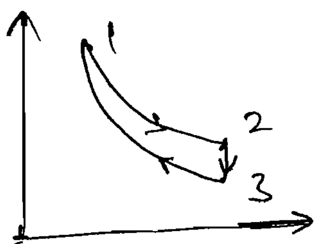
(A)

$C_v = \frac{fR}{2}$

$C_p = \frac{(f+2)}{2}R$

85.

$W = 10 J$



$1 \to 2$ $\Delta U_1 = 0$

$2 \to 3$ $\Delta U_2 = -20 J$

$3 \to 1$ $\Delta U_3 = 20 J$ (total $\Delta U = 0$)

$3 \to 1$ $W_{3\to 1} = -20 J$

$2 \to 3$ $W_{2\to 3} = 0$ (const V)

now $W = W_{1-2} + W_{2-3} + W_{3-1}$

$10 = W_{1\to 2} + 0 - 20$

$W_{1\to 2} = 30 J$

$Q_{1\to 2} = \Delta U_{1\to 2} + W_{1\to 2}$

$= 30 J$

(D)

86.

$W = 20 KJ$ $Q = 16 KJ$

$Q = W + \Delta U \Rightarrow \Delta U = -4 KJ$

as Initial & final states are same,

ΔU = remain constant.

$Q = +9$ $W = ?$ $\Delta U = -4$

87. $Q = nC_p\Delta T$ $\qquad C_p = \dfrac{5R}{2}$

$W = nR\Delta T$

$= nR\dfrac{Q}{nC_p} = \dfrac{2QR}{5R}$

$W = \dfrac{2Q}{5}$ (C)

88. $P/V = \text{Const.} \Rightarrow PV^{-1} = K$

$x = -1$

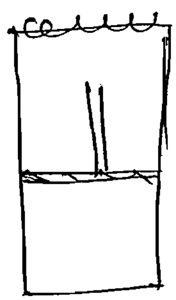
$C = C_V + \dfrac{R}{1-x} = C_V + \dfrac{R}{2} = \dfrac{3R}{2} + \dfrac{R}{2}$

$C = 2R$

Heat $Q = nC\Delta T$

$= 1 \times 2R \times T_0$ (A)

89.



$V_i = V$ $\qquad$ increase by η

$V_f = \eta V$ $\qquad$ $T = \text{const}$, Isothermal process

$W = nRT \ln\dfrac{V_2}{V_1}$

$= \cancel{RT_0 \ln(\eta+1)}\ RT\ln(\eta)$ (A) Correct

Work done $= P_0(\eta V - V) = RT_0(\eta - 1)$ (B)

$\Delta U = 0$ (T constant) (C) Correct

$P_1V_1 = P_2V_2$

$P_1V = P_2\eta V \Rightarrow P_2 = \dfrac{P_1}{\eta}$ (D)

90. $Q = \cancel{\Delta U}^{\,0} + \Delta W$ $\qquad Q_{out} = 3W$

(in a cycle)

$Q_{in} - Q_{out} = W$

$Q_{in} = 4W$ $\qquad \eta = \dfrac{W}{4W} = \dfrac{1}{4}$ (A)

91.

$$\frac{dP}{dV} = -\frac{\gamma P}{V} \quad \text{(for adiabatic)}$$

$$\beta = -\frac{\Delta P}{\Delta V/V} = +\frac{\gamma P}{V} \times V = \gamma P$$

$$= \frac{7}{5} \times 10^5$$

$$= 1.4 \times 10^5 \quad (D)$$

92.

$$PV^m = \text{Const.}$$

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

$$\cancel{R} = \frac{5\cancel{R}}{2} + \frac{\cancel{R}}{1-x}$$

$$\frac{1}{x-1} = \frac{3}{2}$$

$$2 = 3(x-1)$$

$$2 = 3x - 3$$

$$3x = 5$$

$$m = x = 5/3 \quad (D)$$

93.

$$PT^2/V = \text{Const.}$$

$$P \frac{P^2V^2}{(nR)^2 V} = \text{Const.}$$

$$PV = nRT$$

$$T = \frac{PV}{nR}$$

$$P^3 V = K$$

$$P V^{1/3} = K$$

$$C = \frac{5R}{2} + \frac{R}{1-1/3} = \frac{5R}{2} + \frac{3R}{2} = 4R$$

94.

$$PV^2 = K \Rightarrow$$

$$x = 2$$

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

$$= \frac{5R}{2} - R = \frac{3R}{2}$$

$$PV.V = K$$

$$nRTV = K$$

$$VT = K_1$$

So Curve is Hyperbola.

as $C = +ve$ (D)

as gas is expanding, $V\uparrow \Rightarrow T\downarrow$

95. process anti-clock wise $\Rightarrow$ -ve.

$$|W| = \frac{1}{2} \times 10 \times 1 = 5\,J$$

$$W = -5\,J \quad (A)$$

96. $PV^2 = \text{Cons.} \quad \Rightarrow x = 2$

$$C = C_V + \frac{R}{1-x}$$

$$= C_V + \frac{R}{1-2} = C_V - R \quad (B)$$

97. In a Cyclic process $(\Delta U = 0)$,

$$\Delta Q = \Delta W$$

W = Area Under P-V Curve

$$= \pi \frac{(30-10)}{2} kPa \times \frac{(30-10)}{2} \times 10^{-3}$$

$$= 10^2 \pi \ J \quad (C)$$

98.

Conductor who has least Resistance, will Conduct more heat. $R_{th} = \frac{L}{KA}$

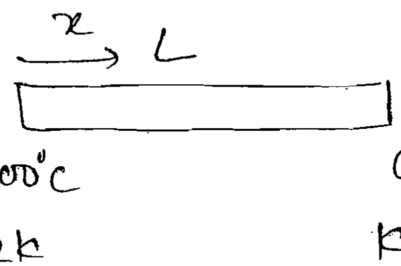
$$R_1 = \frac{.5}{K\pi 4}, \quad R_2 = \frac{2}{K\pi 4}, \quad R_3 = \frac{.5}{\pi(.25)}$$

$$R_4 = \frac{1}{K\pi 1} \quad \text{So } R_{min} = R_1$$

(A)

99. Rate of Heat flow is same for both slap.

100.



so $K_1 = -\frac{K}{L}x + 2K$

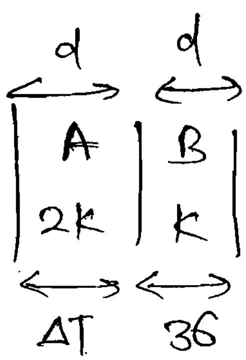
$$i = \frac{dQ}{dt} = -KA\frac{dT}{dx} \Rightarrow \frac{dT}{dx} = \frac{-i}{K\left(2-\frac{x}{L}\right)A}$$

as $x \uparrow$ $T \downarrow$ so $\frac{dT}{dx} = -ve$

now $\frac{d^2T}{dx^2} = -ve \Rightarrow$ maxima

So option (B)

101

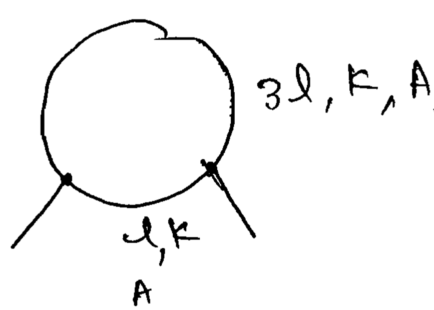


$$i = \text{Constant} = \frac{\Delta T}{\frac{d}{2KA}} = \frac{36}{\frac{d}{KA}}$$

$\Delta T = 18°C$

(C)

102.



both are in $||^{rL}$

$$R_1 = \frac{l}{KA} = R$$

$$R_{eH} = \frac{R \times 3R}{4R} = \frac{3R}{4} \qquad R_2 = \frac{3l}{KA} = 3R$$

$$H = \frac{(T_1 - T_2)}{3R/4}$$

Now ~~$R_1 = 3R$~~ ~~$R_2 = \frac{l}{K_1 A}$~~ $\quad R_1 = \frac{l}{K_1 A} \quad R_2 = 3R$

$R_1 = RK/K_1$

$(T_1 - T_2) \qquad 3RH/4 \qquad 3R$

$\cancel{\frac{3R}{8}}=$ again $\parallel^{rl}$ connection

$$\frac{8}{3R} = \frac{K_1}{RK} + \frac{1}{3R}$$

$$\frac{7}{3R} = \frac{14}{\cancel{R}K}$$

103.

$$K_1 = \frac{7}{3}K$$

(A)

$\Sigma Q_{in} = 0$ at joint

$$\frac{10-T}{R} + \frac{20-T}{2R} + \frac{30-T}{3R} = 0$$

$R_1 = \frac{10}{KA} = R$

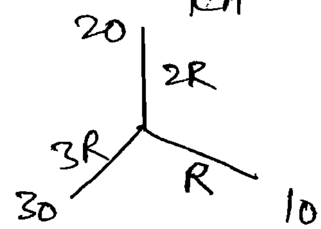
$R_2 = \frac{20}{KA} = 2R$

$R_3 = \frac{30}{KA} = 3R$

$$\frac{60-6T+60-3T+60-2T}{6R} = 0$$

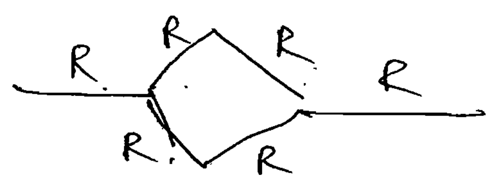
$$11T = 180$$

$$T = \frac{180}{11} = 16.4^\circ C$$



(C)

104.



$R_{eH} = 3R$

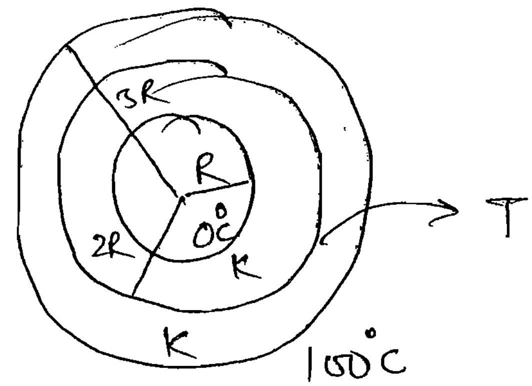
$$i = \frac{180}{3R} = \frac{60}{R}$$

$$i_{AB} = i = \frac{200-T}{R} = \frac{60}{R}$$

$$T = 140^\circ C$$

(C)

105.



$$R_{th1} = \frac{R_2 - R_1}{K\,4\pi R_1 R_2} = \frac{R}{K\,4\pi\,2R^2} = C$$

$i =$ Constant

$$R_{th2} = \frac{R}{K\,4\pi\,6R^2} = \frac{C}{3}$$

$$\frac{100 - T}{C/3} = \frac{T - 0}{C}$$

$$300 - 3T = T \Rightarrow T = \frac{300}{4} = 75^\circ C$$

(C)

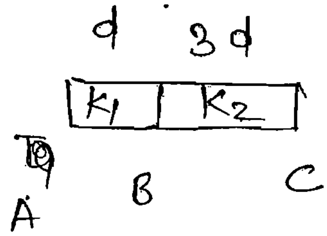
106. as $i =$ Const.

we can say $T_p = 50^\circ C$

$T_Q = 45^\circ C$

So Heat flow from $P \to Q$ (A)

107.



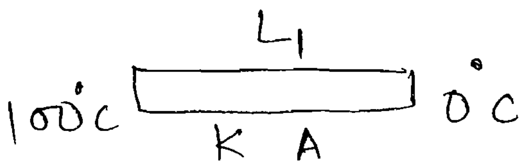
A, B, C are in A.P

so $A - B = B - C$

$$i = \text{Constant} = \frac{K_1 (A - B)}{d} = \frac{K_2 (B - C)}{3d}$$

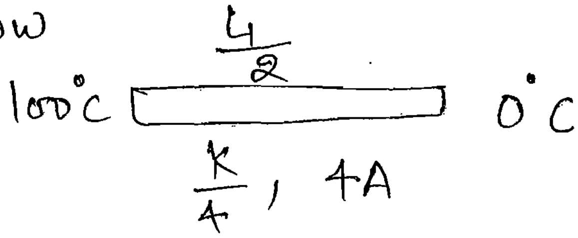
(A) $\frac{K_1}{K_2} = \frac{1}{3}$

108.



$$\frac{dQ}{dt} = .1\,\frac{gm}{sec} = \frac{KA(100)}{L_1}$$

Now

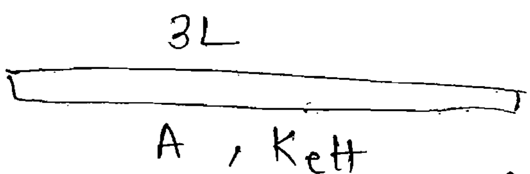


$$\frac{dQ}{dt} = \frac{\cancel{K}\,\cancel{4}A\,(100)}{\cancel{4}\;L_1/2}$$

(C) $= 2 \times .1 = .2\ gm/sec$

109.

$$R_{eff} = \frac{L}{\frac{K}{2}A} + \frac{L}{5KA} + \frac{L}{KA} = \frac{(10+1+5)}{5}\,\frac{L}{KA}$$



$$R_{eff} = \frac{16L}{5KA}$$

$$R_{eff} = \frac{3\cancel{L}}{K_{eff}\cancel{A}} = \frac{16\cancel{L}}{5K\cancel{A}}$$

$$K_{eff} = \frac{15}{16}K \quad (A)$$

110. Suppose junction temp. = T

So $\sum i_i = \sum \frac{dQ}{dt} = 0$

$$\frac{3KA(100-T)}{L} + \frac{2KA(50-T)}{L} + \frac{KA(0-T)}{L} = 0$$

$$300 - 3T + 100 - 2T - T = 0$$

$$6T = 400$$

$$T = 200'c \quad (C)$$

111. as there is no current through K_5

$\Rightarrow$ wheatstone bridge $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

$$\frac{K_1}{K_3} = \frac{K_2}{K_4} \quad \text{option (A)}$$

112. $$\frac{dQ}{dt} = P = \frac{KA\,(\Delta T)}{d}$$

$$d = \frac{4K\pi R^2\,T}{P}$$

(B)

113. as from average Newton's Law of Cooling

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

$$\frac{4}{2} = K\,(363 - 293)$$

$$\Rightarrow 2 = K\ 70 \Rightarrow K = \frac{1}{35}$$

Now $$\frac{2}{t} = K\left(\frac{344+342}{2} - 293\right)$$

$$\frac{2}{t} = \frac{1}{35}\,(50) \Rightarrow t = \frac{70}{50} = \frac{7}{5}\ \text{min}$$

$$t = \frac{7}{\cancel{5}} \times \overset{12}{\cancel{60}} = 84\,s$$

$$\simeq 88\,s$$

(A)

114. from stefan's law

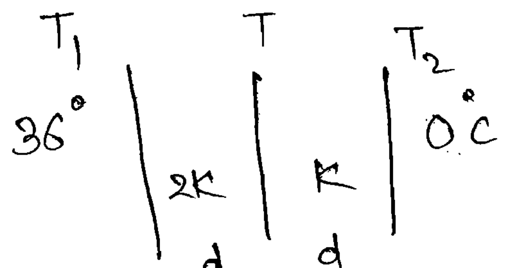
$$P = e\sigma A T^4 \quad \cancel{\propto 450}$$

$$450 = e\sigma \pi (12)^2 (500)^4$$

$$P_1 = e\sigma \pi \left(\frac{12}{2}\right)^2 (2\times 500)^4$$

$$P = \frac{1}{\cancel{4}} \times \frac{\cancel{16}}{4} \times 450 = 1800W$$

115.



(D)

$$T_1 - T_2 = 36^\circ C \qquad T = ?$$

$$R_1 = \frac{d}{2KA} = \frac{R}{2}$$

$$R_2 = \frac{d}{KA} = R$$

$$R_{eff} = \frac{3R}{2}$$

$$i = \frac{36}{3R/2} = \frac{24}{R}$$

also

$$\frac{T_1 - T}{R/2} = \frac{T - T_2}{R} = \frac{24}{R}$$

$$\cancel{2(T_1 - T) = T - T_2} \quad (T_1 - T) = 12$$

$$36 - T = 12$$

$$T = 24^\circ c \quad (d)$$

116. from wien's law

$$\lambda T = b$$

$$\lambda_1 T_1 = \lambda_2 T_2$$

$$P_1 = K T_1^4 = P \qquad \lambda_0 T_1 = \frac{3\lambda_0}{4} T_2$$

$$P_2 = K T_2^4 \qquad T_2 = \frac{4T_1}{3}$$

$$P_2 = \left(\frac{4}{3}\right)^4 P$$

117. $T_1 = 273 \quad T_2 = 2T_1$

So $P_2 = (2)^4 P_1 = 16P$

118. (d) (c)

119. $P = e\sigma A T^4$ or $P = KT^4$

initially $P_1 = K T_1^4$

finally $P_2 = K T_2^4$

Intensity $\Rightarrow \frac{\text{Power}}{\text{Area}} = \cancel{\frac{P_1}{4\pi d_1^2}} \; \frac{P}{4\pi d^2}$

as Radiation power ~~rear~~ is same. (Assume Surface Area a_1)

So $\left(\frac{\cancel{K} T_1^4}{\cancel{4\pi} d_1^2}\right)\cancel{a_1} = \left(\frac{\cancel{K} T_2^4}{\cancel{4\pi} d_2^2}\right)\cancel{a_1}$

$$\frac{d_2^2}{d_1^2} = \frac{T_2^4}{T_1^4} \Rightarrow \frac{d_2}{d_1} = \left(\frac{T_2}{T_1}\right)^2$$

(B)

Exercise - II

Multiple choice Question Answer Ke

1. (b)

$$T_{new} = 2\pi\sqrt{\frac{l_0(1+\alpha\Delta T)}{g}}$$

So it is not proportional.

2. (a) (c) (d)

a ⇒ true reading = Scale reading $(1-\alpha_s \Delta T)$

⇒ Scale reading < true reading.

(c) ⇒ $B = \rho_L V_{in} g = mg$ (equilibrium)

as temp. increases density of liquid (ρ_L) decreases, therefore V_{inside} increases. as mg is Const.

(d) ⇒ weight of a body = $mg - \rho_L V g$

as ~~Same explanation~~ as $T\uparrow$ $\rho_L \downarrow$

So term $\rho_L V g$ decreases. weight of a body inside the liquid increases.

3. (C) & (d)

this can be possible during phase change (Solid → liquid ⇒ Heat absorbed; (liquid - Solid ⇒ Heat released)

4. (b), (c), (d)

~~b~~ $W = mS$ or $m = \frac{W}{S} = \frac{4.5}{.09}$

$= 50$ gm.

b ⇒ $Q = 4.5 \times 8 = 36$ cal.

C ⇒ Water equivalent & thermal capacity both has same value.

D ⇒ during melting, temperature remains Constant ⇒ Calorimeter will not absorbs any heat

$Q = ml$
$= 15 \times 80 = 1200$ cal.

5. (b), (c)

$$\frac{t - t_0}{t_0} = \frac{1}{2} \alpha \Delta T$$
$$= \frac{1}{2} \times 19 \times 10^{-6} \times 10$$

time lost in 1 day $= 24 \times 3600 \times 5 \times 19 \times 10^{-6}$

$= 8.2$ sec.

on hot day time period increases, clock move slow ⇒ time loss.

Cold day ⇒ time gain.

6. (b), (C)

b ⇒ as Volume decrease $W = -ve$

therefore w will be $+ve$ when work is done on the system.

7. (c), (d)

Heat Capacity $C = ms$

8. (b), (c)

if process is phase change temp. will remain constant.

if material is in same phase. temp. will change.

9. (a), (b).

during phase change heat can extracted or supplied to the body, withou changing its temperature.

10. (b), (c), (d)

during Heating process, diameter of disc will increase, therefore moment of Inertia will increase. by conservation of angular momentum $L = I\omega$

$I \uparrow \Rightarrow \omega \downarrow$

11. (c), (d) $Q = \Delta W + \Delta U$

so even if $Q = 0$ $-$ve work done can increases temperature.

12. (a), (c) 1 molecule has $\frac{3}{2}kT$ energy; all gases has N_a molecules in mole. thereto a is correct. (b cant be, because in 1gm different gas have different no. of molecules.)

13. (b) average momentum = $\frac{m_1\vec{V_1} + m_2\vec{V_2} - - -}{m_1+m_2 - -}$

$(\vec{V_1}, \vec{V_2}, \ldots$ all are w.r.t. Container) $= \vec{V}_{cm}/_{\text{Container}} = 0$ (equilibrium)

14. , (c), (d)

total energy should be conserved. So In a particle Collision one may get K.E, other one has to loose K.E.

15. (a) (b) (c) (d)

$$C = \frac{\Delta Q}{n \Delta T}$$

So C can attain any value.

16. (a), (d)

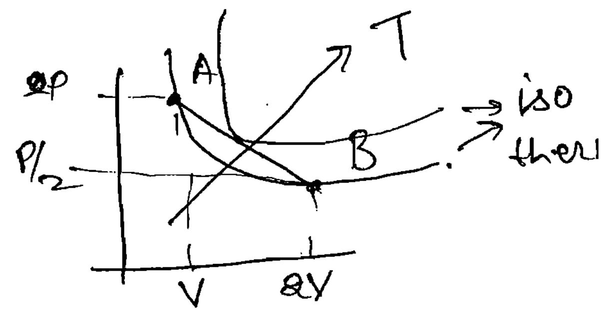
a ⇒ $V_{rms} = \sqrt{\frac{3kT}{m}}$

So depends upon mass.

d ⇒ isothermal process $PV = \text{Constant}$.

17. (a), (b), (d)

$P_A V_A = P_B V_B$



So A & B should lie on isotherms.

therefore ω = area under Curve

(a) $W_{A \to B}$ (along straight line) $> W_{A \to B}$ (Along isothermal curve)

(18)

$$p - P = \frac{P - P/2}{V - 2V}(v - V)$$

$$p = P - \frac{P}{2V}(v - V) = \frac{3P}{2} - \frac{Pv}{2V}$$

now from $PV = nRT$

V → T equation would be :-

$$\left(\frac{3P}{2} - \frac{Pv}{2V}\right) v = nRT$$

equation of parabola. (b)

P → T equation

$$\left(p + \frac{3P}{2}\right) \frac{2V}{P}\, p = nRT$$

from the graph we can say T will increase as we move one isotherm to next isotherm
(d)

19. ~~Read~~ explained in ~~above~~ the 17 question.
(A)

20.

(A)(D) $V_{rms} = \sqrt{\frac{4+9+16}{3}\,v^2} = \sqrt{\frac{29}{3}}\,v$

$V_{avg.} = 3v$

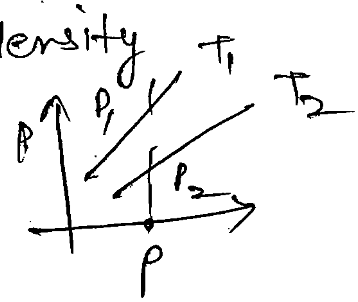
21. (a) ~~K.E = ½MV²rms~~

Internal energy $= \frac{fnRT}{2}$

as argon is monoatomic, therefore

$f_{Argon} < f_{H_2} \;\&\; f_{N_2}$

22. (a,c) $P = \frac{\rho RT}{M}$ for a Const. density



line $P_1 > P_2$

$\Rightarrow T_1 > T_2$

also $U = \frac{fnRT}{2}$

$U_1 > U_2$

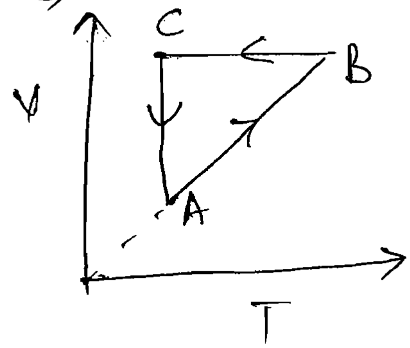
23. (A, C) Cyclic process $\Delta Q = \Delta W$ $\Delta U = 0$

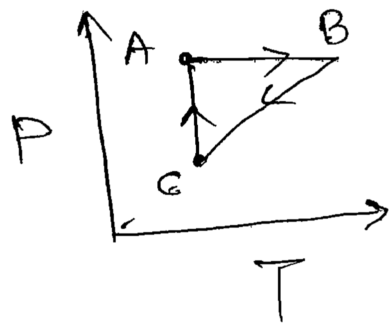
$\Delta W =$ Area Under the Curve

24. (9) $\Delta Q = \frac{4}{\cancel{8}} J$

$\Delta W = +\frac{1}{2} \times 8 \times 1 = +4 J$ (clock wise)

25. (A) (C)





$A \to B$ p const.

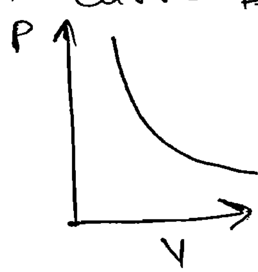
$B \to C$ – V ~~const~~ const.

$C \to A$ – T constant (isothermal)

also $T_A = T_C < T_B$

$V_C > V_A \Rightarrow P_C < P_A$

isotherm curve is



so (d) not possible.

26. (A), (C) Cyclic process $\Delta U = 0$

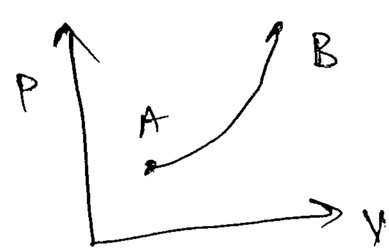
$\Rightarrow \Delta U_1 + \Delta U_2 = 0$

also $\Delta Q = \Delta W + \cancel{\Delta U}^{0}$

$\Delta Q - \Delta W = 0$

27. (A), (B), (C)

polytropic process with



28. a, b,

$P_i = P_f$ & $V_i = V_f$

$P_i V_i = P_f V_f$, therefore Intial & final states lie on isotherm. $\Rightarrow T = \text{Const.}$

(c & d) not possible because

$$\Delta Q = \Delta W + \cancel{\Delta U}^{\,0}$$

work done may be +ve, −ve or zero.

29. (C) (d)

adiabatic $\Rightarrow$

$PV^{\gamma} = \text{Constant.}$

γ is same for He & Neon but differ for O_2.

therefore, final pressure & temp. would be same for He & Neon but not with O_2.

30. 100°C — 0°C only (d)

different part has different temp. therefore, they are not in thermal eq.

(a, b, c) not possible.

31. (A, D) they are in series, therefore

$$\therefore \quad i = \frac{\Delta T}{R_{eff}} = \frac{T_i - \theta}{R_1}$$

$$\theta = T_i - \frac{R_1}{R_{eff}} \Delta T$$

$$\theta = T_i - \frac{\frac{L_1}{K_1 A}}{\frac{L_1}{K_1 A} + \frac{L_2}{K_2 A}} \Delta T$$

$$\theta = T_i - \frac{\Delta T}{\left(1 + \frac{K_1}{K_2} \times \frac{L_2}{L_1}\right)}$$

$$\cancel{\theta = T_i - \frac{K_2 \Delta T}{K_1 + K_2} = T_i - \frac{\Delta T}{\frac{K_1}{K_2} + 1}}$$

Now

(a) $K_2 \uparrow \Rightarrow \frac{K_1}{K_2} \downarrow \Rightarrow \frac{\Delta T}{\frac{L_2}{L_1}\frac{K_1}{K_2} + 1} \uparrow$

$\theta \downarrow$

Now for (d) part

$L_1 \uparrow$ again $\frac{L_2}{L_1} \downarrow \quad \frac{\Delta T}{1 + \frac{K_1}{K_2}\frac{L_2}{L_1}} \uparrow$

$\theta \downarrow$

32. c, d

(a) = good reflectors $\Rightarrow$ bad absorber

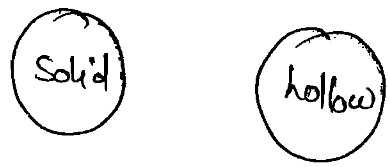
So bad absorber are bad emitter.

(b) $\Rightarrow$ Steam has extra energy (Latent heat) as comparison to 100°c water.

(c) Since air is a bad Conductor of Heat, the atmosphere acts as a blanket for the ... keeps the earth warm during

33. B, D Evergy object emits and absorbs the radiation simultemeously.

34. a, b



$$\frac{dQ}{dt} = E = e\sigma A T^4$$
$$= e\sigma 4\pi R^2 T^4$$

$m_s > m_h$ (same Radius)

therefor a, b is true.

$$\frac{dT}{dt} = \frac{e\sigma A T^4}{m s}$$

as $m_s > m_h$

$$\left(\frac{dT}{dt}\right)_s < \left(\frac{dT}{dt}\right)_h$$

[c, d not possible

35. a, c

$\lambda T = $ Const.

so $\lambda = \frac{b}{T}$ frequency $f \propto \frac{1}{\lambda}$

$f \propto T$

temp. doubled $\Rightarrow$ frequency doubled.

$E \propto T^4$

temp. doubled $\Rightarrow$ $E_{New} = 16E$

Exercise – III

Paragraph / Match the Column.

GMP Problems

1. Volume of bar $= \frac{m}{\rho} = \frac{5}{50} = .1\ m^3$

$\Delta V = 3\alpha V\ \Delta T = 3\times10^{-3} \times .1 \times 50 = 15\times10^{-3}$

Work done $= P\,\Delta V = 10^5 \times 15\times10^{-3} = 1500\ J.$ (C)

2. $Q = m s\,\Delta T = 5\times 200\times 50$

$= 50{,}000\ J$ (b)

3. $\Delta U = Q - W = 50{,}000 - 1500 = 48500\ J.$ (b)

---

4. from the graph (0°c to 80°c)

$Q = m s\,\Delta T \Rightarrow 800 = m\times .5\times 80$

$m = \frac{10}{.5} = 20\,g$ (a)

5. $Q = mL$ (A to B)

$800 = 20\,L \Rightarrow L = 40\ cal/gm.$ (C)

6. $(B \to C)$ $Q = m s\,\Delta T$

$600 = 20\times S\times 40$

$S = \frac{6}{8} = .75\ cal/gm°c$

(d)

7. $-10°c \longrightarrow -2°c$

$Q = m s\,\Delta T = 64$

$10\times S\times 8 = 64 \Rightarrow S = .8\ cal/\ldots$ (C)

20 cal additional energy to raise temp. from $1° \rightarrow 3°C$

$$20 = 10 \times S \times 2 \Rightarrow S = 1 \text{ cal/gm}°C$$

(d)

(C) 9.

880 cal required from $-2°C \rightarrow 1°C$

$$\boxed{-2°C} \xrightarrow{Q = 10 \times .8 \times 2 = 16} \boxed{0°C} \xrightarrow{10 \times L} \boxed{0°C} \xrightarrow{10 \times 1 \times 1} \boxed{1°C}$$

Solid $\quad$ Liquid

(a)

$$10L + 26 = 880$$

$$10L = 854$$

$$L = 85.4 \text{ cal/gm}$$

10. adiabatic lie below isothermal, therefore 'ab'

(A)

11. $P_A = 16$, $T_A = 600$, $V_A = 1$

$P_B = ?$, $T_B = ?$, $V_B = 4$

Eqn for AB process

$$P_A V_A^{\gamma} = P_B V_B^{\gamma}$$

$$16(1)^{1.5} = P_B (4)^{1.5} \Rightarrow P_B = \frac{16}{8} = 2 \text{ atm}$$

11. 13. $A \to C$ is isotherm

$$P_A V_A = P_C V_C$$

$$\Rightarrow 16 \times 1 = 2 V_C \Rightarrow 8 \text{ litre}$$

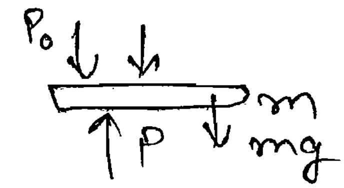
12. $T_C = 600\,K$ (isotherm) | 13. $V_C = 8$ Li

14.

$n = .01$ mole. $\quad M = .8$ kg $\quad V = 1.4 \times 10^{-4}$ m

$A = 10^{-4}$ m² $\quad m = 1$ kg $\quad k = 16$ N/m

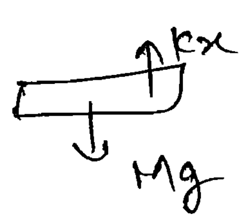
spring. is relaxed $\Rightarrow$



$$P = P_0 + \frac{mg}{A}$$

$$P = 10^5 + \frac{1 \times 10}{10^{-4}} = 2 \times 10^5 \text{ Pa}$$

15. force balance on M



$$kx = Mg$$

$$x = \frac{10 \times 0.8}{16} = \frac{1}{2}\text{m}$$

$$\Delta V = Ax = 10^{-4} \times \frac{1}{2}$$

New Volume $= 1.4 \times 10^{-4} + \frac{1}{2} \times 10^{-4} = \cancel{2.025 \times 10^{-4}}$

1.9×10^{-4}

$$T_1 = \frac{PV}{nR} = \frac{2\times10^5 \times 1.4\times10^{-4}}{.01\times 8.314}$$

$$= 336.78K$$

$$P_f = \frac{kx}{A} + \frac{mg}{A} + P_0$$

$$= \frac{1.8\times10}{10^{-4}} + 10^5 = 2.8\times10^5$$

now $$T_f = \frac{P_f V_f}{nR} = \frac{2.8\times10^5 \times 1.9\times10^{-4}}{.01\times 8.314}$$

$$= \cancel{682.40}\ \cancel{632K}$$
$$639.88K$$

$$\cancel{Q = .8\times10\times\frac{5}{8} + \frac{1}{2}\times16\times\left(\frac{5}{8}\right)^2 + P_0\Delta V}$$
$$\cancel{10^5\times\frac{5}{8}\times10^{-4}}$$
$$\cancel{+ .01\times\frac{5}{2}\times8.314\times345.22}$$

$$=$$

$$Q = mgh + \frac{1}{2}kx^2 + P_0\Delta V + nC_v\Delta T$$

$$= 1\times10\times\frac{1}{2} + \frac{1}{2}\times16\times\left(\frac{1}{2}\right)^2 + 10^5\times\frac{1}{2}\times10^{-4}$$
$$+ .01\times\frac{5\times8.314}{2}\times 303.$$

$$= 5 + 2 + 5 + 63.00$$

$$= 75 \text{ Joule}$$

16. iaf 16.

$\Delta Q = \omega + \Delta U$

$50 = 20 + \Delta U_{fi} \Rightarrow \Delta U_{fi} = 30J$

along ibf

$\Delta Q = \omega + \Delta U$

$36 = \omega + \Delta U_{fi} \Rightarrow \omega = 6J$

17. $W_{i\to f} = 13$

$Q_{i\to f} = W_{i\to f} + \Delta U_{i\to f}$

$= 13 + 30 = 43J$

therefore $Q_{f\to i} = -43J$

18. $U_f - U_i = 30$

$U_f = 40J$

19. $W_{ibf} = \cancel{W_{ib}}^{0} + W_{bf} = 6J$

$Q_{ib} = W_{ib} + U_{ib}$

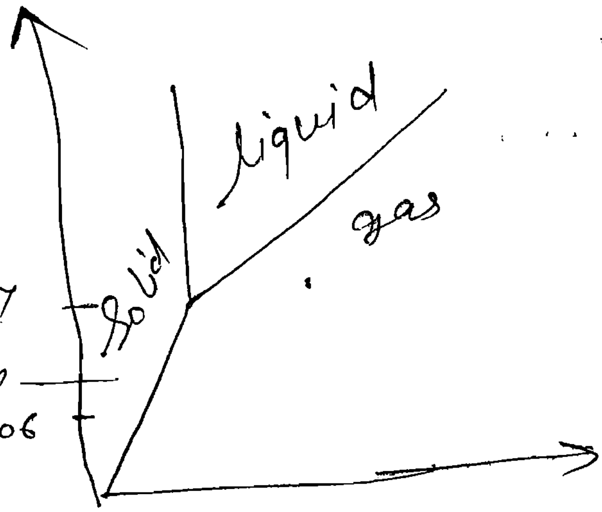
$= 0 + U_b - U_i = 22 - 10$

$Q_{ib} = 12\,Cal$

~~20. hyperbola $\Rightarrow$ $VT = $ Const.~~

~~$PV = nRT$ $\quad P = nKT^2$~~

20. (A)



So from diagram we can say

they intiatiall are in solid state, after that A will go in gas state white B will go in liquid

21. (a) Same

22.

$U = \text{Constent} \Rightarrow T = \text{Constent.}$

AB rectangular hyperbola

$\Rightarrow \quad U\rho = K \text{ (Constent)}$

$TP = K_1$ 　　　 $P = \frac{\rho RT}{M}$

$\Rightarrow P = \text{Constant}$

$AB \rightarrow \text{isobaric}$

(d)

23. ~~T = Constant in A~~ · P = Constent in AB

$Q = nC_p \Delta T = 2 \times \frac{5R}{2} \times (T_B - T_A)$

$= 5R \times \left(\frac{3000R}{2 \times \frac{3R}{2}} - 300 \right)$

24. $C \to A$ density Constant

$\Rightarrow V =$ Constant

$\Rightarrow W = 0$

$Q = \Delta U$

$= U_A - U_C = 2 \times \frac{3R}{2} \times (300) - 3000R$

$= 900R - 3000R$

(d) $= -2100R$

25. Heat $P = \sigma T^4 (4\pi R^2)$

both are of same Radius & Temp.

therefore 1 : 1 (A)

26. $P = \frac{dQ}{dt} = \underline{\sigma T^4 (4\pi R^2)}$

$ms \frac{dT}{dt} = \sigma T^4 (4\pi R^2)$

$\frac{dT}{dt} = \frac{\sigma T^4 \cancel{(4\pi R^2)} A}{\rho V s}$

$\frac{\left(\frac{dT}{dt}\right)_1}{\left(dT/dt\right)_2} = \frac{\rho_2 s_2}{\rho_1 s_1} = \frac{130 \times 2.7}{900 \times 10}$

$= \frac{39}{1000}$

(σ, T^4, A & V all same for both)

27. (b) $\frac{dT}{dt} \propto c(T - T_s)$

Newtons' Law of Cooling

28.

Energy incident on body per sec

$= (S \times A \times a)$

| S = Intensity of Sun
A = Area of body
a = absorptivity
= e

power emitted by body

$= e\sigma A T_0^{4}$

net rate of Heat gain

$$\frac{dQ}{dt} = SAa - e\sigma A T_0^4$$

$$ms\frac{dT}{dt} = SAa - e\sigma A T_0^4$$

$$\frac{dT}{dt} = \frac{SAa - e\sigma A T_0^4}{ms}$$

$= 3.6$ K/sec

29. T would be max when

Heat gain = Heat lost

$\Rightarrow (S - \sigma T^4) eA = 0$

$T_{max} = \left(\frac{S}{\sigma}\right)^{1/4} = 396$ K

Match the Column

1.

I → c , II → a , III → d , IV → b

fraction of Volume submerged $f_s = \frac{V_s}{V}$

$= \frac{\rho}{\rho_L}$

as temp. changes

new fraction $f_s' = \frac{\rho'}{\rho_L'}$

change in fraction $= \frac{f_s' - f_s}{f_s}$

$= \frac{\rho'}{\rho_L'} \times \frac{\rho_L}{\rho} - 1 = (\gamma_2 - \gamma_1)\Delta T$

(γ_2 = mercury volume coeff.)

γ_1 = metal Volume coeff.

so if $\gamma_2 > \gamma_1$ ~~so~~ fraction increases

⇒ body sinks.

2. i → c, ii → a, iii → d, (iv) → b

$\boxed{20}$ 100°c steam

$Q = 20 \times 540 = 10800$

$\boxed{20}$ 100°c water

$\boxed{100}$ 20°

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

$\boxed{100}$ 8 100°c

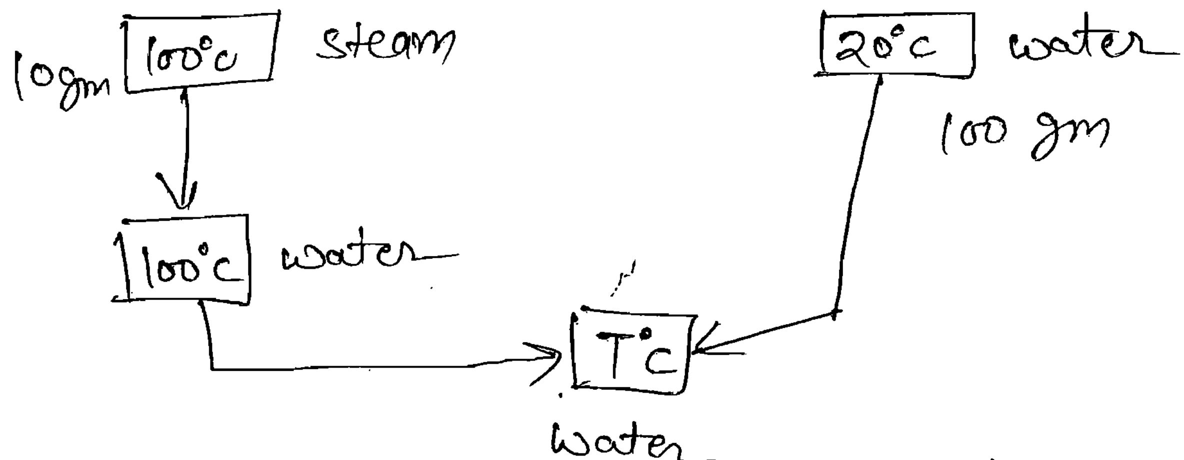
So all steam will not convert in water

So final Composition

114.18 gm water, 5.2 gm steam

$T_{mix.} = 100^\circ C$

if $m = 10$ gm



Heat absorbed = Heat gain

$10 \times 54\cancel{0} + 1\cancel{0} \times 1 \times (100 - T) = 10\cancel{0} \times 1 \times (T - 20)$

~~$5400 - 540T = 10T - 200$~~

~~$550T = 5420$~~

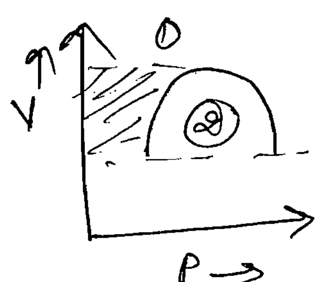
$540 + 100 - T = 10T - 200$

$11T = 840$

$T = \frac{840}{11} = 76.36^\circ C$

3. i → d, ii → b, (iii) → c, (iv) → b

Area of ② > area of ①



W = −ve

Curve (ii) from $PV = nRT$

$A \rightarrow B$

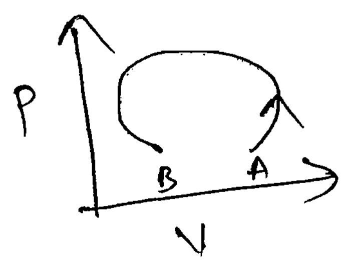
V is decreasing $\Rightarrow w = -ve$

T " " $\Rightarrow \Delta U = -ve$

(iii) $V \uparrow$ & $T \downarrow$

$w = +ve$ $\Delta U = -ve$

(iv)



$w = -ve$

$A \rightarrow B$ $V \downarrow$

$\Rightarrow T \downarrow$

$w = -ve$, $\Delta U = -ve$

4.

(i) $\longrightarrow$ AE

(ii) $\longrightarrow$ AC

(iii) $\longrightarrow$ AF

$TV^{\gamma-1} = k$

$TV^{\frac{5}{3}-1} = k$

$T_0 V_0^{\frac{2}{3}} = T (2V_0)^{\frac{2}{3}}$

$T = T_0 \frac{1}{2^{2/3}}$

Exercise-IV Subjective

1. Volume of air inside = Constant.
it is possible only when increase in Volume of glass = increase in volume of mercury.

$$\boxed{\begin{aligned} V &= V_0(1+\gamma\Delta \\ V - V_0 &= V_0\gamma\Delta \end{aligned}}$$

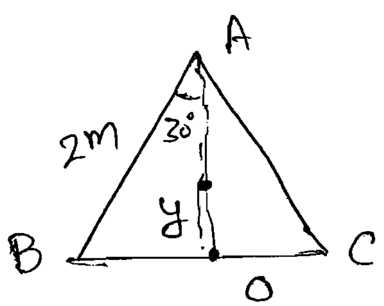
$$V_g \gamma_g \Delta T = V_{Hg}\gamma_{Hg}\Delta T$$

$$V_g \times 3 \times \cancel{18}\,9 \times 10^{-6} = 300 \times 1.8 \times 10^{-4}$$

$$V_g = \frac{\cancel{300}^{100} \times \cancel{1.8}^{.2} \times 10^{-4}}{\cancel{3} \times \cancel{9} \times 10^{-6}} = 2000\ cm^3$$

Ans

2.



when we increase temp. distance b/w any two points on solid increases ~~by~~ in same pattern

$(l = l_0(1+\alpha\Delta T))$

$$d(COM) = y = \frac{1}{3} \times 2\cos 30^\circ$$

$$\text{change} = l_0 \alpha \Delta T$$

$$= \frac{2\cos 30^\circ}{3} \times 4\sqrt{3} \times 10^{-6} \times 1 = 4 \times 10^{-6}\ m$$

3.

$$\underset{l}{\overset{\alpha}{\overline{\qquad\qquad}}}\cdot\underset{2l}{\overset{2\alpha}{\overline{\qquad\qquad}}}$$

eq $\underset{\alpha_{eq.}}{\overset{3l}{\overline{\qquad\qquad\qquad}}}$

change in both rod should be same

$$3l\alpha_{eq}\Delta T = l\alpha\Delta T + 2l \times 2\alpha\Delta T$$

$$\alpha = \frac{5l\alpha}{\ } \quad \frac{5\alpha}{\ }$$

4. Rod A $\Delta l = l_0 \alpha \Delta T$

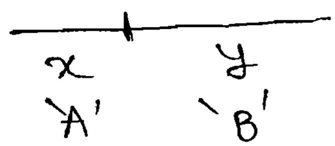
$$.05 = 25\,\alpha_A\,100 \Rightarrow \alpha_A = \frac{5\times10^{-2}}{25\times10^{2}}$$

$$\alpha_A = \frac{1}{5}\times10^{-4} = 2\times10^{-5}$$

Rod B $\Delta l = l_0 \alpha \Delta T$

$$.04 = 40 \times \alpha_B \times 100 \qquad \alpha_B = 10^{-5}$$

Rod C



also $x + y = 50$ —①

$$.03 = x\alpha_A 50 + y\alpha_B 50$$

$$.03 = (x\,100 + y\,50)\times10^{-5}$$

$$50\,(y + 2x) = 300$$

$$y + 2x = 60 \rightarrow ②$$

② − ① $x = \cancel{40}$ 10 cm, $y = 40$ cm.

⑤

$$Y = \frac{F/A}{\Delta l/L} \Rightarrow F = \frac{YA\,\Delta l}{L}$$

$$= .91\times10^{11}\times\pi\times10^{-6}\times 2\times10^{-5}\times66$$

$$= 377.368\ \text{N}$$

⑥ fractional change $= \dfrac{\rho - \rho_0}{\rho_0} = \dfrac{\rho_0(1-\gamma\Delta T) - \rho_0}{\rho_0}$

$$= -\gamma\Delta T$$

$$= -49\times10^{-5}\times30$$

$$= -.0147$$

7. change in diameter $= -.01$ cm.

$$-.01 = 8.7 \times 1.2 \times 10^{-5} \times \Delta T$$

$$\Delta T = -95.78\,^\circ C$$

$$T_f - T_i = -95.78^\circ$$

$$T_f = 27 - 95.78$$

$$= -68.78\,^\circ C$$

Ans

8. Copy

$m_1 = \rho_0 \times 300$ $\quad$ $m_2 = \rho_{100} \times 110$

Suppose. final temp $= T$

(1)

$$m_1 S\,(T-0) = m_2 S\,(100-T)$$

$$\rho_0 \times 300\; T = \rho_{100} \times 110\,(100-T)$$

$$300\,\rho_0 T = \frac{\rho_0 \times 110}{(1+\gamma \times 100)} \times (100-T)$$

$$300\,T = \frac{110}{1.1} \times (100-T)$$

$$3T = 100 - T$$

$$\Rightarrow T = 25^\circ$$

~~$V_{final} = 300(1+ .001 \times 25)(1 - 110 \times .001 \times 75$~~

$=$

$$V_{final} = 300\,(1 + .001 \times 25) + 110\,(1 - .001 \times 75)$$

$$= 410 + 7.5 - 8.25 = 409.25\ cm^3$$

change $= .75\ cm^3$

9.

m 20°C m 20°C

X Y

Suppose water equivalent = W

initial 5gm, 40°C

find Condition 22°C 23°

Container − 1

$(m+w) S_w 2 = 5 S_x 18$

$m+w = \frac{5 \times .2 \times 18}{2}$

$m+w = 9$

Container − 2

$(m+w) S_w 3 = 5 S_y 17$

$9 \times 1 \times 3 = 5 S_y \times 17$

$S_y = \frac{27}{85} = .317$

10. if ice Converted into water, then Heat absorb

$2 \times 50 \times .5 \times 15 + 2 \times 50 \times 80 = 8750$ cal

~~$+ 400 \times 1 \times T =$~~

(2) if water come to 0°C, energy released

$250 \times 25 \times 1 = 6250$ cal

as we dont have sufficient energy, all ice will not melt.

ice $\boxed{100}$ −15°C $\rightarrow$ Q = 750 $\rightarrow$ $\boxed{100}$ 0°C ice

$\boxed{250}$ 25°C $\rightarrow$ 6250 $\rightarrow$ $\boxed{0°C}$

Suppose x gm ice Convert into water

$x \times 80 = 6250 - 750 = 5500$

$x = \frac{550}{8} = \frac{275}{4}$

Remaing ice $= 100 - 275 \quad 125$

11.

3 C

$$Q = ms\,\Delta T$$

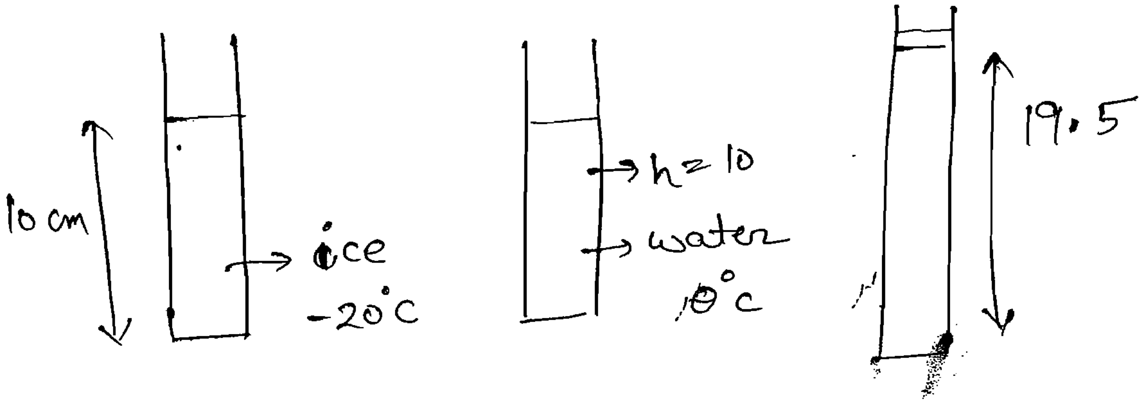
$$\frac{dQ}{dt} = \left(\frac{dm}{dt}\right) s\,\Delta T$$

$$250 = 2\times10^{-3} \times S \times 25$$

$$S = 5000\ J/Kg\,K$$

12.

4



level ~~too~~ fall because ice is melting & Converting into water.

Suppose x gm ice melt.

So $\rho_{ice}(A h_{ice}) = x = \rho_{water}(A h_{water})$

$$.9\, h_{ice} = h_{water}$$

also $h_{ice} - h_{water} = .5$

$$.1\, h_{ice} = .5$$

$$h_{ice} = 5\text{ cm.}$$

So mass of ice melt $= .9 \times (A\times5) = 4.5A$

energy absorbed by ice = energy released by water.

$$2\times(4.5A)\times(.5)(20) + 4.5A\times80 = (A10)\times1\times\theta$$

① All ice go to 0°c
② Some portion of ice will melt.

13. (5)

$Q = m s \Delta T$

(a) $\frac{dQ}{dt} = m s \Delta T = 180\,gm \times .1 \times 4.2 \times .5$

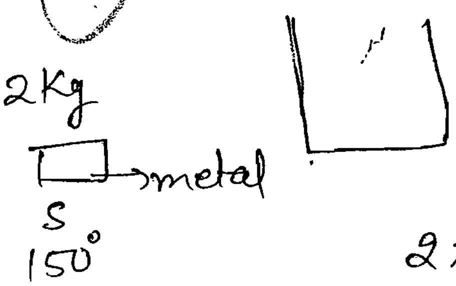
$= 37.8\ J/sec$

(b) $w = \tau \theta$

$\frac{dw}{dt} = P = \tau \omega$

$\tau = \frac{37.8}{3\ \frac{180 \times 2\pi}{60}} = 2.005\ N\text{-}m.$

14. (9)



$w = .025\,Kg$

$2 \times S \times (150 - 40) = .175 \times 1 \times 13$

$S = \frac{13 \times .175}{2 \times 110} = .0103\ Cal/gm$

15. (10) final temp. $= 0°C$

$2.5 \times .39 \times 500 = x \times 335$

$x = 1.45\ Kg$

16. (11)

$P = 10 \times 10^3\ W$

$W = Pt = 10^4 \times 150 = 15 \times 10^5$ Joule

only 50% is used in Heat.

$Q = \frac{15}{2} \times 10^5 = 8 \times .991 \times 10^3\ \Delta T$

17. (12)

$$\frac{dQ}{dt} = \left(\frac{dm}{dt}\right)_{water} S\Delta T = 3\times10^{-3}\times 50\times10^{3}\ \text{Cal}/\text{min}$$

$$= 150\ \text{Cal}/\text{min}$$

$$\left(\frac{dm}{dt}\right)_{fuel}\times 4\times10^{4} = 150\times4.2\ \text{J}/\text{min}$$

$$= .0157\ \text{Kg}/\text{min}$$

18. (13)

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{3RT_1}{M_{Ar}} = \frac{3R\,(253)}{4}$$

$$T_1 = \frac{253\times39.9}{4} = 2524\ K$$

19. (14)

at STP

$$10^5 P\times10^{-3} = \frac{.177}{M}\times8.314\times273$$

$$M = 4\ gm$$

$$V_{rms} = \sqrt{\frac{3\times8.314\times273}{4\times10^{-3}}}$$

$$= 1302\ m/s.$$

20. (15)

$$C_{v\,mix} = \frac{n_1C_{v_1}+n_2C_{v_2}}{n_1+n_2} = \frac{\frac{3R}{2}+\frac{5R}{2}}{2} = 2R$$

as V_{rms} is doubled $\Rightarrow$ T should be 4 time

so $T_f = 1200\ K \qquad \Delta T = 900K$

21.

16

$$(V_{rms})_f = 1.5\,(V_{rms})_i$$

$$\sqrt{T_f} = \frac{3}{2}\sqrt{T_i} \Rightarrow T_f = \cancel{4}\frac{9}{4}T_i$$

(i) adiabatically

$$\Rightarrow PV^{\gamma} = K \Rightarrow TV^{\gamma-1} = K$$

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1} \qquad \gamma = \frac{7}{5}$$

$$V_1^{\gamma-1} = \frac{9}{4} V_2^{\gamma-1}$$

$$\cancel{\frac{V_2}{V_1}}\ \frac{V_1}{V_2} = \left(\frac{9}{4}\right)^{\frac{1}{\gamma-1}} = \left(\frac{9}{4}\right)^{\frac{5}{2}}$$

$$= \frac{3^5}{2^5} = 7.6$$

(ii) Isobarically

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow \frac{V_1}{V_2} = \frac{4}{9}$$

(ii) $\dfrac{W_{adia}}{W_{iso}} = -\dfrac{nR\Delta T}{(\gamma-1)\,nR\Delta T} = -2.5$

22.

17

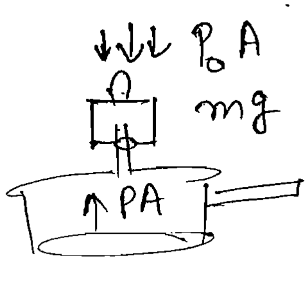
$$P = \frac{\rho RT}{M} \quad \text{so} \quad P = \frac{\rho_0 R T_0}{M}$$

$$3P = \frac{\rho_B R\, 2T_0}{M}$$

$$\rho_B = \frac{3}{2}\rho_0$$

23.

18



$$P_0 A + mg = PA$$

$$P = P_0 + \frac{mg}{A} = 10^5 + \frac{.1 \times 10}{.1 \times 10^{-4}}$$

∴ Initially $10^5 \times 10 = nR\,300$

finally $2\times10^5 \times 10 = nR\,T$

$T = 600K \Rightarrow 327^\circ C$

<u>24.</u>

19. $\frac{B}{W} = \frac{(\rho_{liquid})_{300}\, V_{inside}\, g}{(\rho_{liquid})_{400}\, V_{inside}\, g} = \frac{\rho_{300}}{\rho_{400}}$

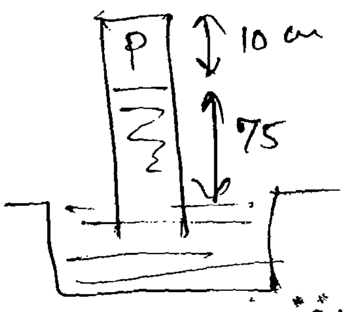
now $\Rightarrow P = \frac{\rho R T}{M}$

$\Rightarrow \rho = \frac{M P}{R T}$

$\frac{B}{W} = \frac{400}{300} = \frac{4}{3}$.

<u>25.</u>

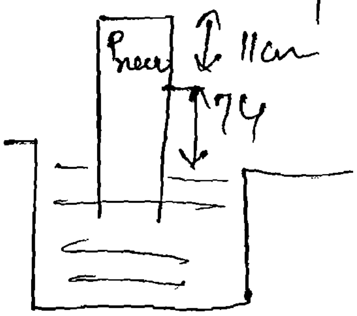
20.



Case (i)

$P_0 = 76$ $P + 75 = 76$

$P = 1$ cm of Hg



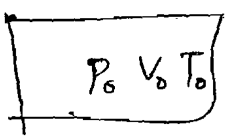
$P_{new} V_{new} = P_1 V_1$

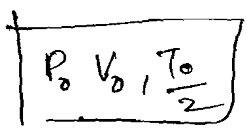
$P_{new} = \frac{1\,cm \times A \times 10}{11 \times A} = \frac{10}{11}$

$P_{atm} = 74 + \frac{10}{11} = 74.9$ cm of Hg.

<u>26.</u>

21.





$P_0 V_0 = \frac{m_0}{32} R T_0$

$P V = m_H \ldots T$

27. (6)

10 ltr	10 ltr	10 ltr
	$\frac{160}{32}$	$\frac{70}{28}$

$n_1 = \frac{30gm}{2}$
$= 15$ mole H_2 5 mole of O_2 $\frac{5}{2} N_2$

H_2 moles	5	5	5
O_2 moles	0	5	0
N_2 moles	0	$\frac{5}{4}$	$\frac{5}{4}$

$= 5, \frac{45}{4}, \frac{25}{4}$

$\because P \propto n$

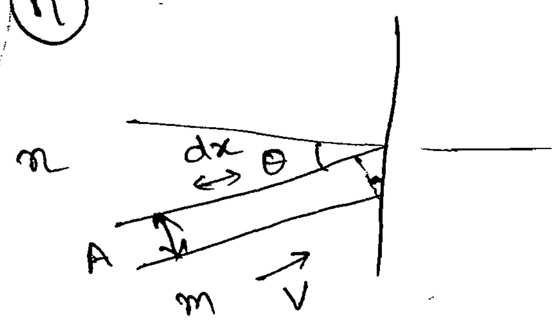
$P_1 : P_2 : P_3 = 5 : \frac{45}{4} : \frac{25}{4}$

$= 1 : \frac{9}{4} : \frac{5}{4}$

$$P_1 = \frac{5 \times 8.314 \times 300}{10 \times 10^{-3}} = 12.47 \times 10^{6}\ Pa$$

Ans

28. (7)



$A_1 \cos\theta = A$

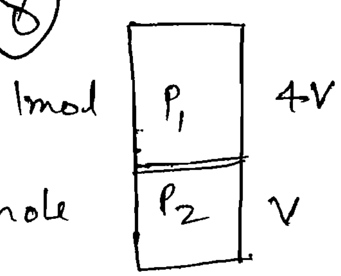
$P = \frac{F}{A}$

no. of particles striking per sec $= n \times \frac{A\,dx}{dt}$
$= nAv$

$$\Rightarrow P = \frac{\frac{\Delta p}{\Delta t}}{A_1} = \frac{(2mv\cos\theta)\,nAv}{A_1}$$

$$P = 2mnv^2\cos^2\theta$$

29. (8)

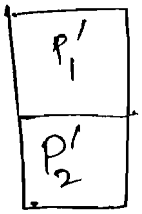


$P_1 + \frac{mg}{A} = P_2$

$P_1\, 4V = 1R\,300$ —(1) $\Rightarrow P_2 = 4P_1$

$P_2\, V = 1R\,300$ —(2)

∴ now suppose Temp. T



$\frac{10V}{3}$

$\frac{5V}{3}$

$P_1' + \frac{mg}{A} = P_2'$

$P_1' + 3P_1 = P_2'$

also $P_1' \times \frac{10V}{3} = 1RT$ — ③

$P_2' \times \frac{5V}{3} = 1RT$ — ④ $\quad P_2' = 2P_1'$

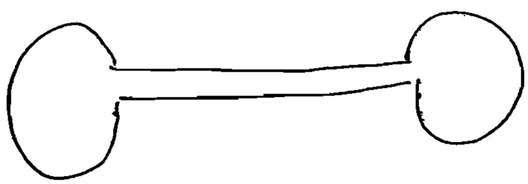
$\Rightarrow 3P_1 = P_1'$

eq. $\frac{①}{③} \Rightarrow \frac{P_1 4V}{P_1' \frac{10V}{3}} = \frac{\cancel{R}300}{\cancel{R}T}$

$\frac{4}{10} = \frac{300}{T} \Rightarrow T = 750K$

30.

9



$n, 273, 10^5 \qquad n, 273, 10^5$

$\Rightarrow 10^5 V = nR273$ — ①

$\Rightarrow n = \frac{10^5 \times 10^{-3}}{8.314 \times 273}$

$= .044$

$(n-x)$ ~~(n+x)~~, P $\qquad (n+x)$, P

373 $\qquad$ 83

$PV = (n-x)R\,373$ — ② $\qquad PV = (n+x)R\,83$ — ③

$\Rightarrow (n-x)373 = (n+x)83$

$\frac{n+x}{n-x} = \frac{373}{83} \Rightarrow \frac{2n}{2x} = \frac{456}{290}$

$x = \frac{290}{456} = \frac{145}{228}n$

Now ①

$10^5 \quad n\,273$

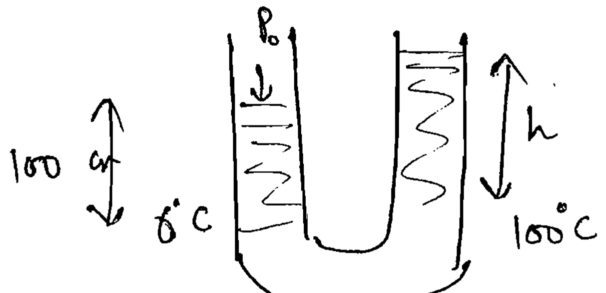
$$P = \frac{(n-x)}{n} \frac{373}{273} \times 10^5 \qquad \frac{n-x}{n} = .364$$

$$= .497 \text{ atm}$$

mass flow $= x \times 2 = .056$ gm.

31.

22.



$$P_0 + \rho_{0^\circ C}\, g\, 100 - \rho_{100}\, g\, h = P_0$$

$$\rho_0 \, 100 = \frac{\rho_0}{1+\gamma\, 100} h$$

$$h = (100)(1 + 10^{-5} \times 100)$$

diff $= h - 100$

$= .1$ cm.

32.

23.

$$\frac{t-t_0}{t_0} = \frac{1}{2}\alpha \Delta T = \frac{1}{2} \times 10^{-6} \times 10 = 5 \times 10^{-6}$$

~~$t - t_0 =$~~

So clock will move slow

$(t - t_0)$ in 10^6 sec $\longrightarrow 5 \times 10^{-6} \times 10^6 = 5$ s

33.

24.

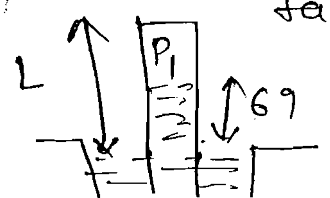
$$F = Y A \alpha \Delta T = 10^{11} \times 10^{-3} \times 100 \times 10^{-6}$$

$$= 10^4 \text{ N}$$

34.

10

~~Tor~~ faulty Case (i) $P_{atm} = 73$



$P_1 + 69 = 73$

$P_1 = 4$

$$P_1 V_1 = P_2 V_2$$

$$4 \cancel{A} [L-69] = 5 \cancel{A} [L-70]$$

$$4L - \cancel{469}\ 4 \times 69 = 5L - 5 \times 70$$

$$L = 350 - 4 \times 69 = 74 \text{ cm.}$$

(ii)

$$P = P_3 + 69.5$$

$$= 69.5 + \frac{20}{4.5}$$

$$P = 73.94$$

air will lie in

$74 - 69.5 = 4.5$ cm.

$$P_1 V_1 = P_3 V_3$$

$$4 \times 5 = P_3 \times 4.5$$

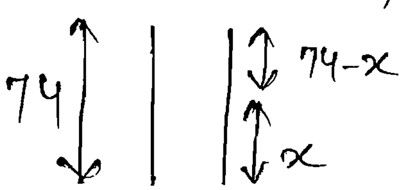
(iii)

$$P = P_4 + l_{Hg}$$

$$74 = P_4 + l_{Hg}$$

$$P_1 V_1 = P_4 V_4$$

$$4 \times 5 = P_4 (74 - x)$$



$l_{Hg} = x$

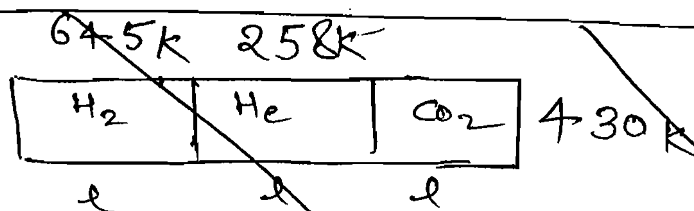
$$74 = P_4 + x$$

$$74 = \frac{20}{74-x} + x$$

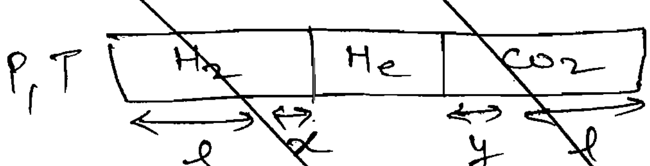
$$(74-x)^2 = 20$$

$$x = 74 - \sqrt{20} = \underline{\underline{69.52 \text{ cm}}}$$

35.



$\frac{372}{273}$



no of moles remain constant.

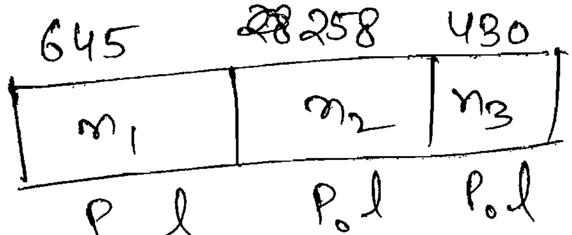
$$n = \frac{PV}{RT}$$

$$\frac{P_0 A l_0}{R\,645} = \frac{P(l+x)A}{RT}$$

$$P = \frac{P_0 l T}{}$$

35. (11)

$T =$



$P_0 A l = n_1 R\, 645$ — (1)

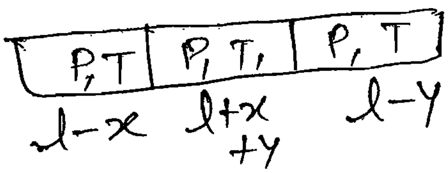
$P_0 A l = n_2 R\, 258$ — (2)

$P_0 A l = n_3 R\, 430$ — (3)

$\frac{(1)}{(2)} \Rightarrow \frac{n_1}{n_2} = \frac{2}{5}$

$\frac{(1)}{(3)} \Rightarrow \frac{n_1}{n_3} = \frac{2}{3}$

now



$PA(l-x) = n_1 RT$ — (4)

$PA(l+x+y) = n_2 RT$ — (5)

$PA(l-y) = n_3 RT$ — (6)

$\frac{(4)}{(5)} \Rightarrow \frac{l-x}{l+x+y} = \frac{2}{5}$ — (7)

$\frac{(4)}{(6)} = \frac{l-x}{l-y} = \frac{2}{3}$ — (8)

from (7) $\quad 5l - 5x = 2l + 2x + 2y$

$7x + 2y = 3l \rightarrow$ (9)

from (8) $\quad 3l - 3x = 2l - 2y$

$l = 3x - 2y$ — (10)

(9) + (10) $\quad 10x = 4l$

$x = .4, \quad y = .1$

So final length $.6l, \; 1.5l, \; .9l$ Ans

36. $\frac{\Delta Q}{\Delta T} = \frac{2500}{100} = nC_p$ (given Const pressure)

25.

$n = 1$

$C_p = 25$

$C_v = 25 - \frac{25}{3} = \frac{50}{3}$

$\gamma = \frac{C_p}{C_V} = \frac{3}{2} = 1.5$

37.

26.

$\cancel{T = KV^2 + C}$

$\cancel{T = \frac{K}{V} + C}$

$V_{rms} = \sqrt{\frac{3RT}{M}}$

$V_s = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$

from the data

we can say $\cancel{T = \frac{K}{\sqrt{V}} + C}$

$P = \frac{\rho RT}{M}$

$T \propto \frac{1}{\sqrt{V}}$

$\frac{V_{rms}}{V_s} = \sqrt{\frac{3}{\gamma}}$

$T\sqrt{V} = K$

now for adiabatic $TV^{\gamma-1} = K_1$

Comparing $\gamma - 1 = \frac{1}{2}$

$\gamma = 3/2$

$\frac{V_{rms}}{V_s} = \sqrt{2}$

38. $V_{sound} = \sqrt{\frac{\gamma RT}{M}}$

27.

now $d(\text{Nodes}) = \frac{\lambda}{2}$

$20.4 = \frac{\lambda}{2}$

$\lambda = 40.8\text{cm}$

$V_s = \lambda f = .408 \times 1000$

$= 408 \text{ m/s}$

$408 = \sqrt{\frac{\gamma \times 25 \times 300}{3 \times 16 \times 10^{-3}}} = \cancel{\frac{50}{4}\sqrt{\gamma}}$

39.

28.

$$\Delta Q = n C_p \Delta T$$

$$= \frac{\cancel{20}^{5}}{\cancel{28}_{4}} \times \frac{7R}{2} \times 45 = 933.4\ J$$

40.

29.

initially suppose volume $= V_0$

$$2 \times 10^5\ V_0 = nR\ (293)$$

final volume $= V_0 + \frac{V_0}{5} = \frac{6V_0}{5}$

So

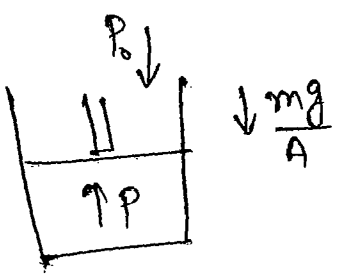
$$P\ \frac{6V_0}{5} = nR\ 313$$

$$\frac{P \times 6}{5 \times 2 \times 10^5} = \frac{313}{293}$$

$$P = 178.04\ kPa$$

41.

12



$$P = P_0 + \frac{mg}{A}$$

$$= 10^5 + \frac{1 \times 10}{10 \times 10^{-4}} = 11 \times 10^4$$

Now in space

$$P = P_0 = 10^5$$

So as no. of moles remain Constant.

$$n = \frac{PV}{RT} \Rightarrow \frac{10^5\ A l}{RT} = \frac{11 \times 10^4\ (A)(.2)}{RT}$$

$$l = .22\ m$$

42 ~~as Rotational Kinetic Energy = $\frac{1}{2}RT$ degree of freedom~~

~~$= \frac{1}{2} I\omega^2 = \frac{3}{2} kT$~~

42. (30) R.K.E $\frac{1}{2}I\omega^2 = \frac{1}{2}kT$

$$\omega = \sqrt{\frac{kT}{I}} = \sqrt{\frac{1.38\times 30}{2}} \times 10^9$$

$$= 4.55 \times 10^9 \text{ rad/s}$$

43. (31)

$$V_{O_2} = \sqrt{\frac{3R(273)}{32}} = 460$$

$$V_{He} = \sqrt{\frac{3R(313)}{4}} = 460\sqrt{\frac{313}{4} \times \frac{32}{273}}$$

$$= 1393 \text{ m/s}$$

$$V_{Ar} = 460\sqrt{\frac{313}{40} \times \frac{32}{273}} = 441 \text{ m/s}$$

44. (32) mean T ↑ by 4 times

final T = 1200

$\Delta T = 900K$

$$\Delta Q = \frac{5R}{2} \times \frac{15}{28} \times 900 = 10.02 \text{ KJ}$$

45. (33)

$$V = \sqrt{\frac{\gamma P}{\rho}} \Rightarrow 330 = \sqrt{\frac{\gamma \times 10^5}{1.3}}$$

$$\gamma = 1.41 = \frac{f+2}{f}$$

$$f = \frac{2}{.41} \approx 5$$

46. $P = 2mnv^2\cos^2\theta$

47. (34) speed is always +ve. av. speed will be zero only at T = 0K.

48. (35)

Energy Conservation

$$n_1 C_{V_1} T_1 + n_2 C_{V_2} T_2 = (n_1 + n_2) C_V T$$

$$T = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2} \qquad C_{V_1} = C_{V_2} = C_V$$

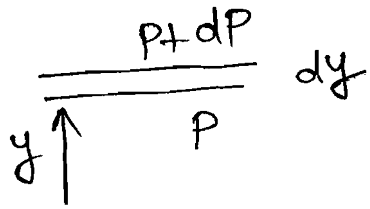
49. (36)

$$n_A = \frac{P_A V}{R T_A} \qquad n_B = \frac{P_B V}{R T_B}$$

finally $P\,2V = (n_A + n_B) R T$ subsitute n_A & n_B.

$$\frac{P}{T} = \frac{1}{2}\left(\frac{P_A}{T_A} + \frac{P_B}{T_B}\right)$$

50. (14)



$$dP = -\rho g\,dy$$

since $PV = nRT$

$$P = \frac{\rho R T}{M}$$

$$dP = -\frac{PM}{RT} g\,dy$$

$$\int_{P_0}^{P} \frac{dP}{P} = -\frac{Mg}{R} \int_0^h \frac{dy}{T} = -\frac{Mg}{R} \int_0^h \frac{dh}{T_0 - ah}$$

$$\ln \frac{P}{P_0} = \frac{-Mg}{-Ra}\Big[\ln(T_0 - ah)\Big]_0^h$$

$\frac{mg}{Ra}$

51. $W =$ Area Under $\overset{P\text{-}V}{}$ Curve

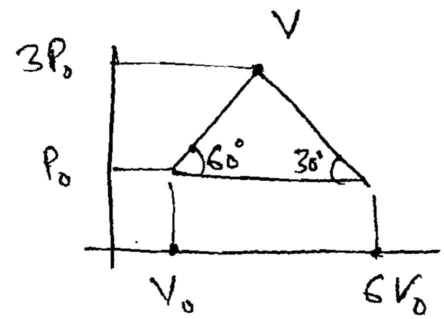
$$= \frac{\pi}{2} \times \frac{2 \times \cancel{10^{3}}}{2} \times \frac{2 \times \cancel{10^{3}}}{2}$$

$$= \frac{\pi}{2} \text{ atm} \times \text{ltr.}$$

27

52.

15



$$\tan 60^\circ = \frac{2P_0}{V - V_0}$$

$$\tan 30^\circ = \frac{2P_0}{6V_0 - V}$$

now $\sqrt{3} = \frac{2P_0}{V - V_0}$ & $\frac{1}{\sqrt{3}} = \frac{2P_0}{6V_0 - V}$

$$\sqrt{3} = \frac{6V_0 - V}{\sqrt{3}(V - V_0)} \Rightarrow 3V - 3V_0 = 6V_0 - V$$

$$4V = 9V_0$$

$$V = \frac{9}{4} V_0$$

$$P_A V_A = nRT_A$$

$$P_B V_B = nRT_B$$

$$\frac{T_B}{T_A} = \frac{P_B V_B}{P_A V_A} = \frac{3P_0 \times \frac{9}{4} V_0}{P_0 V_0} = \frac{27}{4}$$

Ans

53. initial pressure and temp $= P, T$

final pressure $= \frac{P}{n}$

therefore $T = \frac{T}{n}$ $(PV = nRT)$

Heat released $Q = -n C_v (T - T\ )$

isobaric process

$$Q_{given} = n C_p \left(T - \frac{T}{n}\right)$$

$$\text{net } Q = n(C_p - C_v)\left(T - \frac{T}{n}\right)$$

$$= RT\left(1 - \frac{1}{n}\right)$$

54 ~~Q~~.
39

$P = KV$

$PV^{-1} = \text{constant}$

$x = -1$

$$C = C_v + \frac{R}{1-x} = C_v + \frac{R}{2} = \frac{3R}{2} + \frac{R}{2} = 2R$$

55.
I
16

$$Q_{AB} = nRT_A \ln 2 \quad \text{(isothermal process)}$$

$$Q_{BC} = n C_p (T_C - T_B)$$

Now, $P_B = P_C = \frac{P_A}{2}$ (isothermal curve)

$$P\left(\frac{T}{P}\right)^{\gamma} = K$$

$$T^{\gamma} P^{1-\gamma} = K$$

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

$$T^{\frac{3}{2}} P_A^{-\frac{1}{2}} = T_B^{\gamma} \left(\frac{P_A}{2}\right)^{-\frac{1}{2}}$$

$$T_B = \left(2^{-1/2}\right)^{\frac{2}{3}} T = \frac{T}{2^{1/3}}$$

$$C_p = \frac{\gamma R}{\gamma - 1} = 3R$$

$$Q_{BC} = n\, 3R \left(\frac{T}{2^{1/3}} - T\right)$$

$[Q_{BC} = -ve]$

$$\therefore \quad \eta = 1 - \frac{|Q_{out}|}{|Q_{in}|}$$

$$= 1 - \frac{3nR\left(T - \frac{T}{2^{1/3}}\right)}{nRT\ln 2} = 1 - \frac{3\left(1 - \frac{1}{2^{1/3}}\right)}{\ln 2}$$

56.

(4)

~~$V \propto KT$~~ $PV = nRT$

$$V = \left(\frac{nR}{P}\right)T$$

$$\frac{dV}{dT} = \frac{nR}{P} = \tan 53^\circ = \frac{4}{3}$$

(V is in ltr)

$$\frac{2 \times 8.314}{P} = \frac{4}{3} \times 10^{-3}$$

$$P = \frac{6 \times 8.314 \times 10^3}{4}$$

$$= 1.25 \times 10^4 \ N/m^2$$

~~56.~~ 57.

(1.5)

$$PV^m = K$$

$$V^m \frac{dP}{dV} + mPV^{m-1} = 0$$

$$\frac{dP}{dV} = -\frac{mP}{V} = -\frac{3}{4}$$

$$m = \frac{3}{4} \times \frac{4 \times 10^5}{2 \times 10^5} = 1.5$$

58.

(4)

$$\Delta Q = 2\Delta U = W + \Delta U \Rightarrow W = \Delta U$$

$$nC\Delta T = 2nC_V\Delta T$$

$$C = 2C_V = \frac{2 \times 5R}{} \quad 5R$$

59.

17

Adiabatic process.

$$TV^{\gamma-1} = k$$

$$V^{\gamma-1}\frac{dT}{dV} + (\gamma-1)TV^{\gamma-2} = 0$$

Slope of T→V curve $= \frac{1}{m}$

$$\frac{dT}{dV} = -\frac{(\gamma-1)T}{V}$$

$$\frac{(\gamma-1)T_0}{V_0} = \frac{1}{m}$$

$$\gamma-1 = \frac{V_0}{mT_0}$$

$$\gamma = \frac{V_0}{mT_0} + 1$$

$$C_p = \frac{\gamma R}{\gamma-1} = \left(\frac{V_0}{mT_0}+1\right)\frac{R}{V_0/mT_0}$$

$$= \left(1+\frac{mT_0}{V_0}\right)R$$

$$C_V = \frac{R}{\gamma-1} = \frac{mRT_0}{V_0}$$

60.

18

$$T = T_0 e^{\alpha V}$$

$$dT = T_0\alpha e^{\alpha V}\,dV = \alpha T\,dV$$

$$dQ = dW + dU$$

$$nC\,dT = P\,dV + nC_V\,dT$$

$$nC\,dT = \frac{P\,dT}{\alpha T} + nC_V$$

$$PV = nRT$$

$$C = \frac{P}{n\alpha T} + C_V = \frac{R}{\alpha V} + C_V$$

61.

$V \propto \frac{1}{T}$

$VT = K$ now $PV = nRT$

$V\left(\frac{PV}{nR}\right) = K$

$\Rightarrow PV^2 = K_1 \quad x = 2$

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

$= \frac{3R}{2} - R = \frac{R}{2}$

62.

as $T = \text{Const}$

$W = nRT \ln \frac{V_2}{V_1} = 2.303\, nRT \log_{10} \frac{V_2}{V_1}$

~~2304~~

$10^3 = \frac{25}{3} \times T \log_{10} 2$

$T = \frac{3 \times 10^3}{25 \log 2} = \cancel{\ldots}$ 400K

63.

19

$P = aV$

$PV^{-1} = a$

$x = -1$

~~Hen~~ Hence $C = C_v + \frac{R}{1-x} = C_v + \frac{R}{2}$

$= \frac{R}{\gamma - 1} + \frac{R}{2}$

$C = \left(\frac{\gamma+1}{\gamma-1}\right)\frac{R}{2}$

$Q = nC\Delta T$

$= \cancel{n}C\left(\frac{a\,9V_0^2}{\cancel{n}R} - \frac{aV_0^2}{\cancel{n}R}\right)$ $P_0 = aV_0$ $PV = nRT$

$aV^2 = nRT$

$T = aV^2$

64. 45

$$nC_V \Delta T = 6300$$

$$nC_V = \frac{6300}{150}$$

Now $\Delta U = n C_V\, 300$

$$= \frac{6300}{150} \times 300 = 12600\ J$$

65. 46

$$nC_P\, 5 = 70$$

$$C_P = \frac{70}{5\times 2} = 7$$

$$C_V = 7 - 2 = 5$$

Q' at Const. Volume $\quad \Delta Q = nC_V\Delta T$

$$= 2\times 5\times 5$$

$$= 50\ \text{Cal.}$$

66. 20

$V = \frac{a}{T^2} \Rightarrow \quad T^2 V = a \quad \leftarrow \quad T = \frac{PV}{nR}$

$$P^2V^3 = a\,n^2R^2$$

$$PV^{3/2} = \sqrt{an^2R^2}$$

$$C = C_V + \frac{R}{1-3/2} \qquad x = 3/2$$

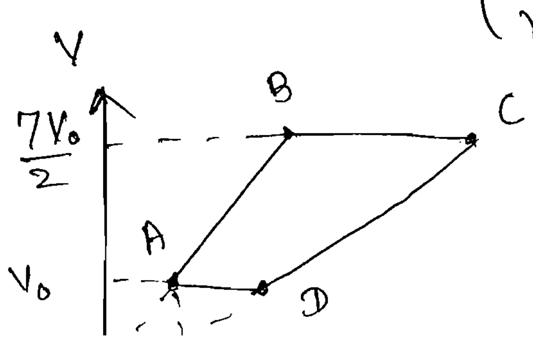
$$C = \frac{R}{\gamma - 1} - 2R = \left(\frac{3-2\gamma}{\gamma-1}\right)R$$

21

$$Q = nC\Delta T = \left(\frac{3-2\gamma}{\gamma-1}\right)R\,\Delta T$$

Ans

67.



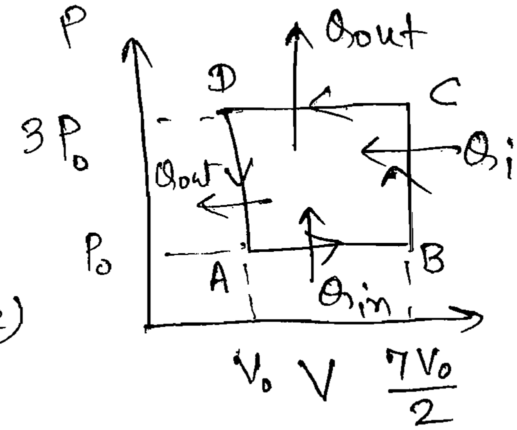
$$P_C = P_D = 3P_0$$

$A \rightarrow B \quad$ Pressure = Const.

$\therefore$ W = Area Under Curve

$$= -\frac{1}{2} 2P_0 \times \frac{5V_0}{2} = -5P_0V_0$$

(Anti clock wise)



$$Q_{in} = Q_{AB} + Q_{BC}$$

$$= nC_p \Delta T_1 + n C_V \Delta T_2$$

$$= n\,4R\,(T_B - T_A) + n\,3R\,(T_C - T_B)$$

$$= 4nR\left(\frac{7}{2}T_0 - T_0\right) + 3nR\left(\frac{21}{2}T_0 - \frac{7}{2}T_0\right)$$

$$= 10nRT_0 + 21nRT_0 = 31nRT_0$$

$C_p = 4R$

$C_V = 3R$

$B \rightarrow C$

$V = \text{Const}$

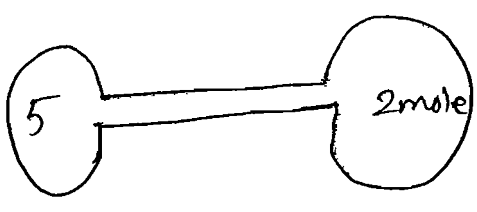
$$\frac{P_B}{T_B} = \frac{P_C}{T_C}$$

$$T_C = \frac{P_C}{P_B} T_B$$

$$= 3 \times \frac{7}{2} T_1$$

68.

22



$T = 35°C$

$P = 1.6 \times 10^5$

$T = 17°C$

$P = 8.3 \times 10^4$

$T_{mix} = 27°C$

35
273
08

(i) Suppose vessel volume = V

$$n_1 = \frac{P_1 V}{RT_1} \qquad n_2 = \frac{P_2 V}{RT_2}$$

finally $p\,2V = (n_1 + n_2) R\,(300)$

(Suppose final pressure p)

$$p\,2\cancel{V} = \frac{\cancel{V}}{\cancel{R}}\left(\frac{P_1}{T_1} + \frac{P_2}{T_2}\right)\cancel{R}\ 300$$

$(.52 + .28) \times 3$

as volume of System is Constant.

$\Delta Q = \Delta U$

$= \Delta U_1 + \Delta U_2$

$= -5 \times \frac{5R}{2} \times 8 + 2 \times \frac{5R}{2} \times 10$

$= -100R + 50R = -50R = -415.7$

(-) sign mean Heat released.

(ii) Heat transfer $= 0$

by energy conservation.

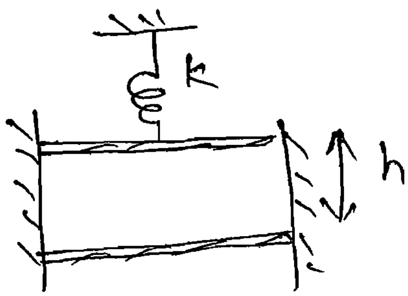
$n_1 C_{V_1} \Delta T + n_2 C_{V_2} \Delta T = 0$

$5 \times \frac{5\cancel{R}}{\cancel{2}} (35 - T) = 2 \times \frac{5\cancel{R}}{\cancel{2}} (T - 17)$

$175 - 5T = 2T - 34$

$7T = 209 \Rightarrow T = 302.851$

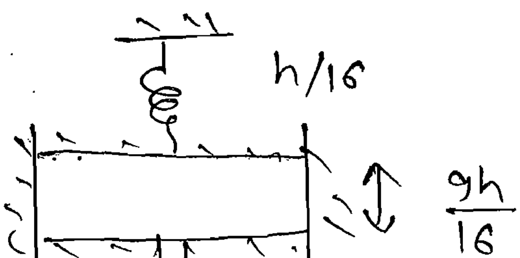
69. 23



$k = 3700 \ N/m$

$A = 27 \ cm^2$

$\gamma = 1.5$



Adiabatic process

$PV^{\gamma} = Const.$

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$$P = \left(\frac{16}{9}\right)^{\gamma} \cdot 1 = \left(\frac{16}{9}\right)^{\frac{3}{2}} \times 1 = \cancel{\quad}\frac{64}{27} \text{ atm}$$

(b) Now

$$TV^{\gamma-1} = k$$

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$273\,(h)^{\frac{1}{2}} = T_2\left(\frac{9h}{16}\right)^{1/2}$$

$$\Rightarrow T_2 = \cancel{2}\,364\,K$$

force balance

$$P = \cancel{\frac{mg}{A}} + P_0 + \frac{kx}{A}$$

$$\cancel{10^5} \times \frac{64}{27} = 1 \times \cancel{10^5} + 37\cancel{00} \times \frac{h}{16 \times 27} \times \cancel{10^4}$$

$$\frac{37}{\cancel{27}} = \frac{\cancel{37}0 \times h}{16 \times \cancel{27}}$$

$$h = 1.6\,m$$

70.

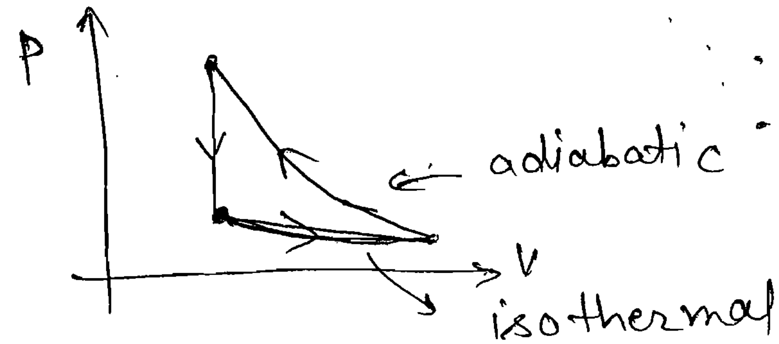
Process -① quickly pused down
no time for Heat exchange.

$\Delta Q = 0 \Rightarrow$ adiabatic process.

process -② Volume remain Constant

process -③ slowly moving up

$\Rightarrow T =$ Constant



Now

Energy gain by ice $= 100 \times 80 = 8000$ Cal.

So Work done $W = 8000$ cal.

71.

(a) W_{AD} = Area under Curve

$= \frac{1}{2}(1.3 - .2)(1.6 \times 10^5) \times 10^{-3}$

$= \frac{1.1 \times 1.6 \times 10^5 \times 10^{-3}}{2} = 88$ J.

(b) $W_{DC} + W_{AD} = 85$

$W_{DC} = -3\text{ J} = \frac{1}{2}(V_c - 1.3)(.3 + .6) \times 10^2$

$-3 = 45(V_c - 1.3)$

$V_c = 1.3 - \frac{3}{45} = 1.3 - \frac{1}{15}$

$= 1.223$ lit

(c) $W_{CDA} = -W_{ADC}$

$= -85$ J.

72.

$P \propto \frac{1}{T} \Rightarrow PT = k \Rightarrow P^2V = k_1$

$PV^{1/2} = k_2$

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

C = Molar Heat Capacity.

$$= \frac{3R}{2} + 2R = \frac{7R}{2}$$

$$\text{specific heat} = \frac{7R}{2M}$$

(ii). $Q = W + \Delta U$

$$W = Q - \Delta U = n\frac{7R}{2}\Delta T - n\frac{3R}{2}\Delta T$$

$$= 2nR\Delta T \quad 4R\Delta T$$

(n = 2 mole

73.

$$U = a\sqrt{V}$$

$$nRT = a\sqrt{V}$$

$$\frac{T}{\sqrt{V}} = K \qquad \frac{PV}{\sqrt{V}} = K_1 \Rightarrow PV^{1/2} = K$$

$$x = \frac{1}{2}$$

$$C = C_V + \frac{R}{1-\frac{1}{2}} = \frac{5R}{2} + 2R = \frac{9R}{2} = 4.5R$$

now $\Delta U = 100$

$$n\frac{5R}{2}\Delta T = 100$$

$$n\Delta T = \frac{40}{R}$$

~~W = Q - ΔU =~~

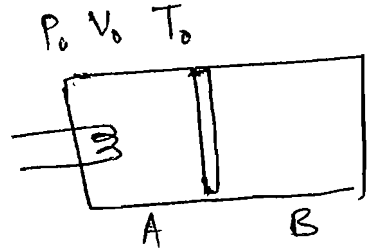
$$Q = nC\Delta T$$

$$= \frac{40}{R} \times \frac{9R}{2} = 180\,J.$$

74.

Adiabatic process. (B) for other container

$PV^{\gamma} = k.$



$\gamma = \frac{5}{3}.$

$\cancel{\frac{T}{V}V^{\gamma} = k}$ $\qquad P\left(\frac{T}{P}\right)^{\gamma} = k_1$

$\cancel{TV^{\gamma-1}}$

$$P^{1-\gamma}\,T^{\gamma} = k_1$$

$$P_1^{1-\gamma}\,T_1^{\gamma} = P_2^{1-\gamma}\,T_2^{\gamma}$$

$$P_0^{-\frac{2}{3}}\,T_0^{\frac{5}{3}} = \left(\frac{243P_0}{32}\right)^{-\frac{2}{3}} T_2^{5/3}$$

$$T_0\left(\frac{243}{32}\right)^{\frac{2}{\cancel{3}}\times\frac{\cancel{3}}{5}} = T_2 \Rightarrow \frac{9}{4}T_0$$

Volume of Container (B)

$$\cancel{P_0}V_0^{\gamma} = \left(\frac{243}{32}\right)\cancel{P_0}\ V^{\gamma}$$

$$V = V_0\left(\frac{243}{32}\right)^{1/\gamma}$$

$$\frac{1}{V} = \frac{1}{V_0}\left(\frac{243}{32}\right)^{3/5} = \frac{27}{8}\ \ \frac{8V_0}{27}$$

then final Volume of Container 'A'

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

final temp. of A $\Rightarrow$ (n = moles remains const.)

$$\frac{P_0\cancel{V_0}}{RT} = \frac{243P_0 \times 46\cancel{V_0}}{32\times 27\,R\,T_A}$$

$\therefore$ for Container 'B' as $P_0V_0 = RT_0$

$$W = -\frac{nR\,\Delta T}{\gamma-1} = -\frac{R\left(\frac{9}{4}T_0 - T_0\right)}{2/3}$$

$$= -\frac{15 P_0 V_0}{8}$$

(Adiabatic process.)

75. Adiabatic process

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$75\,(100)^{\frac{7}{5}} = 80\,(V_2)^{7/5}$$

$$V_2 = \left(\frac{75}{80}\right)^{\frac{5}{7}} \times 100 = 95.5$$

$$W = \frac{P_1V_1 - P_2V_2}{\gamma-1} = -.46 \text{ Joule.}$$

76. (a) Slowly Compressed $\Rightarrow$ Isothermal process

$$P_0V_0 = P_1\,\frac{V_0}{2} \Rightarrow P_1 = 2P_0$$

then, Suddely Compressed $\Rightarrow$ adiabatic process.

$$(2P_0)\left(\frac{V_0}{2}\right)^{\gamma} = P_2\left(\frac{V_0}{4}\right)^{\gamma}$$

$$P_2 = 2P_0 \times 2^{\gamma}$$

(b) Suddenly Compressed → adiabatic

$$P_0 V_0^{\gamma} = P_1 \left(\frac{V_0}{2}\right)^{\gamma}$$

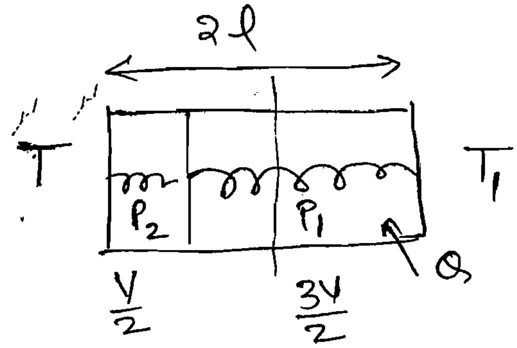
$$P_1 = 2^{\gamma} P_0$$

Slowly Compressed → Isothermal

$$(2^{\gamma} P_0) \frac{V_0}{2} = \frac{V_0}{4} P_2$$

$$P_2 = 2^{\gamma} (2P_0)$$

77.



(final temp.)

force $\quad P_1 A = P_2 A + 2K\frac{l}{2}$

for left Cabin

$$n = \frac{PV}{RT}$$

as T is Const. Isothermal process

$$PV = P_2 \frac{V}{2}$$

$$\Rightarrow P_2 = 2P$$

Right Cabin

therefore,

$$P_1 = P_2 + \frac{Kl}{A}$$

$$P_1 = 2P + \frac{Kl}{A}$$

$$n = \frac{PV}{RT} = \frac{P_1 \frac{3V}{2}}{RT_1}$$

$$T_1 = \frac{3P_1 V}{2nR}$$

$$T_1 = \frac{3V}{2nR}\left(2P + \frac{Kl}{A}\right)$$

choose vessel as a system

(Volume Constant $W_{gas} = 0$)

$$Q = Q' + \left[\frac{1}{2}k\left(\frac{l}{2}\right)^2\right] \times 2 + \Delta U$$

$$Q = Q' + \frac{kl^2}{4} + nC_V(T_1 - T)$$

left cap in at const. Temp $\Delta U = 0$

$PV = nRT$

$V = lA$

$$Q = Q' + \frac{kl^2}{4} + n\frac{3R}{2}\left(\frac{3PV}{nR} + \frac{3klV}{2nRA} - T\right)$$

$$= Q' + \frac{kl^2}{4} + \frac{9nRT}{2} + \frac{9}{4}kl^2 - \frac{3}{2}nRT$$

$$Q = Q' + 3nRT + \frac{5}{2}kl^2$$

$$Q' = Q - 3nRT - \frac{5}{2}kl^2$$ Ans

78. Work done = Area Under Curve

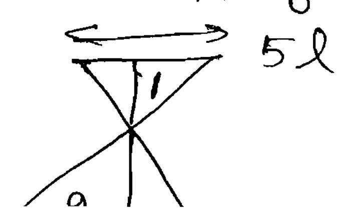
$P_1 = 10^5$, $P_0 = 3\times10^5$, $P_2 = 4\times10^5$

$V_2 - V_1 = 10\ l$

Area of triangle $\Delta 012 \Rightarrow \frac{1}{2}\times 10\times10^{-3}\times(P_0 - P_1)$

$$= \frac{10^{-2}\times 2\times10^5}{2} = 10^3\ J.$$

from triangle

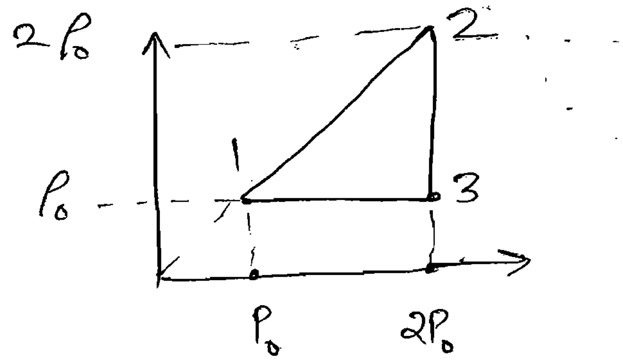


Area of triangle

$\Delta 034 = \frac{1}{2}\times5\times10^{-3}\times10^5$

79.

$$P = \frac{\rho R T}{M}$$



$1 \to 2$ $\quad P \propto \rho$

so T const.

$$W = nRT \ln\frac{V_2}{V_1} = P_1V_1 \ln\frac{V_2}{V_1}$$

$$= \frac{P_0 M}{\rho_0} \ln\left(\frac{m/V_1}{m/V_2}\right)$$

$$= P_0 - \frac{P_0 M}{\rho_0} \ln(2)$$

$\rho_0 = \frac{m}{M_0}$

$\cancel{\frac{nRT}{V} = \frac{mRT}{VM_0} = \frac{\rho_0 RT}{M_0}}$

$\frac{m}{V_1} = \rho_0$

$\frac{m}{V_2} = 2\rho_0$

W_{2-3} = Const. pressure

$$W = 2P_0(V_3 - V_2)$$

$$= 2MP_0\left(\frac{V_3}{M} - \frac{V_2}{M}\right) = 2P_0M\left(\frac{1}{\rho_0} - \frac{1}{2\rho_0}\right)$$

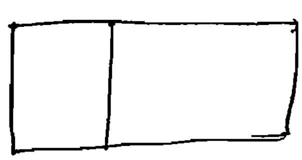
$$= -\frac{2P_0M}{2\rho_0} = -\frac{P_0M}{\rho_0}$$

$3 \to 1$ Const. density

$\Rightarrow$ Const. Volume

$W = 0$

80.



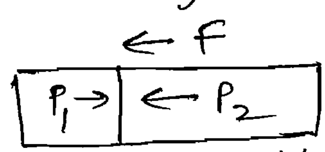
$V \qquad 7V$

$\frac{V_0}{4} \qquad \frac{7V_0}{4}$

$$8V = 2V_0$$

$$\Rightarrow V = \frac{V_0}{4}$$

at any Instant



$$\frac{F}{A} + P_2 = P_1$$

Right chamber $P_2(2V_0 - V) = nRT$

$$P_2 = \frac{nRT}{2V_0 - V}$$

left chamber $P_1 = \frac{nRT}{V}$

$$\cancel{dQ}^{0} = dw + dU$$ (Insulated Vessel)

$$-dw_{ext} = +dU$$

$$-(P_1 - P_2)\,dV = 2n\,C_V\,dT$$

$$-\left(\frac{nRT}{V} - \frac{nRT}{2V_0 - V}\right)dV = 2n\,C_V\,dT$$

$$-R\int_{V_0}^{V_0/4}\left(\frac{1}{V} - \frac{1}{2V_0 - V}\right)dV = \int_{300}^{T} 2\,C_V\frac{dT}{T}$$

$$C_V = \frac{R}{\gamma - 1} = \frac{3R}{2}$$

Solve $T = 395$ K.

81.

$$\eta = 1 - \frac{|Q_{out}|}{|Q_{in}|} = 1 - \frac{Q_{D\to A}}{Q_{B\to C}}$$

$$= 1 - \frac{nC_V(T_4 - T_1)}{nC_P(T_3 - T_2)}$$

$$= 1 - \frac{1}{\gamma}\frac{(T_4 - T_1)}{(T_3 - T_2)}$$

82.

$$P = \alpha V \Rightarrow PV^{-1} = \alpha$$

$$x = -1$$

$$PV = n_1 RT$$

$$\alpha V^2 = n_1 RT$$

$$T = \frac{\alpha V^2}{n_1 R}$$

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

(b) $W = \int P\,dV = \left[\frac{\alpha V^2}{2}\right]_{V_0}^{nV_0}$

$$= \frac{\alpha V_0^2 (n^2 - 1)}{\alpha}$$

(a) $\Delta U = n_1 C_V \Delta T$

$$= n_1 \frac{R}{\gamma - 1}\left(\frac{\alpha n^2 V_0^2}{n_1 R} - \frac{\alpha V_0^2}{n_1 R}\right)$$

$$= \frac{\alpha V_0^2 (n^2 - 1)}{(\gamma - 1)} \quad \text{Ans.}$$

83.

W = Area Under the Curve

$$= \pi R^2 = \pi \frac{6}{2} \times 10^{-3} \times \frac{4 \times 10^5}{2}$$

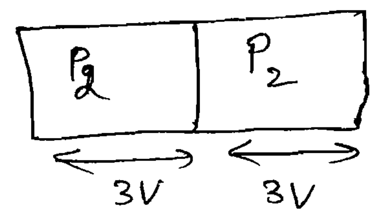
$$= 6\pi \times 10^2 \text{ Joule}$$

84.

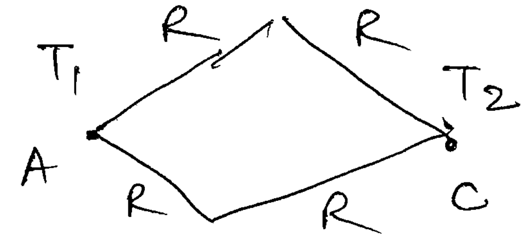
process isothermal

$T =$ constant

$P_1V_1 = P_2V_2$



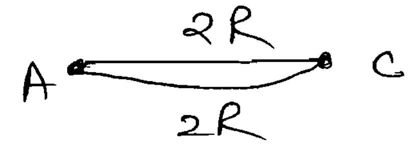
85.



Suppose

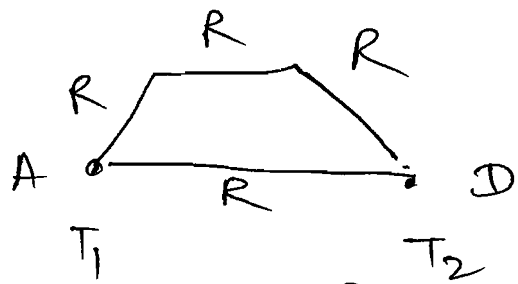
thermal Resistance of every rod = R

$R_{eff} = R$



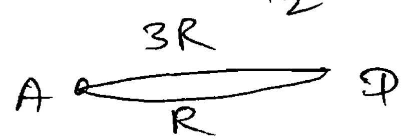
$\omega = \dfrac{T_1 - T_2}{R}$

Now



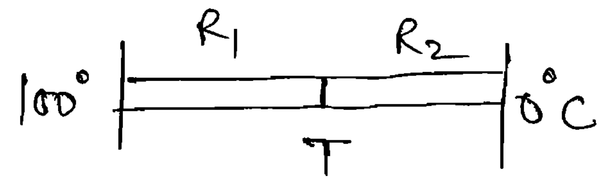
$R_{eff} = \dfrac{3R \times R}{4R}$

$= \dfrac{3R}{4}$



$\omega_1' = \dfrac{T_1 - T_2}{3R/4} = \dfrac{4}{3}\omega$ Ans

86.

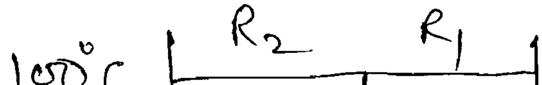


Suppose thermal Resistance = R_1, R_2

$i = \dfrac{dQ}{dt} = \dfrac{100 - T}{R_1} = \dfrac{T - 0}{R_2} \Rightarrow \dfrac{30}{R_1} = \dfrac{70}{R_2}$

$\dfrac{R_2}{R_1} = \dfrac{7}{3}$

Now they are interchanged



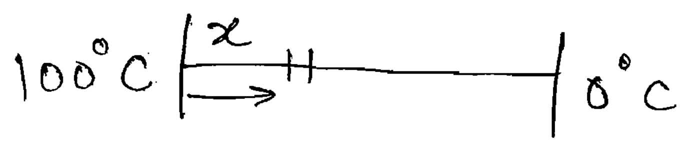
$i = \dfrac{dQ}{} \quad 100 - T \quad T - 0$

$$\frac{100-T}{T} = \frac{7}{3}$$

$$300 - 3T = 7T \Rightarrow T = 30^\circ C$$

Ans

87.



at steady state $i = \text{Const.} = \frac{dQ}{dt} = \frac{KA(100)}{L}$

therefore $\frac{dT}{dx} = \frac{(100-0)}{0-L}$

$$= \frac{-100}{l} = -100$$

(b) take 'dx' portion at a distance x from Hot end

$$T_f = -\frac{100^\circ C}{L}x + 100^\circ C$$

as $\frac{dT}{dx} = \text{Const.}$

T V/s x Linear Curve.

$$T_i = 0^\circ C$$

Energy absorbed by this 'dx' part is

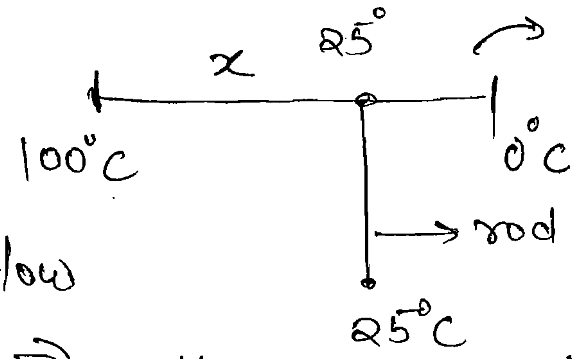
$$dQ = dms\,\Delta T = (\lambda dx)\, s \left(-\frac{100x}{L} + 100\right)$$

$$Q = \int dQ = \int_0^L \left(100 - \frac{100x}{L}\right) s\lambda\, dx$$

$$= s\lambda \left[100x - \frac{100x^2}{2L}\right]_0^L$$

$$= s\lambda \left[100L - \frac{100L}{2}\right] = s\lambda \frac{100L}{2}$$

88.



no Heat flow

$\Rightarrow$ other end should be also at 25°C.

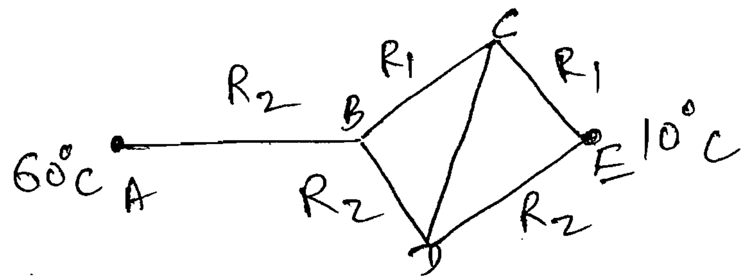
$$\frac{dT}{dx} = \frac{100-0}{0-1} = -100 = \frac{100-25}{0-x}$$

$$x = \frac{75}{100} = \frac{3}{4} = .75\,m$$

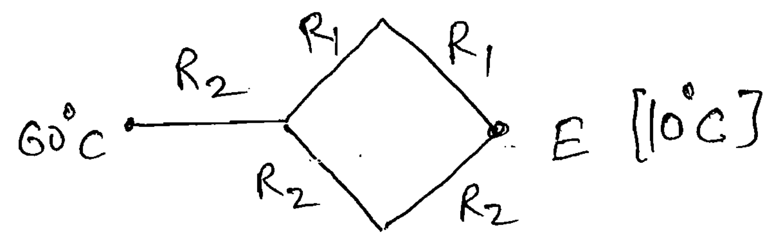
89.

Suppose Rod 'x' has thermal Resistance = R

& Rod 'y' has thermal Resistance = R_2

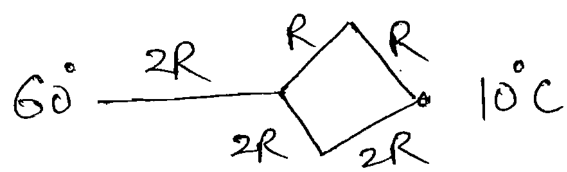


from wheat stone bridge property, we can say there is no ~~...~~ Heat Current from C → D



$R_1 = \frac{L}{.92A} = 1$

$R_2 = \frac{L}{.46A} = 2$



$$i = \frac{60-10}{10R/3} = \frac{50 \times 3}{10R} = \frac{15}{R}$$

Now $A \rightarrow B$

$$i = \frac{60 - T_B}{2\cancel{R}} = \frac{15}{\cancel{R}}$$

$$T_B = 30^\circ C$$

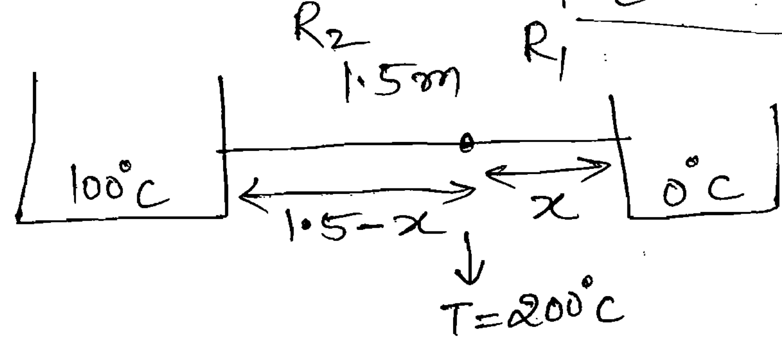
$B \rightarrow C$, & $C \rightarrow D$

same current will flow.

$$\frac{30 - T_C}{\cancel{R}} = \frac{T_C - 10}{\cancel{R}}$$

$$T_C = \frac{40}{2} = 20^\circ C = T_D$$

90.



rate at which ice melting $= m_1$

= rate at which steam is forming

Power / Heat Current absorbed by ice $= m_1 L_f$

Power / Heat Current absorbed by water $= m_1 L_V$

Now ... $= 200°C - 0°C$. $m_1 L_V = \frac{200-100}{\ldots}$

$$m_1 L_f = \frac{200}{R_1} \quad \text{—(1)} \qquad m_1 L_V = \frac{100}{R_2} \quad \text{—(2)}$$

$$R_1 = \frac{x}{KA} \qquad R_2 = \frac{1.5-x}{KA}$$

$$\frac{(2)}{(1)} = \frac{L_V}{L_f} = \frac{100\, R_1}{R_2 \times 200} = \frac{R_1}{2R_2}$$

$$\frac{54\cancel{0}}{8\cancel{0}} = \frac{x}{2(1.5-x)} = \frac{x}{3-2x}$$

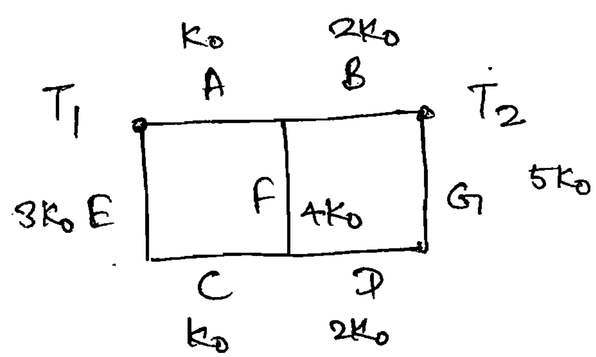
$$\frac{27}{4} = \frac{x}{3-2x}$$

$$27(3-2x) = 4x$$

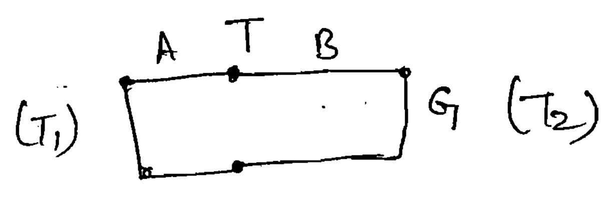
$$x = \frac{27 \times 3}{4+54} = \frac{81}{58} = \cancel{\ldots}\ m$$

$$= 1.396\ m$$

91.



Using wheatstone property, we can say that there is no Heat Current through rod F.



Suppose juction temp. = T

at steady state — i = Heat Current

$$(T - T_1) = 2(T_2 - T)$$

$$3T = 2T_2 + T_1$$

$$T = \frac{2T_2 + T_1}{3}$$

$$i_B = \frac{2K_0 A (T_2 - T)}{L} = \frac{2K_0 A}{L}\left(T_2 - \frac{2T_2 + T_1}{3}\right)$$

$$= \frac{2K_0 A}{L}\left(\frac{T_2 - T_1}{3}\right)$$

by Symmetry

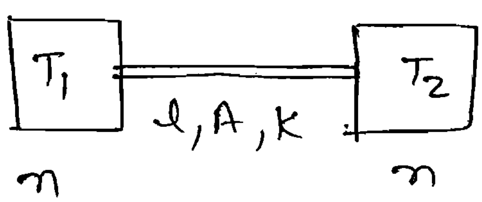
$$i_B = i_D$$

total rate of Heat flow from Rod G

$$= i_B + i_D = \frac{4K_0 A}{L}\frac{(T_2 - T_1)}{3}$$

So Source has to supply same Heat.

92.



$T_1 > T_2$

Suppose at any time temp. of vessels are θ_1 & θ_2.

then Rate of Heat flow through rod

$$dQ = KA(\theta_1 - \theta_2) \quad \text{—(1)}$$

also by Energy Conservation.

~~Heat~~ Energy lost in vessel A

$= $ Energy gain by Vessel 'B'

$$m C_v (T_1 - \theta_1) = m C_v (\theta_2 - T_2)$$

$$T_1 - \theta_1 + T_2 = \theta_2 \quad \text{—(2)}$$

Subs. in eq. (1)

$$\frac{d\theta}{dt} = \frac{KA}{L}\left[\theta_1 - (T_1 - \theta_1 + T_2)\right]$$

$$\frac{d\theta}{dt} = \frac{KA}{L}\left[2\theta_1 - T_1 - T_2\right] \quad \text{—(3)}$$

Suppose vessel 'A' loss $d\theta$ in dt' time.

then, $\quad dQ = m C_v d\theta_1$

or $\quad \frac{dQ}{dt} = -m C_v \frac{d\theta_1}{dt} \quad \text{—(4)}$

put (4) in eq (3)

$$m C_v \frac{d\theta_1}{dt} = -\frac{KA}{L}(2\theta_1 - T_1 - T_2)$$

$$\int_{T_1}^{\theta_1} \frac{d\theta_1}{(2\theta_1 - T_1 - T_2)} = \int_0^t \frac{-KA}{mLC_v}\, dt$$

$$\ln(2\theta_1 - T_1 - T_2)\Big]_{T_1}^{\theta_1} = \frac{-KA}{mLC_v}\, t$$

$$2\theta_1 - T_1 - T_2 \qquad -2KA \qquad t$$

$$2\theta_1 = T_1 + T_2 + (T_1 - T_2)\, e^{-\frac{KA}{nLC_v} t}$$

~~as from~~

temp. diff. b/w two vessels.

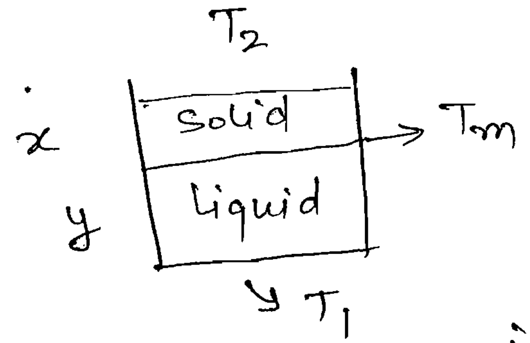
$$\theta_1 - \theta_2 = \theta_1 - (T_1 - \theta_1 + T_2)$$ using eq. (2)

$$= 2\theta_1 - T_1 - T_2$$

$$= (T_1 - T_2)\, e^{-\frac{2KA}{nLC_v} t}$$

$$= (T_1 - T_2)\, e^{-\frac{4KA}{3nRL} t}$$

93.



m (conductivity)

K m (conductivity)

at steady state $i =$ Constant

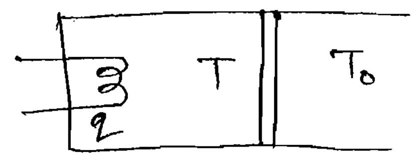
$$\frac{dQ}{dt} = \frac{(T_1 - T_m) K \cancel{m} A}{y} = \frac{(T_m - T_2) \cancel{m A}}{x}$$

$$\text{fraction} = \frac{y}{x+y} = \frac{y}{\frac{(T_m - T_2)\, y}{K(T_1 - T_m)} + y} = \frac{(T_1 - T_m) K}{K(T_1 - T_m) + (T_m - T_2)}$$

Ans

94.

94.



Suppose at any time vessel volume is V & temp = T

pressure would be remain same both side of the piston.

there fore
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$
$$\frac{V_0}{T_0} = \frac{V}{T} \quad \text{—①}$$

$$\frac{dQ_{in}}{dt} = q$$

$$\frac{dQ_{out}}{dt} = \frac{KA}{L}(T - T_0)$$

$$\frac{dQ_{absorb}}{dt} = \frac{dQ_{in}}{dt} - \frac{dQ_{out}}{dt}$$

$$nC_p \frac{dT}{dt} = q - \frac{KA}{L}(T - T_0)$$

$$\int_{T_0}^{T} \frac{nC_p\, dT}{q - \frac{KA}{L}(T - T_0)} = \int_0^t dt$$

$$-\frac{nC_pL}{KA} \ln\left[q - \frac{KA}{L}(T - T_0)\right]_{T_0}^{T} = t$$

$$\frac{q - \frac{KA}{L}(T - T_0)}{q} = e^{-\frac{KA}{nC_pL}t}$$

(b) temp will be max at $t \to \infty$

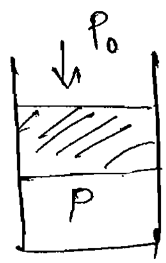
$$T_{max} = \cancel{KQ}\ \frac{LQ}{KA} + T_0$$

(c) from eq (1) $\quad \frac{V}{T} = \frac{V_0}{T_0}$

$$\frac{V_{max}}{V_0} = \frac{\cancel{V_0}}{T_0} T_{max} = \frac{LQ}{KA T_0} + 1$$

95.

$P = P_0 + \rho L g$



as pressure is constant.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad -(1)$$

$$\frac{dQ}{dt} = \frac{KA}{L}(T - T_0) = -nC_p \frac{dT}{dt}$$

$$-\frac{nC_pL}{KA}\int_{T_1}^{T} \frac{dT}{(T-T_0)} = \int dt$$

$$\left[\ln(T-T_0)\right]_{T_1}^{T} = -\frac{KA}{nC_pL}t$$

$$\frac{T-T_0}{T_1-T_0} = e^{-\frac{KA}{nC_pL}t}$$

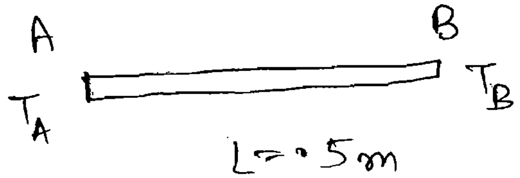
$$\boxed{\begin{aligned} PV_0 &= nRT_1 \\ \frac{V_0}{T_1} &= \frac{nR}{P} \end{aligned}}$$

using eq (1)

$$A\frac{V_0}{T_1} = \frac{Al}{T} \Rightarrow l = \frac{TV_0}{T_1 A}$$

$$l = \frac{V_0}{T_1 A}\left[T_0 + (T_1 - T_0)e^{-\frac{KA}{nC_pL}t}\right]$$

96.



$K = 17$

$\lambda_0 = 75000 \mathring{A}$

$e = 1$

from $\lambda T = b$

$$T_B = \frac{b}{\lambda} = \frac{.288 \text{ cm K}}{75 \times 10^3 \times 10^{-8} \text{ cm}} = \frac{28800}{75} \text{ K} = 384$$

$$\frac{dQ}{dt} = \frac{(T_A - T_B)\, 17 \cancel{A}}{.5} = e \sigma \cancel{A} (T_B)^4$$

$$(T_A - T_B) = \frac{1}{2} \times 5.67 \times 10^{-8} \times \left(\frac{28800}{75}\right)^4$$

$$T_A = 420.2 \text{ K}$$

97.

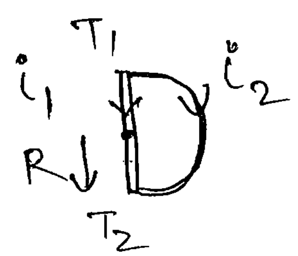
Heat loss due to radiation

$$= e \sigma A T^4$$

$$= .25 \times 5.67 \times 10^{-8} \times .15 \times .12 \, (873)^4$$

$$= 148.201 \text{ W}$$

98.



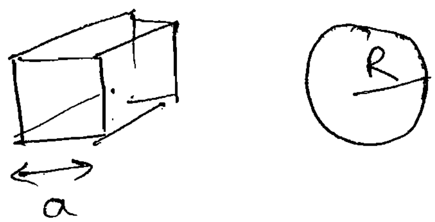
A, K

$$i_1 = \frac{KA}{2R}(T_1 - T_2)$$

$$i_2 = \frac{KA(T_1 - T_2)}{\pi R}$$

$$\frac{i_2}{i_1} = \frac{2}{\pi}$$

99.



both has same mass $\Rightarrow \cancel{\rho} a^3 = \cancel{\rho} \frac{4}{3}\pi R^3$

$$a = \left(\frac{4}{3}\pi\right)^{\frac{1}{3}} R$$

Now

$$\frac{\left(\frac{dT}{dt}\right)_{cube}}{\left(\frac{dT}{dt}\right)_{sphere}} = \frac{ms\left(\frac{dT}{dt}\right)_{cube}}{ms\left(\frac{dT}{dt}\right)_{sphere}}$$

$$= \frac{(dQ/dt)_{cube}}{(dQ/dt)_{sphere}}$$

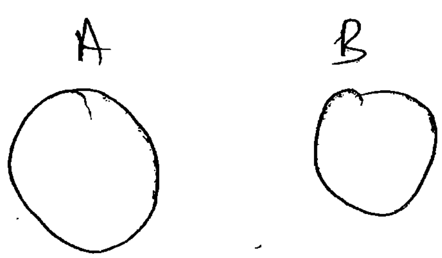
$$= \frac{e\sigma A_1 T^4}{e\sigma A_2 T^4} = \frac{A_1}{A_2}$$

$$= \frac{6a^2}{4\pi R^2} = \frac{6}{4\pi} \times \left(\frac{4\pi}{3}\right)^{\frac{2}{3}}$$

$$= \frac{3}{2\pi} \times \left(\frac{16\pi^2}{9}\right)^{1/3}$$

$$= \left(\frac{27}{\cancel{4}\,8\,\pi^2} \times \frac{16\pi^2}{9}\right)^{1/3}$$

$$= \left(\frac{6}{\pi}\right)^{1/3}$$



100. let assume 1, 1, 1 $\quad \alpha, \beta, \gamma$

$$\frac{dQ}{dt} = ms\frac{dT}{dt} = e\sigma A T^4$$

ration $\quad \frac{m_1 s_1 (dT/dt)_1}{m_2 s_2 (dT/dt)_2} = \frac{A_1}{A_2}$

$$= \frac{\cancel{\frac{4}{3}\pi} R_2^3 \rho_2 S_2 \; 4\pi R_1^2}{\cancel{\frac{4}{3}\pi} R_1^3 \rho_1 S_1 \; 4\pi R_2^2}$$

$$= \frac{R_2 \rho_2 S_2}{R_1 \rho_1 S_1} = \frac{\alpha\beta\gamma}{1}$$

(ii) $$\frac{\frac{d\theta_1}{dt}}{\frac{d\theta_2}{dt_1}} = \frac{A_1}{A_2} = \frac{4\pi R_1^2}{4\pi R_2^2} = \frac{1}{\alpha^2}$$

Q 10

$m_{liquid} = 88$ gm

$W = 13$ gm

Power produced by coil $= 6.3 \times 2 = 12.6$

$\frac{dQ}{dt}$ when steady state reached

power produced by coil = power loss to surrounding

So just after switched off,

$$\frac{dQ}{dt} = 12.6$$

$$(88 \times S + 13 \times 1)\frac{dT}{dt} = \frac{12.6}{4.2} = 3$$

$(88 \times S + 13) \times 3.6 = 3$

(b) ~~Rate of Cooling Heat loss~~ $\cancel{= \frac{dQ}{dt} = c(T-T_s)}$

Rate of Cooling $\frac{dT}{dt} = c\,(T - T_s)$

Power produced by Heater = power loss to surroundings

$$I^2R = ms\frac{dT}{dt}$$

$$\frac{I_1^2R}{I_2^2R} = \frac{(dT/dt)_1}{(dT/dt)_2} = \frac{c(T-T_s)_1}{c(T-T_s)_2} = \frac{55-10}{55-26}$$

$$\frac{I_1}{I_2} = \sqrt{\frac{45}{29}}$$

$$I_2 = 2\times\sqrt{\frac{29}{45}} = 1.60\ \text{A}$$

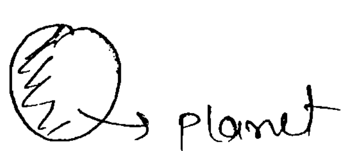
102

$$\frac{dQ}{dt} = E = e\sigma AT^4 = \frac{dm}{dt}c^2$$

$$\frac{dm}{dt} = \frac{1\times 5.67\times10^{-8}\times 4\pi\times 49\times10^{16}\times\left(\frac{.288}{.483\times10^{-4}}\right)^4}{9\times10^{16}}$$

$$= 4.9\times10^{9}\ \text{kg/sec}$$

103. Intensity $I = \frac{P}{A}$



Suppose planet absorbs Heat on Area A_1

Energy absorbed = Energy released

$$IA_1 t = e\sigma A_1 T^4 t$$

$$\frac{P}{4\pi r^2} A_1 t = e\sigma A_1 T^4 t \qquad \text{—— (1)}$$

$$\frac{e\sigma A (6200)^4}{4\pi (r^2)} = e\sigma \cancel{A} T^4$$

$$T = 6200 \times \left(\frac{A}{4\pi r^2}\right)^{1/4}$$

$$= 6200 \times \left(\frac{4\pi R_{sun}^2}{4\pi r^2}\right)^{1/4}$$

$$= 6200 \times \left(\frac{6.9 \times 10^8}{1.5 \times 10^{11}}\right)^{1/2}$$

$$T = 420.5 K$$

(b) if both side radiate then

Replace A_1 by $\rightarrow 2A_1$

$$T = \frac{420.5}{2^{1/4}} = 353.6 K$$

104. using average form of Newton's law of cooling.

$$\frac{\Delta T}{\Delta t} = c\,(T_{mean} - T_s)$$

10 ... —— (1)

$$\frac{10}{t} = c\left(55 - 30\right) \quad -②$$

$$\frac{①}{②} \Rightarrow \frac{t}{5} = \frac{35}{25}$$

$$t = 7 \text{ min}$$

105. again

$$\frac{10}{10} = c\left(55 - 25\right) \quad -①$$

$$\frac{50-T}{10} = c\left(\frac{50+T}{2} - 25\right) \quad -②$$

$$\frac{①}{②} \Rightarrow \frac{\cancel{10}}{50-T} = \frac{3\cancel{0} \times 2}{T}$$

$$T = 300 - 6T$$

$$T = \frac{300}{7} = 42.87^\circ C$$

106.

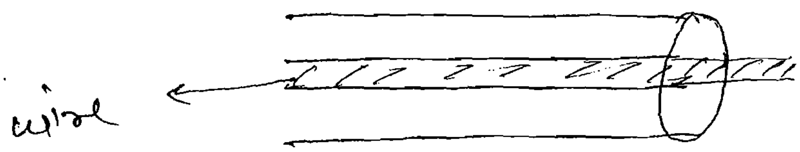
$$P = e\sigma A T^4$$

$$25 = .3 \times 5.67 \times 10^{-8} \times A \times (2000)^4$$

$$A = \frac{25}{.3 \times 5.67 \times 16 \times 10^4} = 9.185 \times 10^{-5} \, m^2$$

$$=$$

107.



$d_1 = 5 \times 10^{-4}$

$d_2 = .12\,m$

$$\cancel{\frac{dQ}{dt} = \frac{KA(1480)}{L}} = 3 \times 10^3$$

$$= \cancel{K\, 4\pi R_1 R_2} = K.$$

In a Cylinder, Heat

$$H = \frac{dQ}{dt} = \frac{2\pi L K (\theta_1 - \theta_2)}{\ln(b/a)}$$

$$3 \times 10^3 = \frac{2\pi \times 1 \times K\ (1480)}{\ln\left(\frac{.12}{5 \times 10^{-4}}\right)}$$

$$K = \frac{3000\ \ln\left(\frac{.12 \times 10^4}{5}\right)}{2\pi \times 1480}$$

$$= 1.77 \quad \text{Ans}$$

108.

rate of net heat loss $= e\sigma A(T^4 - T_s^4)$

$= 1 \times 5.67 \times 10^{-8} \times 4\pi \times 4 \times 10^{-4} \left((400)^4 - (373)^4\right]$

$= 1.78\ J/sec$

109.

$210 = e\sigma A\left((500)^4 - (300)^4\right)$

$700 = \sigma A\left((500)^4 - (300)^4\right)$

$e = \frac{21\cancel{0}}{70\cancel{0}} = \frac{3}{10} = .3$

110. body will energy till its' temp. = surrounding temp.

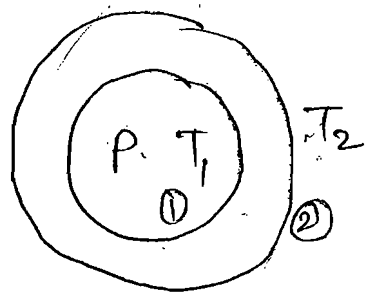
(a) $Q = ms(\theta_1 - \theta_0)$ Ans.

(b) $\int \frac{-d\theta}{\theta - \theta_0} = \int K\,dt \Rightarrow \left[\ln(\theta - \theta_0)\right]_{\theta_1}^{\theta} = -Kt$

$ms(\theta_1 - \theta) = .9\ ms(\theta_1 - \theta)$

111.

initially



$$P = \sigma A (500)^4$$

finally.

for surface ②

$$\sigma A T_1^4 = 2A \sigma T_2^4$$

$$T_1 = 2^{1/4} \cdot T_2$$

for surface ①

$$\sigma A (500)^4 + A\sigma T_2^4 = A\sigma T_1^4$$

$$\sigma A (500)^4 + A\sigma T_2^4 = 2A\sigma T_2^4$$

$$T_2 = 500\ k$$

$$T_1 = 2^{1/4}\ 500 = 595\ k$$

Window to IIT - Jee (Objectives)

1.

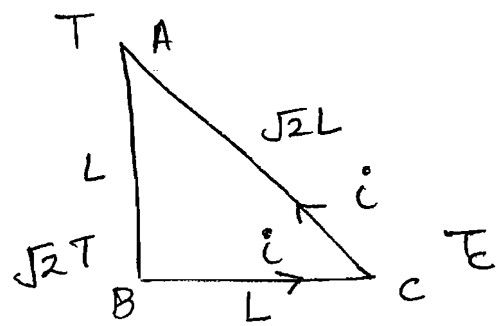
$PV = nRT$

$PdV = nR\,dT$ Now $\gamma = \dfrac{\Delta V}{V\,\Delta T}$

$= \dfrac{\Delta T}{T\,\Delta T} = \dfrac{1}{T}$

for a given Temp. all gas have same coefficient of volume expansion. (A)

2.



$\dfrac{\cancel{KA}(\sqrt{2}T - T_c)}{\cancel{L}} = \dfrac{(T_c - T)\cancel{KA}}{\sqrt{2}\cancel{L}}$

$2T - \sqrt{2}T_c = T_c - T$

(B) $T_c = \dfrac{3T}{1+\sqrt{2}}$

3.

Power loss $\dfrac{dQ}{dt} = e\sigma A T^4$

also $dQ = mc\,dT$

$\dfrac{\Delta T}{dt} = \dfrac{e\sigma A T^4}{mc}$

$m = \frac{4}{3}\pi r^3 \rho$ $A = 4\pi r^2$

$= 4\pi\left(\dfrac{3m}{4\pi\rho}\right)^{2/3}$

$\dfrac{\Delta T}{\Delta t} = k\left(\dfrac{1}{m}\right)^{1/3}$

so $\left(\Delta T/\Delta t\right)_1 = 1 : 1)^{1/3}$ (d)

4.

Average $K.E = \frac{3}{2} kT$

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

Now temp. is increased by 2 times ($300k \to 600$

So $A.K.E = 2 \times 6.21 \times 10^{-21}$

$= 12.42 \times 10^{-21} J$

V_{rms} increased by $\sqrt{2}$ times. (d)

$\Rightarrow V_{rms} = \sqrt{2} \times 484$

$= 684 \ m/s$

5.

Wien's displacement law

$\lambda_m T = c$.

So $T = c/\lambda_m$

$$\frac{T_{sun}}{T_{star}} = \frac{\lambda_{star}}{\lambda_{sun}} = \frac{350}{510} \approx .69 \quad (b)$$

6.

average $K.E = \frac{3}{2} kT$ which depends only on Temp.

(O_2 & N_2 both)

So $A.K.E$ of $N_2 = .048$ ev (c)

7.

$PV = nRT$

as Temp. is doubled

So pressure is also doubled. (as $n = 1$ mole

(C)

8.

$E_0 = e\sigma A T^4 = e\sigma 4\pi r_0^2 T_0^4$

... is doubled

9.

Total Internal energy

10.

$U = 2\times\frac{5}{2}RT + 4\times\frac{3}{2}RT = 11RT$

(d)

$v_{sound} = \sqrt{\frac{\gamma P}{\rho}}$

$P = \frac{\rho RT}{M}$

$= \sqrt{\frac{\gamma RT}{M}}$

$\frac{V_{N_2}}{V_{He}} = \sqrt{\frac{\cancel{7}}{5\times\cancel{28}}\frac{\cancel{4}}{\times\frac{5}{3}}} = \frac{\sqrt{3}}{5}$

(c)

11.

$V_{sound} \propto = \sqrt{\frac{\gamma RT}{M}}$

$\frac{V_1}{V_2} = \sqrt{\frac{M_2}{M_1}}$ (b)

12.

(as γ is same for both)

$TV^{\gamma-1} = cn.$

$T(AL)^{\gamma-1} = \text{Const} \Rightarrow TL^{\gamma-1} = cn.$

$\frac{T_1}{T_2} = \left(\frac{L_2}{L_1}\right)^{\gamma-1}$

$\frac{T_1 L_1^{\gamma-1}}{T_2 L_2^{\gamma-1}} = 1$

$= \left(\frac{L_2}{L_1}\right)^{\frac{5}{3}-1} = \left(\frac{L_2}{L_1}\right)^{2/3}$ (a)

13.

(a)

14.

$$PV = nRT \quad -①$$

$$P\Delta V = nR\Delta T \quad -②$$

$$\frac{②}{①} \Rightarrow \quad \frac{\Delta V}{V} = \frac{\Delta T}{T}$$

$$\delta = \frac{\Delta V}{V\Delta T} = \frac{1}{T} \qquad (c)$$

15.

W = Area Under the curve

$$W_2 > W_1 > W_3 \qquad (a)$$

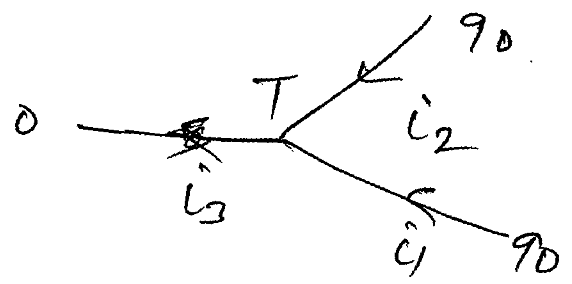
16.

more is the temp., wavelength shift towards left. therefore

$$T_1 > T_3 > T_2$$

(b)

17.



$$i_1 + i_2 = i_3$$

$$\frac{90-T}{R_{th}} + \frac{90-T}{R_{th}} = \frac{T-0}{R_{th}}$$

$$3T = 180^\circ \Rightarrow T = 60^\circ C$$

(A)

18.

$$dQ = \cancel{dW}^{0} + dU$$

as $dQ < 0 \Rightarrow dU < 0$

(a) T is decreasing

19.

$$PV^{\gamma} = \text{Con.}$$

$$P = \frac{\text{Const.}}{V^{\gamma}}$$ more is γ less is pressure.

So 1 represent O_2, $\gamma_{O_2} = \frac{7}{5} = 1.4$

2 represent He, $\gamma_{He} = \frac{5}{3} = 1.67$

(b)

21.

$\beta = -\frac{dP}{\Delta V/V}$

T = Cons. $\Rightarrow$ slope of P–V curve

$$\frac{dP}{dV} = -P/V$$

So $$\beta = -\frac{dV}{V\,dP}$$

$$= -\frac{-V}{VP} = \frac{1}{P}$$ Hyperbola variation

(a)

20

~~$Q = \Delta W + \cancel{\Delta U}^{0}$~~ (as cyclic process)

~~$\Delta W = 5\text{ J}$~~ $W_{C\to A} = \frac{1}{2} \times 10 \times 1 = -5\text{ J}$

(C→A volume decreasing)

(a)

22.

Initially, it will absorb all the radiant Energy incident on it, so it is the darkest one when temp. of black body = temp. of furnace ~~is~~ black body radiates maximum, therefore B.B. is brightest. (a)

23.

$$\left|-\frac{dT}{dt}\right| \propto e$$

from graph $\left(\frac{-dT}{dt}\right)_x > \left(\frac{-dT}{dt}\right)_y$

$\Rightarrow e_x > e_y$

as good absorber is good emitter.

$\Rightarrow a_x > a_y$

(C)

24.

given $\Delta l_1 = \Delta l_2$

$$l_1 \alpha_a t = l_2 \alpha_s t$$

$$\frac{l_1}{l_2} = \frac{\alpha_s}{\alpha_a}$$

$$\frac{l_1}{l_1 + l_2} = \frac{\alpha_s}{\alpha_s + \alpha_a} \quad (C)$$

25.

$AB \Rightarrow T = \text{Const} \Rightarrow$ isothermal ~~($V_C \approx V_B$)~~

$AC \Rightarrow$ adiabatic

$BT \Rightarrow$ isobaric

$P_A > P_B = P_C$

$\Rightarrow T_C > T_B$

$\Downarrow$

$V_C > V_B$

(b)

26.

$\boxed{20^\circ C} \xrightarrow{5\,kg} \boxed{0^\circ C}$ $\quad Q = 5 \times 20 = 100$

$\boxed{-20} \rightarrow \boxed{0^\circ C}$ ice $\quad Q = 2 \times .5 \times 20 = 20$

$\boxed{0^\circ C}$ ice $\rightarrow \boxed{0^\circ C}$ water $\quad Q = 2 \times 80 = 160$

So whole ice wouldn't melt.

Suppose x gm melt

$100 - 20 = x \times 80 \Rightarrow x = 1\,Kg$

amount of water $= 5 + 1 = 6\,Kg$ (b)

27.

$Q = AT^4$ and $\lambda_m T = \text{Const}$.

$$\Rightarrow Q \propto \frac{A}{\lambda_m^4} \propto \frac{r^2}{\lambda_m^4}$$

$$Q_1 : Q_2 : Q_3 = \frac{4}{3^4} : \frac{16}{4^4} : \frac{36}{5^4}$$

28.

$$\frac{dQ}{dt} = \text{Const.} = K$$

now = $$dQ = n C_p \, dT$$

$$\Rightarrow \quad n C_p \frac{dT}{dt} = K$$

$$\frac{dT}{dt} = \frac{K}{nC_p} = \text{Const.}$$

So straight line.

but after some time O_2 Converts ~~from~~ Liquid to gas, during which temp remains constant. So (C)

29.

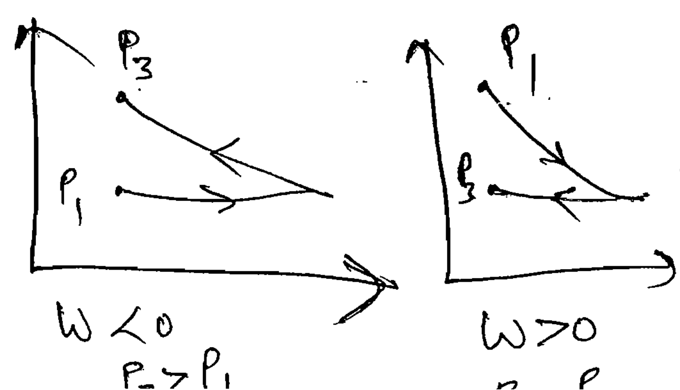
Series $\Rightarrow (R_{th})_2 = R_1 + R_2 = 2R \qquad q_2 = \dfrac{100-0}{2R}$

Parallel $\Rightarrow (R_{th})_1 = \dfrac{R_1 R_2}{R_1+R_2} = \dfrac{R}{2} \qquad q_1 = 100/R/2$

$$\frac{q_2}{q_1} = \frac{1}{4} \qquad (d)$$

30.

(b)



31:

$\lambda_m T = \text{Const.}$

from the graph $T_3 > T_2 > T_1$

Temp. of sum is max.

so option (C)

32: (d) Radiation.

33. ~~amount of Heat absorbed by spherical body = amount of heat radiated.~~

~~$E =$~~

33. (A)

34.

$$\text{net } \frac{dQ}{dt} = \frac{ms\,\Delta T}{t}$$

$$1000 - 160 = \frac{2 \times 4200 \times 50}{t}$$

$$t = \frac{\cancel{4200} \times 100}{\cancel{840}}$$

$$= \frac{1000}{2} = 500 \text{ sec}$$

$\Rightarrow$ 8 min 20 s.

35

$PT^2 = \text{Const.}$ $\left(P = \frac{nRT}{V}\right)$

$\Rightarrow T^3 = KV$

$3T^2 \Delta T = K \Delta V$

$$\gamma = \frac{\Delta V}{V \Delta T} = \frac{3T^2}{VK} \times \frac{T}{T}$$

$$= \frac{3}{T}$$

(C)

Multiple choice

(more than one Correct)

1.

$70 = 2 C_p \Delta T$ $\quad C_p = 7$

$C_v = 5$

$Q = n C_v \Delta T = 2\times5\times5$
$= 50$ cal

(b)

2. Suppose 'm' mass Condensed

$Q = mL + ms\,20 = m(540 + 1\times20) = m\,560$

energy absorbed by water

$Q = 1.12 \times 1 \times 65$

$\therefore m \times 560 = 1.12 \times 65$

(a) $\quad m = .130$ kg

3. $R_1 = \frac{L}{KA} = \frac{L}{K_1 \pi R^2}$

$R_2 = \frac{L}{KA} = \frac{L}{K_2 \pi((2R)^2 - R^2)} = \frac{L}{K_2 \pi 3R^2}$

both are in $\parallel$rd

$R_{eff} = \dfrac{\frac{1}{K_1} \times \frac{1}{3K_2}}{\frac{1}{K_1} + \frac{1}{3K_2}} = \frac{0.1}{4K_{eff}}$ (effective area $4\pi R^2$)

4. b, c, d

5.

$$\frac{\Delta Q}{\Delta U} = \frac{nC_p \Delta T}{nC_v \Delta T} = \gamma = 7/5$$

$$\text{fraction} = \frac{\Delta U}{\Delta Q} = \frac{1}{\gamma} = 5/7 \quad (d)$$

6.

$$V_{av} = \sqrt{\frac{8kT}{\pi m}} \quad \text{so} \quad (V_{avg})_{O_2} = V_1 \quad (b)$$

7. (a, b, d) explained in exercise - 2

8.

$$Q = e_A \sigma A T_A^4 = e_B \sigma A T_B^4$$

$$\cancel{T_A = \left(\frac{e_B}{e_A}\right)^{1/4} T_B =}$$

$$T_B = \left(\frac{e_A}{e_B}\right)^{1/4} T_A = 1934\,K$$

Now

$$\lambda_A T_A = \lambda_B T_B$$

$$\lambda_A = \frac{\lambda_B}{3}$$

$$\lambda_B - \lambda_A = 10^{-6} \quad \text{soling} \Rightarrow \lambda_B = 1.5 \times 10^{-6}$$

(a, b)

9. Temp. increased 4 times

$$V_{rms} \propto \sqrt{T} \quad \text{so} \quad V_{new} = 2V$$

10. chab mer 'A'

$$-\Delta p = P_i - P_f$$

$$= \frac{n_A RT}{V} - \frac{n_A RT}{2V} = \frac{n_A RT}{2V}$$

in chamber 'B'

$$-1.5\,\Delta p = P_i - P_f = \frac{n_B RT}{V} - \frac{n_B RT}{2V}$$

$$= \frac{n_B RT}{2V}$$

now $\frac{n_A}{n_B} = \frac{1}{1.5} = \frac{2}{3}$

$$\frac{m_A/M}{m_B/M} = \frac{2}{3} \Rightarrow 3m_A = 2m_B$$

(C)

11. for isothermal $\frac{\Delta P}{\Delta V} = -P/V$

$$\beta = -\frac{\Delta P}{\Delta V/V} = -V \times \frac{-P}{V} = P$$

(b)

12. piston A is Constant pressure.

$$Q = nC_p\,\Delta T = nC_p\,30$$

piston B is fixed

$$Q = nC_v\,\Delta T$$

as same heat is supplied

$$nC_p\,30 = nC_v\,\Delta T$$

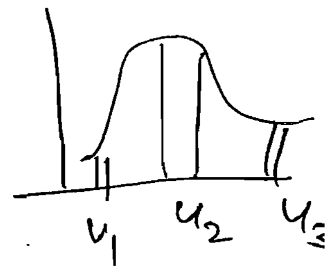
$$\Delta T = \frac{C_p}{C_v} \times 30 = 7 \times$$

13. (b, c)

14. $\lambda_m T = \text{Const} = .288 \text{ cmK}$

$\lambda_m = 1000 nm$

So U_2 would'd be maximum



(d) $U_2 > U_1$

15.

$$R = \frac{S}{(\alpha_1 - \alpha_2)\Delta T}$$

so . b, d.

16. as temp. of black body is same

rate of absorb = rate of emission (constant)

so rate of reflection also constant.

(a, b, c, d)

IIT-Jee - fill in the blanks

Q. ① (a) partly solid partly liquid

(Solid to liquid transition state)

Q. ②

$VP^2 = K$ $\quad$ $(PV = nRT)$

$V\left(\frac{T^2}{V^2}\right) = K$

$T^2 = KV$ $\quad$ as V is doubled

T become $\sqrt{2}$ times.

$T_{new} = \sqrt{2}\,T$

③

0°C $\boxed{100}$ ice $\xrightarrow{}$ 0°C water $\boxed{100 gm}$

$Q = 100 \times 80 = 8000$

$\boxed{25°C} \xrightarrow{} \boxed{0°C}$

$Q = 300 \times 1 \times 25 = 7500$

as we can see all ice wouldn't melt, so mixture temp = 0°C

④ Intensity $= \frac{P}{A} = 1400$

$\frac{\sigma A T^4}{4\pi r^2} = 1400$ $\quad$ $A = 4\pi \times (7 \times 10^8)^2$

$r = 1.5 \times 10^{11}$

Solving this ⇒ $T = 5803\ K$

5. Power radiated $P = e\sigma A T^4$

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

$$\int_0^t dt = \int_{200}^{100} -\frac{mc}{\sigma A} T^{-4}\, dT$$

$$\Rightarrow t = 1.71\, \rho\, r\, c$$

(ρ = density, r = radius, c = specific heat)

6. thermal "resistance" $= \frac{L}{KA} = \frac{t}{K4\pi R^2}$

rate of heat transfer $= \frac{\Delta T}{R_{th}}$

$$= \frac{T}{t/4\pi K R^2} = \frac{4\pi K T R^2}{t}$$

7. when we supply power 'p' it remains in molten state. rate of Heat loss = P

~~latent heat~~

Heat loss in solidifying $= mL = Pt$

$$L = \frac{Pt}{m}$$

8. free expansion

$W = 0$

$\Delta Q = 0$ (adiabatic wall)

$\Rightarrow \Delta U = 0$ (T = Const)

9.

isothermal $PV = \text{const.}$

$$P_i (2V) = PV \Rightarrow P_i = P/2$$

adiabatic $PV^{\gamma} = \text{Const.}$

$$P_a (2V)^{1.67} = PV^{1.67}$$

$$P_a = P/2^{1.67}$$

ratio $\rightarrow \frac{P_a}{P_i} = \frac{2}{2^{1.67}} = .628$

10.

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

$R \propto \frac{1}{K}$ (L & A same for both)

$$\frac{R_A}{R_B} = \frac{K_B}{K_A} = \frac{200}{300} = \frac{2}{3}$$

$$\frac{K_A A (100 - T)}{L} = \frac{K_B A (T - 0)}{L}$$

$$\Rightarrow 300 - 3T = 2T$$

$$\Rightarrow T = 60°C$$

11.

gas thermometer has const. Volume V

$T \propto P$

$$\frac{T_2}{T_1} = \frac{P_2}{P_1}$$

$$T_2 = 273.16 \times \frac{3.5 \times 10^4}{3 \times 10^4} = 318.68\,K$$

12.

Power incident on lens = Intensity × Area

$= 1400 \times .2$

$= 280$

suppose ice melts in 't' time.

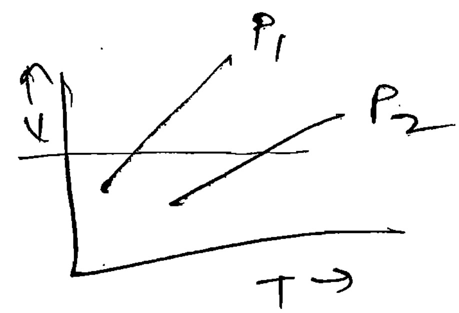
$$\frac{280}{1000} \times 3.3 \times 10^5 = 280 \times t \times 60$$

$t = 5.5$ mins.

True – false

① $V_{rms} = \sqrt{\frac{3kT}{m}}$ as V_{rms} depends upon 'm', it is different for different gases. (F)

②. at const. Volume line $T \uparrow \Rightarrow P \uparrow$



so $P_2 > P_1$

(F)

③. not possible. different gas ⇒ different 'm'

(F)

5.

$$C_p - C_v = R$$

so $C_p > C_v$ (at fix temp.)

(T)

6.

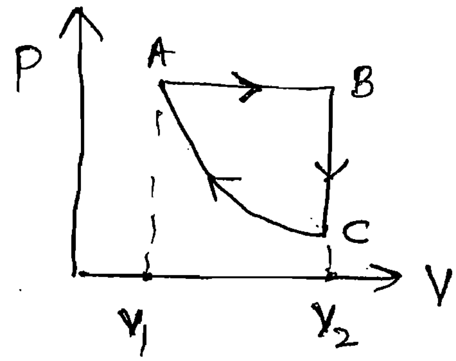
$$E \propto AT^4$$

$$\frac{E_1}{E_2} = \left(\frac{1}{4}\right)^2 \left(\frac{4000}{2000}\right)^4 = 1$$

$$E_1 = E_2$$ (T)

Subjective Problems

1.



$C \to A$

$T = $ Const.

Isothermal curve

also Volume $V \downarrow$

$V_A < V_C$

Now $B \to C$ Volume is Const.

straight line $\parallel^{el}$ to Y-axis

$A \to B$ $V \propto T$ $\Rightarrow P = $ Const.

Isobaric curve.

2.

$$W = \frac{P_i V_i - P_f V_f}{\gamma - 1}$$

$$W = -972 \text{ J}$$

Now

$$P_i V_i^{\gamma} = P_f V_f^{\gamma}$$

$$10^5 (6)^{\frac{5}{3}} = P_f (2)$$

$$P_f = 6.24 \times 10^5$$

3.

Net rate of heat radiation $\left(\frac{dQ}{dt}\right)$ is same for both as temp & area is same.

$$ms\left(-\frac{d\theta}{dt}\right) = \frac{dQ}{dt}$$

$$-\frac{d\theta}{dt} \propto \frac{1}{m}$$

So hollow sphere will cool faster than solid sphere.

4. applying $\frac{PV}{T} = \text{Const}$ for both chambers,

$$\frac{P_0 V_0}{T_0} = \frac{P V_1}{T_1} = \frac{P V_2}{T_2}$$

$$V_1 = \frac{32}{243}\left(\frac{T_1}{T_0}\right) V_0$$

& $$V_2 = \frac{32}{243}\left(\frac{T_2}{T_0}\right) V_0$$

also $$V_1 + V_2 = 2V_0$$

$$\Rightarrow T_1 + T_2 = \frac{243}{16} T_0$$

Right chamber is adiabatic

$$\Rightarrow \left(\frac{T_0}{T_2}\right)^{\frac{5}{3}} = \left(\frac{243 P_0}{32 P_0}\right)^{1-5/3}$$

$$\Rightarrow T_2 = 2.25\, T_0$$

$$\& \quad T_1 = 12.94\, T_0$$

(b) Work done $= -\Delta U$ (Adiabatic process)

$$= n C_v (T_i - T_f)$$

$$= 1\left(\frac{3R}{2}\right)(T_0 - 2.25\, T_0)$$

$$= -1.875\, RT_0$$

5. let x moles transfer from bulb of higher temp. to lower temp.

$$76 \times V = nR \times 273$$

$$P' \times V = (n+x)\,R \times 273$$

$$P' \times V = (n-x)\,R \times 335$$

solving these eq. we get $n = \frac{602}{62}x$

$$\frac{P'}{76} = \frac{n+x}{n} = 1 + \frac{x}{n} = 1 + \frac{62}{602}$$

$$P' = 83.83 \text{ cm of Hg}$$

6. all 3 are in series, therefore

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

$$= \frac{2.5\times10^{-2}}{.125\times137} + \frac{10^{-2}}{1.5\times137} + \frac{25\times10^{-2}}{1\times137}$$

$$= .33\times10^{-2}\ {}^\circ C/W$$

$$\frac{dQ}{dt} = \frac{\Delta T}{R_{th}} = \frac{30}{.33\times10^{-3}} = 9000 W$$

7. as vessel is closed V = Constant

$W = 0$

$$\Delta Q = \Delta U = nC_v\,\Delta T$$

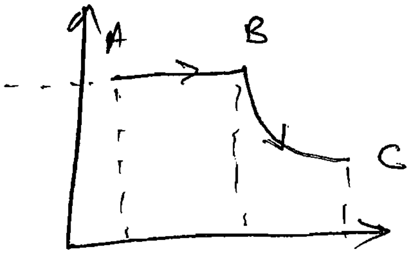
$$\Delta T = \frac{2.49\times10^{4}}{nC_v}$$

$n = \frac{PV}{RT}$

$C_v = \frac{3R}{2}$

Solving we get $\Delta T = 375$ K

8.



$P_A = \frac{nRT_A}{V_A}$

$= \frac{2 \times 8.31 \times 300}{20 \times 10^{-3}}$

$= 2.49 \times 10^5$ Pa

$B \to C \to$ adiabatic

$T^{\gamma} P^{1-\gamma} = \text{Const.}$

$T_B = 600K$

$V_A = 20L, V_B = 40L$

$$\left(\frac{600}{300}\right)^{5/3} = \left(\frac{2.49 \times 10^5}{P_C}\right)^{\frac{5}{3}-1}$$

$$\Rightarrow P_C = .44 \times 10^5 \ N/m^2$$

$$W_{AB} = 2.49 \times 10^5 \times (40-20) \times 10^{-3} = 4980 J$$

$$W_{BC} = -\Delta U = 2 \times \frac{3}{2} \times 8.31 \times (600-300) = 7479 J$$

$$W_{total} = 4980 + 7479 = 12459 J$$

9.

final pressure $= P_0 + \frac{kx}{A}$

$= 1 \times 10^5 + \frac{8000 \times .1}{8 \times 10^{-3}}$

$= 2 \times 10^5$ Pa

final Volume $= 2.4 \times 10^{-3} + .1 \times 8 \times 10^{-3}$

$= 3.2 \times 10^{-3} \ m^3$

moles are Conserved

$\frac{P_i V_i}{T_i} = \frac{P_f V_f}{T_f} \Rightarrow T_f = 800K$

$$\text{Heat supplied} = Q = W_{gas} + \Delta U$$

$$= P_0 (\Delta V) + \frac{1}{2} k x^2 + n C_V \Delta T$$

$$= 80 + 40 + 600 = 720\,J$$

10.

(a) $$T V^{\gamma-1} = \text{Const.}$$

$$T V^{\gamma-1} = \left(\frac{T}{2}\right) (5.66\,V)^{\gamma-1}$$

$$(5.66)^{\gamma-1} = 2$$

$$\gamma = 1.4$$

So $\gamma = 1 + \frac{2}{f} = \quad \Rightarrow f = 5$

(b) $$PV^{\gamma} = \text{Const.}$$

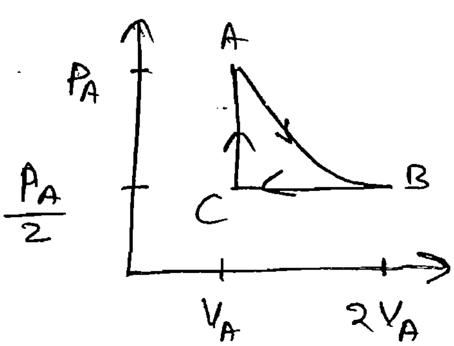
$$PV^{1.4} = P_f (5.66\,V)^{1.4}$$

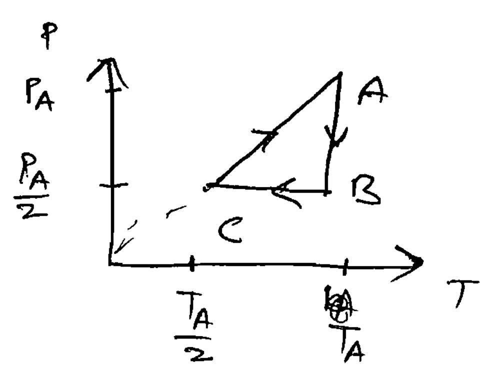
$$P_f = .09\,P$$

$$W = \frac{P_i V_i - P_f V_f}{\gamma - 1} = \frac{PV - .09\,P \times 5.66\,V}{\gamma - 1}$$

$$= 1.23\,PV$$

11.





$Q = W_{AB} + W_{BC}$

$= \quad nRT_A \ln\left(\frac{2V_A}{V_A}\right) = 3RT_A \ln 2 = 2.08RT_A$

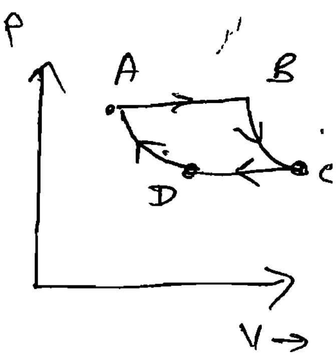
$W_{BC} = -\frac{P_A}{2} \times (2V_A - V_A) = -\frac{P_A V_A}{2} = -\frac{3RT_A}{2}$

$= -1.5RT_A$

$Q = W_{net} = .58RT_A$

12.

Cyclic process $\Delta U = 0$



W = Area Under curve

$= W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$= Q_{AB} + Q_{BC} + Q_{CD} + Q_{DA}$

$= \cancel{C\,2Q}$

$= nC_p 100 + W_{BC} - nC_p 100 + W_{DA}$

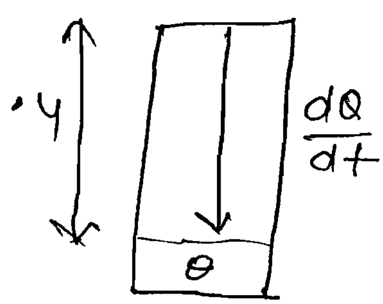
$V_A = \frac{2 \times 8.314 \times 300}{2 \times 10^5} = \frac{25}{1000}$

$= 2 \times 8.314 \times 400 \ln\frac{2}{1} + 2 \times 8.314 \times 300 \ln\frac{1}{2}$

$V_B =$

$W = Q = 1152\,J$

13.



$\frac{dQ}{dt} = \frac{KA}{L}(\theta_0 - \theta)$

$= ms\frac{d\theta}{dt}$

therefore, $\frac{d\theta}{\theta_0 - \theta} = \frac{KA}{msl}\,dt$

$\left[-\ln(\theta_0 - \theta)\right]^{350} = \frac{KA}{\ldots}t$

14.

(14)

$T_A = 1000\,K, \quad P_B = \frac{2}{3}P_A, \quad P_C = \frac{P_A}{3}$

$n = 1, \quad \gamma = \frac{C_P}{C_V} = \frac{5}{3}$ (mono atomic)

$A \to B$ adiabatic process.

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

$$T_B = T_A \left(\frac{P_A}{P_B}\right)^{\frac{1-\gamma}{\gamma}} = 1000 \times .85$$
$$= 850\,K$$

$$W_{A\to B} = \frac{R}{1-\gamma}(T_B - T_A) = 1869.75\,J$$
$$\approx 1870\,J$$

(b) $B \to C$ isochoric process.

$$\frac{T_B}{T_C} = \frac{P_B}{P_C}$$

$$T_C = \left(\frac{P_C}{P_B}\right) T_B = \left(\frac{1/3\,P_A}{2/3\,P_A}\right) \times 880\,k$$

$$= 425\,k$$

$$Q_{BC} = nC_V\,\Delta T = \frac{3R}{2}(T_C - T_B)$$

$$= -5297.6\,J$$

(c) $C \to D$ adiabatic process

$$P_C^{1-\gamma} T_C^{\gamma} = P_D^{1-\gamma} T_D^{\gamma}$$

subsitute P_D, P_C & T_C interms of T_A, T_B, T_C

15.

Cyclic process $\Delta U = 0$

$$\Delta Q = \Delta W$$

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

$$\Rightarrow W_4 = 765 \text{ J}$$

(b) efficiency $\eta = \dfrac{\Delta W}{Q_{supplied}} \times 100$

$$= \frac{1040}{9605} \times 100 = 10.82\%$$

16.

Suppose mass of neon $= m$

then mass of argon $= 28 - m$

$$n_1 = \frac{m}{20}, \quad n_2 = \frac{28-m}{40}$$

$$P = \frac{(n_1 + n_2) RT}{V}$$

Solving this eq. we get $m = 4.078$ gm.

$28 - m = 23.926$ gm

17.

for a mixture

$$\frac{n_1 + n_2}{\gamma - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$$

$$\frac{1+n}{\frac{19}{?} - 1} = \frac{1}{\frac{5}{?} - 1} + \frac{n}{\frac{7}{?}}$$

(b) $$M_{mix} = \frac{n_A m_A + n_B M_B}{n_A + n_B}$$

$$= 22.67$$

$$v_{sound} = \sqrt{\frac{\gamma RT}{M}} \approx 401 \text{ m/s}$$

(c) $$v \propto \sqrt{T} \Rightarrow v = k\, T^{1/2}$$

$$\frac{dv}{dT} = \frac{k}{2} k\, T^{-1/2}$$

$$\frac{dv}{v} \times 100 = \frac{1}{2} \times \frac{dT}{T} \times 100$$
$$= .167\%$$

(d) $$\text{Compressibility} = \frac{1}{\text{Bulk modulus}}$$

adiabatic bulk modulus is $= \gamma P$

$$\Delta B = \frac{1}{\gamma P'} - \frac{1}{\gamma P} = \frac{1}{\gamma P}\left(\frac{1}{5\gamma} - 1\right) \quad \left(P = \frac{nRT}{V}\right)$$

$$\Delta B = -8.27 \times 10^{-5}\, V \quad \gamma = 19/13$$

18. adiabatic process $TV^{\gamma-1} = \text{Const.}$

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 300\left(\frac{V}{2V}\right)^{\frac{5}{3}-1}$$

$$= 189\text{ K}$$

(b) change in internal Energy

$$\Delta U = 2 \times \frac{3R}{2}(189 - 300)$$

$$= -2767 \text{ J}$$

(c) Work done

adiabatic process $\Rightarrow \Delta Q = 0$

$$\Delta W = -\Delta U = 2767 \text{ J}$$

19. energy absorbed by water

$$Q = 100 \times 1 \times 66 = 6600$$

Suppose 'm' is required, therefore

$$Q_{released} = m \times 540 + m \times 1 \times (100 - 90) = m \times 550$$

$$\Rightarrow \quad 550 \times m = 6600$$

$$m = \frac{6600}{550} = 12 \text{ gm.}$$

22. $T_A = 300$, $n = 1$, $\gamma = 1.4$, $\frac{V_A}{V_B} = 16$

$$\frac{V_C}{V_B} = 2$$

temp. at B

as AB is adiabatic

$$T_A V_A^{\gamma-1} = T_B V_B^{\gamma-1}$$

$$T_B = T_A \left(\frac{V_A}{V_B}\right)^{r-1}$$

$$= 300\,(16)^{1.4-1} = 909\,K$$

<u>Temp. at D</u>

$B \to C$ isobaric process

$$\frac{T_B}{V_B} = \frac{T_C}{V_C} \Rightarrow T_C = 1818\ K$$

$C \to D$ adiabatic process

$$T_D = T_C \left(\frac{V_C}{V_D}\right)^{r-1} = 791.4\,K$$

<u>efficiency of the cycle</u>

$$\eta = \frac{W_{total}}{Q_{given}} \times 100$$

$$= \frac{-V}{\gamma(n_A + n_B)RT}\left[1 - \left(\frac{1}{5}\right)^{\gamma}\right] \quad \left(\because p = \frac{nRT}{V}\right)$$

$$= \frac{-V}{\left(\frac{19}{13}\right)(1+2)(8.31)(300)}\left[1 - \left(\frac{1}{5}\right)^{\frac{19}{13}}\right]$$

$$\left(\gamma = \gamma_{\text{mixture}} = \frac{19}{13}\right)$$

$$\Delta\beta = -8.27 \times 10^{-5}\ V$$

24. Given $T_1 = 27°\text{C} = 300\ \text{K}$

$$V_1 = V, V_2 = 2V$$

(a) Final temperature :

In adiabatic process, $TV^{\gamma-1} = \text{constant}$

$\therefore \quad T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

or $\quad T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 300\left(\frac{V}{2V}\right)^{5/3-1}$

$\gamma = \frac{5}{3}$ for a monoatomic gas

$$T_2 \approx 189\ \text{K}$$

(b) Change in internal energy

$$\Delta U = nC_V\Delta T$$

$$\Delta U = (2)\left(\frac{3}{2}R\right)(T_2 - T_1)$$

$$\Delta U = 2\left(\frac{3}{2}\right)(8.31)(189 - 300)\ \text{J}$$

$$\Delta U = -2767\ \text{J}$$

(c) Work done :

Process is adiabatic, therefore $\Delta Q = 0$ and from first law of thermodynamics,

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

$$\Delta W = -\Delta U = -(-2767\ \text{J})$$

$$\Delta W = 2767\ \text{J}$$

25. Let m be the mass of the steam required to raise the temperature of 100 g of water from 24°C to 90°C.

Heat lost by steam = Heat gained by water

$\therefore \quad m(L + s\Delta\theta_1) = 100s\Delta\theta_2$

or $\quad m = \frac{(100)(s)(\Delta\theta_2)}{L + s(\Delta\theta_1)}$

Here, s = Specific heat of water = 1 cal/g-°C,

L = Latent heat of vaporization = 540 cal/g.

$$\Delta\theta_1 = (100 - 90) = 10°\text{C}$$

and $\quad \Delta\theta_2 = (90 - 24) = 66°\text{C}$

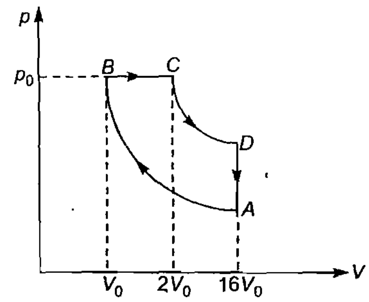
Substituting the values, we have

$$m = \frac{(100)(1)(66)}{(540) + (1)(10)} = 12\ \text{g}$$

$\therefore \quad m = 12\ \text{g}$

26. The corresponding p-V diagram is as shown

Given : $T_A = 300\ \text{K}, n = 1, \gamma = 1.4, V_A/V_B = 16$ and $V_C/V_B = 2$



Let $\quad V_B = V_0 \quad$ and $\quad p_B = p_0$

Then, $\quad V_C = 2V_0 \quad$ and $\quad V_A = 16V_0$

Temperature at B

Process A-B is adiabatic.

Hence, $\quad T_AV_A^{\gamma-1} = T_BV_B^{\gamma-1}$

or $\quad T_B = T_A\left(\frac{V_A}{V_B}\right)^{\gamma-1}$

$$= (300)(16)^{1.4-1}$$

$$T_B = 909\ \text{K}$$

Temperature at D

$B \rightarrow C$ is an isobaric process (p = constant)

$\therefore \quad T \propto V, V_C = 2V_B$

$\therefore \quad T_C = 2T_B = (2)(909)\ \text{K}$

$$T_C = 1818\ \text{K}$$

Now, the process $C \rightarrow D$ is adiabatic.

Therefore,

$$T_D = T_C\left(\frac{V_C}{V_D}\right)^{\gamma-1} = (1818)\left(\frac{2}{16}\right)^{1.4-1}$$

$$T_D = 791.4\ \text{K}$$

Efficiency of cycle

Efficiency of cycle (in percentage) is defined as

$$\eta = \frac{\text{Net work done in the cycle}}{\text{Heat absorbed in the cycle}} \times 100$$

or $\quad \eta = \frac{W_{\text{Total}}}{Q_{+\text{ve}}} \times 100$

$$= \frac{Q_{+\text{ve}} - Q_{-\text{ve}}}{Q_{+\text{ve}}} \times 100 = \left(1 - \frac{Q_1}{Q_2}\right) \times 100 \quad \text{... (i)}$$

where, Q_1 = Negative heat in the cycle (heat released)

and $\quad Q_2$ = Positive heat in the cycle (heat absorbed)

In the cycle

$$Q_{AB} = Q_{CD} = 0 \quad \text{(Adiabatic process)}$$

$$Q_{DA} = nC_V\ \Delta T = (1)\left(\frac{5}{2}R\right)(T_A - T_D)$$

$$\left(C_V = \frac{5}{2}R \text{ for a diatomic gas}\right)$$

$$= \frac{5}{2} \times 8.31(300 - 791.4) \text{ J}$$

or $\quad Q_{DA} = -10208.8 \text{ J}$

and $\quad Q_{BC} = nC_p\Delta T = (1)\left(\frac{7}{2}R\right)(T_C - T_B)$

$$\left(C_p = \frac{7}{2}R \text{ for a diatomic gas}\right)$$

$$= \left(\frac{7}{2}\right)(8.31)(1818 - 909) \text{ J}$$

or $\quad Q_{BC} = 26438.3 \text{ J}$

Therefore, substituting $Q_1 = 10208.8$ J and $Q_2 = 26438.3$ J in Eq. (i), we get

$$\therefore \quad \eta = \left\{1 - \frac{10208.8}{26438.3}\right\} \times 100$$

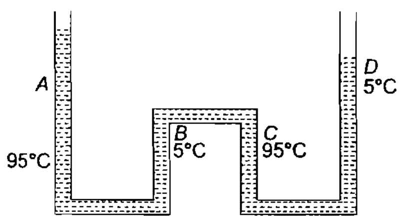
or $\quad \eta = 61.4\%$

23. Density of a liquid varies with temperature as

P-23

$$\rho_{t°C} = \left(\frac{\rho_{0°C}}{1 + \gamma t}\right)$$

Here, γ is the coefficient of volume expansion of temperature.



In the figure

$h_1 = 52.8$ cm, $h_2 = 51$ cm and $h = 49$ cm.

Now, pressure at B = pressure at C

$$p_0 + h_1\rho_{95°}g - h\rho_{5°}g = p_0 + h_2\rho_{5°}g - h\rho_{95°}g$$

$$\Rightarrow \quad \rho_{95°}(h_1 + h) = \rho_{5°}(h_2 + h)$$

$$\Rightarrow \quad \frac{\rho_{95°}}{\rho_{5°}} = \frac{h_2 + h}{h_1 + h}$$

$$\Rightarrow \quad \frac{\dfrac{\rho_{0°}}{1 + 95\gamma}}{\dfrac{\rho_{0°}}{1 + 5\gamma}} = \frac{h_2 + h}{h_1 + h}$$

$$\Rightarrow \quad \frac{1 + 5\gamma}{1 + 95\gamma} = \frac{51 + 49}{52.8 + 49}$$

$$= \frac{100}{101.8}$$

Solving this equation, we get

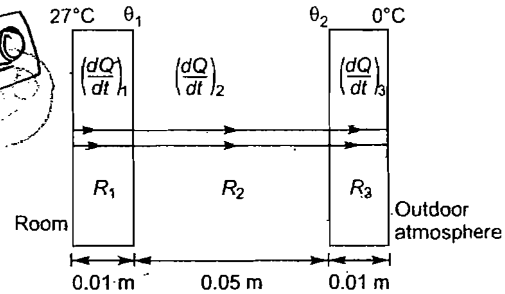
$$\gamma = 2 \times 10^{-4}/°C$$

$\therefore$ Coefficient of linear expansion of temperature,

$$\alpha = \frac{\gamma}{3} = 6.7 \times 10^{-5}/°C$$

18. Let θ_1 and θ_2 be the temperatures of the two interfaces as shown in figure.

P-20



Thermal resistance, $R = \frac{l}{KA}$

$$\therefore \quad R_1 = R_3 = \frac{(0.01)}{(0.8)(1)}$$

$$= 0.0125 \text{ K/W or °C/W}$$

and $\quad R_2 = \frac{(0.05)}{(0.08)(1)} = 0.625°\text{C/W}$

Now the rate of heat flow $\left(\frac{dQ}{dt}\right)$ will be equal from all the three sections and since rate of heat flow is given by

$$\frac{dQ}{dt} = \frac{\text{Temperature difference}}{\text{Thermal resistance}}$$

and $\quad \left(\frac{dQ}{dt}\right)_1 = \left(\frac{dQ}{dt}\right)_2 = \left(\frac{dQ}{dt}\right)_3$

Therefore,

$$\frac{27 - \theta_1}{0.0125} = \frac{\theta_1 - \theta_2}{0.625} = \frac{\theta_2 - 0}{0.0125}$$

Solving this equation, we get

$$\theta_1 = 26.48°C$$

and $\quad \theta_2 = 0.52°C$

and $\quad \frac{dQ}{dt} = \frac{27 - \theta_1}{0.0125}$

$$\frac{dQ}{dt} = \frac{(27 - 26.48)}{0.0125} = 41.6 \text{ W}$$

20. Number of gram moles of He,

P-21

$$n = \frac{m}{M} = \frac{2 \times 10^3}{4} = 500$$

(a) $V_A = 10 \text{ m}^3$, $p_A = 5 \times 10^4 \text{ N/m}^2$

$$\therefore \quad T_A = \frac{p_A V_A}{nR} = \frac{(10)(5 \times 10^4)}{(500)(8.31)} \text{ K}$$

or $\quad T_A = 120.34$ K

Similarly, $V_B = 10 \text{ m}^3$, $p_B = 10 \times 10^4 \text{ N/m}^2$

$$\therefore \quad T_B = \frac{(10)(10 \times 10^4)}{(500)(8.31)} \text{ K}$$

$$\therefore \quad T_B = 240.68 \text{ K}$$

$V_C = 20 \text{ m}^3$, $p_C = 10 \times 10^4 \text{ N/m}^2$

$$\therefore \quad T_C = \frac{(20)(10\times 10^4)}{(500)(8.31)}\text{K}$$

$$T_C = 481.36\text{K}$$

and $V_D = 20\text{m}^3$, $p_D = 5\times 10^4$ N/m^2

$$\therefore \quad V_D = \frac{(20)(5\times 10^4)}{(500)(8.31)}\text{K}$$

$$T_D = 240.68\text{K}$$

(b) **No,** it is not possible to tell afterwards which sample went through the process ABC or ADC. But during the process if we note down the work done in both the processes, then the process which require more work goes through process ABC.

(c) In the process ABC

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

$$= (500)\left(\frac{3}{2}\right)(8.31)(481.36 - 120.34)\text{ J}$$

$$\Delta U = 2.25\times 10^6\text{ J}$$

and ΔW = Area under BC

$$= (20-10)(10)\times 10^4\text{ J} = 10^6\text{ J}$$

$$\therefore \Delta Q_{ABC} = \Delta U + \Delta W = (2.25\times 10^6 + 10^6)\text{ J}$$

$$\Delta Q_{ABC} = 3.25\times 10^6\text{ J}$$

In the process ADC ΔU will be same (because it depends on initial and final temperatures only)

$$\Delta W = \text{Area under } AD$$

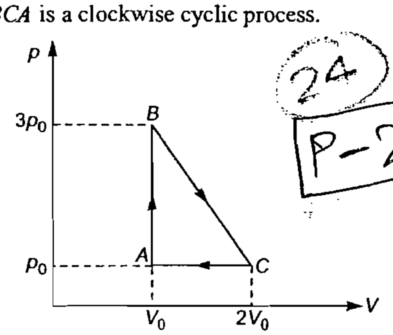
$$= (20-10)(5\times 10^4)\text{ J}$$

$$= 0.5\times 10^6\text{ J}$$

$$\Delta Q_{ADC} = \Delta U + \Delta W = (2.25\times 10^6 + 0.5\times 10^6)\text{ J}$$

$$\Delta Q_{ADC} = 2.75\times 10^6\text{ J}$$

39. (a) $ABCA$ is a clockwise cyclic process.



24

P-24

$\therefore$ Work done by the gas

$$W = +\text{ Area of triangle } ABC$$

$$= \frac{1}{2}(\text{base})(\text{height})$$

$$= \frac{1}{2}(2V_0 - V_0)(3p_0 - p_0)$$

$$W = p_0V_0$$

(b) Number of moles $n = 1$ and gas is monoatomic, therefore

$$C_V = \frac{3}{2}R \quad \text{and} \quad C_p = \frac{5}{2}R$$

$$\Rightarrow \quad \frac{C_V}{R} = \frac{3}{2} \quad \text{and} \quad \frac{C_p}{R} = \frac{5}{2}$$

(i) Heat rejected in path CA (Process is isobaric)

$$\therefore \quad dQ_{CA} = C_p dT = C_p(T_f - T_i)$$

$$= C_p\left(\frac{p_fV_f}{R} - \frac{p_iV_i}{R}\right)$$

$$= \frac{C_p}{R}(p_fV_f - p_iV_i)$$

Substituting the values

$$dQ_{CA} = \frac{5}{2}(p_0V_0 - 2p_0V_0) = -\frac{5}{2}p_0V_0$$

Therefore, heat rejected in the process CA is $\frac{5}{2}p_0V_0$.

(ii) Heat absorbed in path AB (Process is isochoric)

$$\therefore \quad dQ_{AB} = C_V dT$$

$$= C_V(T_f - T_i)$$

$$= C_V\left(\frac{p_fV_f}{R} - \frac{p_iV_i}{R}\right)$$

$$= \frac{C_V}{R}(p_fV_f - p_iV_i)$$

$$= \frac{3}{2}(p_fV_f - p_iV_i)$$

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

$$dQ_{AB} = 3p_0V_0$$

$\therefore$ Heat absorbed in the process AB is $3\ p_0V_0$.

(c) Let dQ_{BC} be the heat absorbed in the process BC:

Total heat absorbed,

$$dQ = dQ_{CA} + dQ_{AB} + dQ_{BC}$$

$$dQ = \left(-\frac{5}{2}p_0V_0\right) + (3p_0V_0) + dQ_{BC}$$

$$dQ = dQ_{BC} + \frac{p_0V_0}{2}$$

Change in internal energy, $dU = 0$

$$\therefore \quad dQ = dW$$

$$\therefore \quad dQ_{BC} + \frac{p_0V_0}{2} = p_0V_0$$

$$\therefore \quad dQ_{BC} = \frac{p_0V_0}{2}$$

$\therefore$ Heat absorbed in the process BC is $\frac{p_0V_0}{2}$.

(d) Maximum temperature of the gas will be somewhere between B and C. Line BC is a straight line. Therefore, p-V equation for the process BC can be written as :

$$p = -mV + c \qquad (y = mx + c)$$

Here, $m = \dfrac{2p_0}{V_0}$ and $c = 5p_0$

$\therefore \quad p = -\left(\dfrac{2p_0}{V_0}\right)V + 5p_0$

Multiplying the equation by V,

$$pV = -\left(\frac{2p_0}{V_0}\right)V^2 + 5p_0V \qquad (pV = RT \text{ for } n = 1)$$

$$RT = -\left(\frac{2p_0}{V_0}\right)V^2 + 5p_0V$$

or
$$T = \frac{1}{R}\left[5p_0V - \frac{2p_0}{V_0}V^2\right] \qquad \text{...(i)}$$

For T to be maximum, $\dfrac{dT}{dV} = 0$

$$\Rightarrow \quad 5p_0 - \frac{4p_0}{V_0}V = 0$$

$$\Rightarrow \quad V = \frac{5V_0}{4}$$

ie, at $V = \dfrac{5V_0}{4}$, (on line BC), temperature of the gas is maximum. From Eq. (i) this maximum temperature will be :

$$T_{\max} = \frac{1}{R}\left[5p_0\left(\frac{5V_0}{4}\right) - \frac{2p_0}{V_0}\left(\frac{5V_0}{4}\right)^2\right]$$

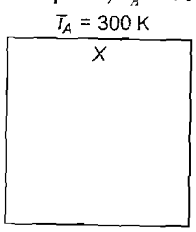
$$T_{\max} = \frac{25}{8}\frac{p_0V_0}{R}$$

31. In the first part of the question ($t \le t_1$)

At $t = 0, T_X = T_0 = 400$ K and at $t = t_1, T_X = T_1 = 350$K

Temperature of atmosphere, $T_A = 300$ K (constant)

P-25



This cools down according to Newton's law of cooling. Therefore, rate of cooling $\propto$ temperature difference.

$$\therefore \quad \left(-\frac{dT}{dt}\right) = k(T - T_A)$$

$$\Rightarrow \quad \frac{dT}{T - T_A} = -k\,dt$$

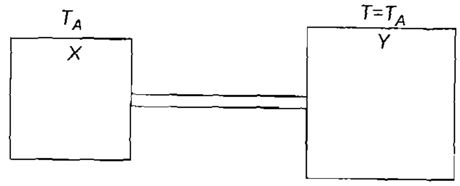
$$\Rightarrow \quad \int_{T_0}^{T_1}\frac{dT}{T - T_A} = -k\int_0^{t_1} dt$$

$$\Rightarrow \quad \ln\left(\frac{T_1 - T_A}{T_0 - T_A}\right) = -kt_1$$

$$\Rightarrow \quad kt_1 = -\ln\left(\frac{350 - 300}{400 - 300}\right)$$

$$\Rightarrow \quad kt_1 = \ln(2) \qquad \text{... (i)}$$

In the second part ($t > t_1$), body X cools by radiation (according to Newton's law) as well as by conduction.



Therefore, rate of cooling

= (cooling by radiation) + (cooling by conduction)

$$\therefore \quad \left(-\frac{dT}{dt}\right) = k(T - T_A) + \frac{KA}{CL}(T - T_A) \qquad \text{... (ii)}$$

In conduction, $\dfrac{dQ}{dt} = \dfrac{KA(T - T_A)}{L} = C\left(-\dfrac{dT}{dt}\right)$

$$\therefore \quad \left(-\frac{dT}{dt}\right) = \frac{KA}{LC}(T - T_A)$$

where, C = heat capacity of body X

$$\left(-\frac{dT}{dt}\right) = \left(k + \frac{KA}{CL}\right)(T - T_A) \qquad \text{... (iii)}$$

Let at $t = 3t_1$, temperature of X becomes T_2

Then from Eq. (iii)

$$\int_{T_1}^{T_2}\frac{dT}{T - T_A} = -\left(k + \frac{KA}{LC}\right)\int_{t_1}^{3t_1} dt$$

$$\ln\left(\frac{T_2 - T_A}{T_1 - T_A}\right) = -\left(k + \frac{KA}{LC}\right)(2t_1)$$

$$= -\left(2kt_1 + \frac{2KA}{LC}t_1\right)$$

or $\ln\left(\dfrac{T_2 - 300}{350 - 300}\right) = -2\ln(2) - \dfrac{2KAt_1}{LC}$;

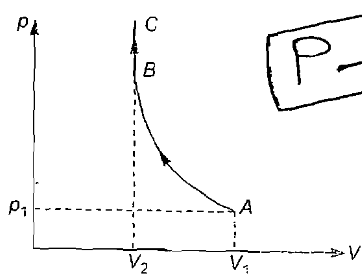
$kt_1 = \ln(2)$ from Eq. (i).

This equation gives

$$T_2 = \left(300 + 12.5e^{\frac{-2KAt_1}{CL}}\right)\text{K}$$

32. (a) The p-V diagram for the complete process will be as shown below :

P-26



Process $A \to B$ is adiabatic compression and

Process $B \to C$ is isochoric.

(b) (i) Total work done by the gas

Process $A \to B$

$$W_{AB} = \frac{p_A V_A - p_B V_B}{\gamma - 1} \quad W_{\text{adiabatic}} = \frac{p_i V_i - p_f V_f}{\gamma - 1}$$

$$= \frac{p_1 V_1 - p_2 V_2}{\frac{5}{3} - 1} \quad \gamma = 5/3 \text{ for monoatomic gas}$$

$$= \frac{p_1 V_1 - p_1 \left(\frac{V_1}{V_2}\right)^{\gamma} V_2}{2/3} \qquad \left[\begin{array}{l} p_1 V_1^{\gamma} = p_2 V_2^{\gamma} \\ \therefore\ p_2 = p_1 \left(\frac{V_1}{V_2}\right)^{\gamma} \end{array}\right]$$

$$= \frac{3}{2} p_1 V_1 \left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma - 1}\right]$$

$$= -\frac{3}{2} p_1 V_1 \left[\left(\frac{V_1}{V_2}\right)^{5/3 - 1} - 1\right]$$

$$= -\frac{3}{2} p_1 V_1 \left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right]$$

Process $B \to C$ $W_{BC} = 0$ (V = constant)

$$\therefore W_{\text{Total}} = W_{AB} + W_{BC} = -\frac{3}{2} p_1 V_1 \left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right]$$

(ii) Total change in internal energy

Process $A \to B$ $Q_{AB} = 0$ (Process is adiabatic)

$$\therefore\ \Delta U_{AB} = -W_{AB} = \frac{3}{2} p_1 V_1 \left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right]$$

Process $B \to C$ $W_{BC} = 0$

$$\therefore\ \Delta U_{BC} = Q_{BC} = Q \qquad \text{(Given)}$$

$$\therefore\ \Delta U_{\text{Total}} = \Delta U_{AB} + \Delta U_{BC}$$

$$= \frac{3}{2} p_1 V_1 \left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right] + Q$$

(iii) Final temperature of the gas

$$\Delta U_{\text{Total}} = n C_V \Delta T = 2\left(\frac{R}{\gamma - 1}\right)(T_C - T_A)$$

$$\therefore\ \frac{3}{2} p_1 V_1 \left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right] + Q = \frac{2R}{5/3 - 1}\left(T_C - \frac{p_A V_A}{2R}\right)$$

$$\text{or } \frac{3}{2} p_1 V_1 \left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right] + Q = 3R\left(T_C - \frac{p_1 V_1}{2R}\right)$$

$$\therefore\ T_C = \frac{Q}{3R} + \frac{p_1 V_1}{2R}\left(\frac{V_1}{V_2}\right)^{2/3} = T_{\text{final}}$$

33. (a) Number of moles, $n = 2$, $T_1 = 300$ K

During the process $A \to B$

pT = constant or $p^2 V$ = constant $= K$ (say)

P-27

$$\therefore \quad p = \frac{\sqrt{K}}{\sqrt{V}}$$

$$\therefore\ W_{A \to B} = \int_{V_A}^{V_B} p.dV = \int_{V_A}^{V_B} \frac{\sqrt{K}}{\sqrt{V}} dV$$

$$= 2\sqrt{K}[\sqrt{V_B} - \sqrt{V_A}]$$

$$= 2[\sqrt{KV_B} - \sqrt{KV_A}]$$

$$= 2[\sqrt{(p_B^2 V_B) V_B} - \sqrt{(p_A^2 V_A) V_A}]$$

$$= 2[p_B V_B - p_A V_A]$$

$$= 2[nRT_B - nRT_A]$$

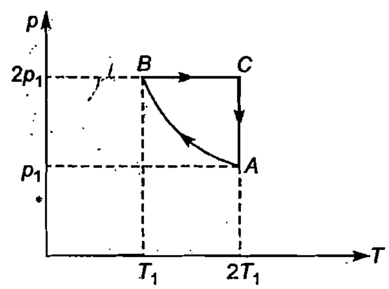
$$= 2nR[T_1 - 2T_1]$$

$$= (2)(2)(R)[300 - 600]$$

$$= -1200R$$

$\therefore$ Work done on the gas in the process AB is $1200R$.

Alternate solution :



$$pV = nRT$$

$$\therefore \quad pdV + Vdp = nRdT$$

$$\text{or} \quad pdV + \frac{(nRT)}{p}.dp = nRdT \qquad \text{... (i)}$$

From the given condition

$$pT = \text{constant}$$

$$pdT + Tdp = 0 \qquad \text{... (ii)}$$

From Eqs. (i) and (ii), we get

$$pdV = 2nRdT$$

$$\therefore W_{A \to B} = \int pdV = 2nR\int_{T_A}^{T_B} dT = 2nR(T_B - T_A)$$

$$= 2nR(T_1 - 2T_1)$$

$$= (2)(2)(R)(300 - 600)$$

$$\text{or} \quad W_{A \to B} = -1200R$$

(b) 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 $A \to B$: $\Delta U = nC_V \Delta T$

$$= (2)\left(\frac{3}{2}R\right)(T_B - T_A)$$

$$= (2)\left(\frac{3}{2}R\right)(300 - 600)$$

$$= -900R$$

$$\therefore \quad Q_{A \to B} = W_{A \to B} + \Delta U$$

$$= (-1200R) - (900R)$$

$$Q_{A \to B} = -2100R \text{ (released)}$$

Alternate solution :

In the process pV^x = constant

Molar heat capacity, $C = \dfrac{R}{\gamma - 1} + \dfrac{R}{1-x}$

Here the process is p^2V = constant or $pV^{1/2}$ =constant

ie, $x = \dfrac{1}{2}$

$\therefore \quad C = \dfrac{R}{\frac{5}{3} - 1} + \dfrac{R}{1 - \frac{1}{2}}$

$\therefore \quad C = 3.5R$

$\therefore \quad Q_{A \to B} = nC\Delta T$

$= (2)(3.5R)(300 - 600)$

or $\quad Q_{A \to B} = -2100R$

Process $B \to C$: Process is isobaric.

$\therefore Q_{B \to C} = nC_p\Delta T$

$= (2)\left(\dfrac{5}{2}R\right)(T_C - T_B) = 2\left(\dfrac{5}{2}R\right)(2T_1 - T_1)$

$= (5R)(600 - 300)$

$Q_{B \to C} = 1500R$ (absorbed)

Process $C \to A$: Process is isothermal.

$\therefore \quad \Delta U = 0$

and $\quad Q_{C \to A} = W_{C \to A} = nRT_C \ln\left(\dfrac{p_C}{p_A}\right)$

$= nR(2T_1)\ln\left(\dfrac{2p_1}{p_1}\right)$

$= (2)(R)(600)\ln(2)$

$Q_{C \to A} = 831.6R$ (absorbed)

Note In first law of thermodynamics, ($dQ = dU + dW$) we come across three terms dQ, dU and dW.

$dU = nC_VdT$ for all the processes whether it is isobaric, isochoric or else and $dQ = nCdT$ where

$$C = \frac{R}{\gamma - 1} + \frac{R}{1 - X}$$

in the process pV^X = constant.

In both the terms we require dT ($= T_f - T_i$) only. The third term dW is obviously $dQ - dU$. Therefore if in any process change in temperature (dT) and p-V relation is known, then the above method is the simplest one. Note that even if we have V-T or T-p relation, it can be converted into p-V relation by the equation $pV = nRT$

34. Let m be the mass of the container.

28 P-28

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

$\therefore \quad (0.1)(8 \times 10^4) + (0.1)(10^3)(27)$

$= -m\int_{500}^{300} (A + BT)dT$

or $\quad 10700 = -m\left[AT + \dfrac{BT^2}{2}\right]_{500}^{300}$

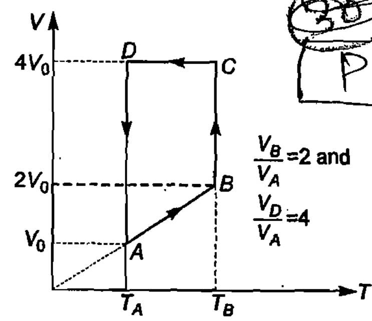
After substituting the values of A and B and the proper limits, we get

$m = 0.495$ kg.

35. Given :

Number of moles, $n = 2$

30 P-30



$C_V = \dfrac{3}{2}R$ and $C_p = \dfrac{5}{2}R \qquad$ (monoatomic)

$T_A = 27°C = 300$ K

Let $V_A = V_0$ then $V_B = 2V_0$ and $V_D = V_C = 4V_0$

(a) Process $A \to B$:

$V \propto T \quad \Rightarrow \quad \dfrac{T_B}{T_A} = \dfrac{V_B}{V_A}$

$\therefore \quad T_B = T_A\left(\dfrac{V_B}{V_A}\right) = (300)(2) = 600$ K

$\therefore \quad T_B = 600$ K

(b) Process $A \to B$:

$V \propto T \quad \Rightarrow \quad p$ = constant

$\therefore \quad Q_{AB} = nC_pdT = nC_p(T_B - T_A)$

$= (2)\left(\dfrac{5}{2}R\right)(600 - 300)$

$Q_{AB} = 1500R \qquad$ (absorbed)

Process $B \to C$:

T = constant $\qquad \therefore dU = 0$

$\therefore \quad Q_{BC} = W_{BC} = nRT_B\ln\left(\dfrac{V_C}{V_B}\right)$

$= (2)(R)(600)\ln\left(\dfrac{4V_0}{2V_0}\right)$

$= (1200R)\ln(2) = (1200R)(0.693)$

or $\quad Q_{BC} \approx 831.6R$ (absorbed)

Process $C \to D$: V = constant

$\therefore \quad Q_{CD} = nC_V\, dT = nC_V(T_D - T_C)$

$= n\left(\dfrac{3}{2}R\right)(T_A - T_B) \quad (T_D = T_A$ and $T_C = T_B)$

$= (2)\left(\dfrac{3}{2}R\right)(300 - 600)$

$Q_{CD} = -900R$ (released)

Process $D \to A$: $T = \text{constant} \Rightarrow \Delta U = 0$

$$\therefore \quad Q_{DA} = W_{DA} = nRT_D \ln\left(\frac{V_A}{V_D}\right)$$

$$= (2)(R)(300)\ln\left(\frac{V_0}{4V_0}\right)$$

$$= 600R\ln\left(\frac{1}{4}\right)$$

$$Q_{DA} \approx -831.6R \text{ (released)}$$

(c) In the complete cycle : $\Delta U = 0$

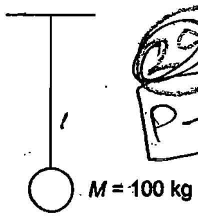
Therefore, from conservation of energy

$$W_{\text{net}} = Q_{AB} + Q_{BC} + Q_{CD} + Q_{DA}$$

$$W_{\text{net}} = 1500R + 831.6R - 900R - 831.6R$$

or $W_{\text{net}} = W_{\text{total}} = 600R$

36. Given :



P-29

Length of the wire, $l = 5$ m

Radius of the wire, $r = 2 \times 10^{-3}$ m

Density of wire, $\rho = 7860 \text{kg/m}^3$

Young's modulus,

$$Y = 2.1 \times 10^{11} \text{N/m}^2$$

and specific heat, $s = 420$ J/kg-K

Mass of wire, m = (density) (volume)

$$= (\rho)(\pi r^2 l)$$

$$= (7860)(\pi)(2 \times 10^{-3})^2(5) \text{ kg}$$

$$= 0.494 \text{ kg}$$

Elastic potential energy stored in the wire,

$$U = \frac{1}{2}\text{(stress) (strain) (volume)}$$

$$\left[\frac{\text{energy}}{\text{volume}} = \frac{1}{2} \times \text{stress} \times \text{strain}\right]$$

or $$U = \frac{1}{2}\left(\frac{Mg}{\pi r^2}\right)\left(\frac{\Delta l}{l}\right)(\pi r^2 l)$$

$$= \frac{1}{2}(Mg)\cdot\Delta l \qquad \left(\Delta l = \frac{Fl}{AY}\right)$$

$$= \frac{1}{2}(Mg)\frac{(Mgl)}{(\pi r^2)Y}$$

$$= \frac{1}{2}\frac{M^2g^2l}{\pi r^2 Y}$$

Substituting the values, we have

$$U = \frac{1}{2}\frac{(100)^2(10)^2(5)}{(3.14)(2 \times 10^{-3})^2(2.1 \times 10^{11})} \text{ J}$$

$$= 0.9478 \text{ J}$$

When the bob gets snapped, this energy is utilised in raising the temperature of the wire.

So, $$U = ms\,\Delta\theta$$

$$\therefore \quad \Delta\theta = \frac{U}{ms} = \frac{0.9478}{0.494\,(420)} \text{°C or K}$$

$$\Delta\theta = 4.568 \times 10^{-3}\text{°C}$$

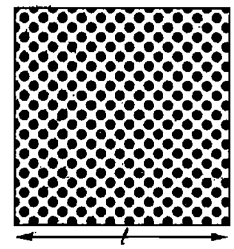
37. Volume of the box $= 1 \text{ m}^3$

P-31

Pressure of the gas $= 100 \text{N/m}^2$

Let T be the temperature of the gas. Then,

(a) Time between two consecutive collisions with one wall $= \frac{1}{500}$ s. This time should be equal to $\frac{2l}{v_{rms}}$, where l is the side of the cube.



$$\frac{2l}{v_{rms}} = \frac{1}{500}$$

or $$v_{rms} = 1000 \text{ m/s} \quad (\text{as } l = 1 \text{m})$$

or $$\sqrt{\frac{3RT}{M}} = 1000$$

$$\therefore \quad T = \frac{(1000)^2 M}{3R} = \frac{(10)^6(4 \times 10^{-3})}{3(25/3)} = 160 \text{ K}$$

(b) Average kinetic energy per atom

$$= \frac{3}{2}kT$$

$$= \frac{3}{2}(1.38 \times 10^{-23})(160) \text{ J}$$

$$= 3.312 \times 10^{-21} \text{ J}$$

(c) 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

$$m = \frac{(100)(1)(4)}{(25/3)(160)} = 0.3 \text{ g}$$

38. Decrease in kinetic energy = increase in internal energy of the gas

$$\therefore \quad \frac{1}{2}mv_0^2 = nC_V\Delta T = \left(\frac{m}{M}\right)\left(\frac{3}{2}R\right)\Delta T$$

$$\therefore \quad \Delta T = \frac{Mv_0^2}{3R}$$

P-32

39. (a) Rate of heat loss per unit area due to radiation

$$I = e\sigma(T^4 - T_0^4)$$

P-33

Here, $T = 127 + 273 = 400$ K

and $T_0 = 27 + 273 = 300$ K

$$\therefore \quad I = 0.6 \times \frac{17}{3} \times 10^{-8}[(400)^4 - (300)^4]$$

$$= 595 \text{ W/m}^2$$

(b) Let θ be the temperature of the oil.

Then, rate of heat flow through conduction = rate of heat loss due to radiation

$$\therefore \quad \frac{\text{temperature difference}}{\text{thermal resistance}} = (595)A$$

$$\frac{(\theta - 127)}{\left(\dfrac{l}{KA}\right)} = (595)A$$

Here, A = area of disc ; K = thermal conductivity and l = thickness (or length) of disc

$$\therefore \ (\theta - 127)\frac{K}{l} = 595$$

$$\therefore \quad \theta = 595\left(\frac{l}{K}\right) + 127$$

$$= \frac{595 \times 10^{-2}}{0.167} + 127 = 162.6\,°\text{C}$$

40. At constant pressure, $V \propto T$

$$\text{or} \quad \frac{V_2}{V_1} = \frac{T_2}{T_1} \quad \text{or} \quad \frac{Ah_2}{Ah_1} = \frac{T_2}{T_1}$$

$$\therefore \quad h_2 = h_1\left(\frac{T_2}{T_1}\right) = (1.0)\left(\frac{400}{300}\right)\text{m} = \frac{4}{3}\text{ m}$$

P-34

As there is no heat loss, process is adiabatic.

For adiabatic process,

$$T_f V_f^{\gamma - 1} = T_i V_i^{\gamma - 1}$$

$$\therefore \quad T_f = T_i\left(\frac{V_i}{V_f}\right)^{\gamma - 1} = (400)\left(\frac{h_i}{h_f}\right)^{1.4 - 1}$$

$$= 400\left(\frac{4}{3}\right)^{0.4} = 448.8\text{ K}$$

P-37

41. 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. Upthrust = Weight. Therefore, upthrust should not change

$$F = F'$$

$$\therefore \quad V_i \rho_L g = V_i' \rho'_L g \qquad (V_i = \text{volume immersed})$$

$$\therefore \ (Ah_i)(\rho_L)(g) = A(1 + 2\alpha_s \Delta T)(h_i)\left(\frac{\rho_L}{1 + \gamma_l \Delta T}\right) g$$

P-36

Solving this equation, we get $\gamma_l = 2\alpha_s$

42. Rate of heat conduction through rod = rate of the heat lost from right end of the rod.

$$\therefore \quad \frac{KA(T_1 - T_2)}{L} = eA\sigma\,(T_2^4 - T_s^4) \qquad \text{... (i)}$$

Given that $T_2 = T_s + \Delta T$

$$\therefore \quad T_2^4 = (T_s + \Delta T)^4 = T_s^4\left(1 + \frac{\Delta T}{T_s}\right)^4$$

Using binomial expansion, we have

$$T_2^4 = T_s^4\left(1 + 4\frac{\Delta T}{T_s}\right) \qquad (\text{as } \Delta T << T_s)$$

$$\therefore \quad T_2^4 - T_s^4 = 4(\Delta T)(T_s^3)$$

Substituting in Eq. (i), we have

$$\frac{K(T_1 - T_s - \Delta T)}{L} = 4e\sigma T_s^3 . \Delta T$$

$$\text{or} \quad \frac{K(T_1 - T_s)}{L} = \left(4e\sigma T_s^3 + \frac{K}{L}\right)\Delta T$$

$$\therefore \quad \Delta T = \frac{K(T_1 - T_s)}{(4e\sigma L T_s^3 + K)}$$

Comparing with the given relation, proportionality constant

$$= \frac{K}{4e\sigma L T_s^3 + K}$$

43. (a) From $\Delta Q = ms\Delta T$

P-38

$$\Delta T = \frac{\Delta Q}{ms} = \frac{20000}{1 \times 400} = 50°\text{C}$$

(b) $\Delta V = V\gamma\Delta T = \left(\dfrac{1}{9000}\right)(9 \times 10^{-5})(50)$

$$= 5 \times 10^{-7}\text{ m}^3$$

$$\therefore \quad W = p \cdot \Delta V = (10^5)(5 \times 10^{-7}) = 0.05\text{J}$$

(c) $\Delta U = \Delta Q - W = (20000 - 0.05)\text{ J}$

$$= 19999.95\text{ J}$$

P-39

44. 0.05 kg steam at 373 K $\xrightarrow{Q_1}$ 0.05 kg water at 373 K

0.05 kg water at 373 K $\xrightarrow{Q_2}$ 0.05 kg 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

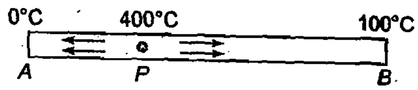
$Q_2 = (50)(1)(100) = 5000$ cal = 5 kcal

$Q_3 = (450)(0.5)(20) = 4500$ 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 273 K from 253 K, but whole ice will not melt. Therefore, temperature of the mixture is 273 K.

45.



Heat will flow both sides from point P.

$$L_1 \frac{dm_1}{dt} = \left(\frac{\text{Temperature difference}}{\text{Thermal resistance}}\right)_1$$

$$= \frac{400}{(\lambda x)/kA} \qquad \text{...(i)}$$

$$L_1 \frac{dm_2}{dt} = \frac{400 - 100}{(100 - \lambda)x/kA} \qquad \text{...(ii)}$$

In about two equations, $\dfrac{dm_1}{dt} = \dfrac{dm_2}{dt}$ (given)

$L_1 = 80\text{ calg}^{-1}$ and $L_2 = 540\text{ calg}^{-1}$

Solving these two equations, we get $\lambda = 9$.

~~Mathe~~ Match the Column

1. (a) $J \to K$ $\quad w = 0$ & $P\downarrow \Rightarrow T\downarrow$

$\Delta T = -ve$

So $Q = \cancel{w}^{0} + \Delta U = -ve$ (ii)

(b) $K \to L$ $\quad w > 0$ & $Q > 0$ (i) (iii)

(c) $L \to M$ $\quad w = 0$ but $T\uparrow \Rightarrow Q = +ve$ (i)

(d) $M \to J$ $\quad w = -ve$ $\left[T = \frac{PV}{nR} \Rightarrow T_M = \frac{400}{nR} > T_J = \frac{300}{nR}\right]$

So $T\downarrow$ $\Delta U = -ve$

$Q = -ve$

(ii), (i

Mathe the Column

2. (a) free expansion $\Rightarrow$ $T = $ Const.

(a) $\Rightarrow$ (ii)

(b) $PV^2 = $ Const.

$x = 2$ $\quad C = C_V + \frac{R}{1-2} = \frac{3R}{2} - R$

$= R/2$

$nRTV = $ Const.

$V\uparrow \Rightarrow T\downarrow \Rightarrow \Delta T = -ve$

therefore $Q = nC\Delta T = -ve$

(b) $\longrightarrow$ (iii)

(c) $PV^{4/3} = $ Const.

$nRTV^{1/3} = $ Const

$V\uparrow \Rightarrow T\downarrow$ $\quad \Delta T = -ve$

$C = \frac{3R}{2} + \frac{R}{1-4} = \frac{3R}{2} - 3R = -\frac{3R}{2}$

(d) as both P & V increasing

from $PV = nRT$

Temp. will increase.

(d) → (i)