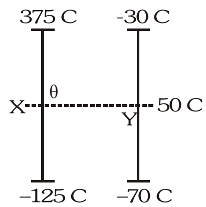
UNIT # 05
THERMAL PHYSICS

EXERCISE –I

1. Let θ = temperature on X–scale corresponding to 50 C on Y–scale
(माना θ = Y पैमाने पर 50 C के संगत X पैमाने पर ताप है)



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

2. For centigrade and Fahrenheit scale
(सेन्टीग्रेड व फारेनहाइट पैमाने के लिये)

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

3. Slope of line AB (रेखा AB का ढाल)

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

4. If we take two fixed points as tripe point of water and 0 K. Then (यदि हम दो स्थिर बिन्दु जल का त्रिक बिन्दु एवं 0 K लेवें तब)

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

5. $\dfrac{X-LFP}{UFP-LFP}$ = constant (for all temperature scales)
(नियत (सभी ताप पैमाने के लिये)

where (जहां)

LFP $\rightarrow$ lower fixed point (निम्न स्थिर बिन्दु)

UFP $\rightarrow$ Upper fixed point (उच्च स्थिर बिन्दु)

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

6. $\Delta L = 6 \quad 10^{-5} = L\alpha\theta \Rightarrow \theta = \dfrac{6\times10^{-5}}{1\times12\times10^{-6}} = 5\ C$

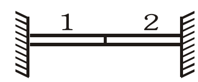
7. Expansions of a metal is same as photographic enlargement. $\Rightarrow d_1$ will increase by 0.3%
(एक धातु का विस्तरण फोटो के बड़े करने की तरह होता है $\Rightarrow d_1$, 0.3% से बढ़ेगा)

8. Let at temperature θ, volume increases by 2% then according to question (माना ताप θ पर आयतन वृद्धि 2% है तो प्रश्नानुसार)

$100 = 98\ [1+3.3 \quad 10\ (\theta-4)]$

$\Rightarrow \theta = 60.4 + 4 = 64.4\ C$

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



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

10. Pressure at the bottom in both arms will be equal
(दोनों भुजाओं में सतह पर दाब समान होगा)

$$\left(\frac{\rho_0}{1+\gamma t_1}\right).\ell_1 = \left(\frac{\rho_0}{1+\gamma t_2}\right)\ell_2 \Rightarrow \gamma = \frac{\ell_1-\ell_2}{\ell_2 t_1 - \ell_1 t_2}$$

11. Strain (विकृति)

$$t = \frac{\Delta\ell}{\ell} = -\alpha\Delta\theta = -12 \quad 10^{-6} \quad (75-25) = -6 \quad 10^{-4}$$

12. Coefficient of linear expansion of brass is greater than that of steel.
(पीतल का रेखीय प्रसार गुणांक स्टील की तुलना में अधिक होगा)

13. $\ell = \ell_0(1+\alpha\Delta T) \Rightarrow \ell - \ell_0 = \ell_0\alpha\Delta T$

$$\Rightarrow \frac{\ell_0\alpha_A\Delta T}{\ell_0\alpha_B\Delta T} = \frac{104-100}{106-100} = \frac{4}{6} \Rightarrow \frac{\alpha_A}{\alpha_B} = \frac{2}{3}$$

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

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

$= (6400)\ (1.2 \quad 10^{-5})\ (30) = 2.3$ km

15. $x = \ell'_A - \ell'_B = \ell_A(1+\alpha_A\Delta T) - \ell_B(1+\alpha_B\Delta T) = \ell_A - \ell_B$

$\Rightarrow \ell_A\alpha_A = \ell_B\alpha_B$

16. For rod A (छड़ A के लिए) $\Delta\ell = \ell_0\ \alpha_A(100)$

For rod B (छड़ B के लिए) $\dfrac{\Delta\ell}{2} = 2\ell_0\alpha_B(100)$

For rod C (छड़ C के लिए)

$2\Delta\ell = x\alpha_A(100) + (3\ell_0 - x)\alpha_B(100)$

$$\Rightarrow x = \frac{5}{3}\ell_0\ \&\ 3\ell_0 - x = \frac{4}{3}\ell_0$$

17. $\Delta\ell = \int$ Expansion in dx =

$$\int \left[(\alpha_0 + \alpha_1 x)dx\right]\Delta T = 100\int_0^2 (1.76\times10^{-5} + 1.2\times10^{-6}x)dx$$

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

=3.76 mm

18. $\because d\ell = \alpha\ell_0 dT \;\therefore\; \Delta\ell = \int d\ell = \int_{T_1}^{T_2}(aT - bT^2)\ell_0 dT$

$$= \ell_0\left[\frac{a}{2}(T_2^2 - T_1^2) - \frac{b}{3}(T_2^3 - T_1^3)\right] = \left[\frac{3}{2}aT_1^2 - \frac{7b}{3}T_1^3\right]\ell_0$$

19. For simple pendulum (सरल लोलक के लिये) T = 2π

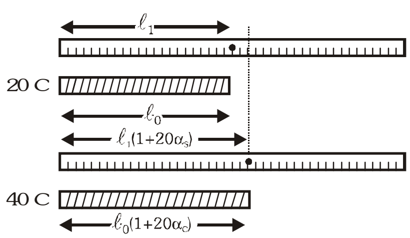
$$\sqrt{\frac{\ell}{g}} \Rightarrow T \propto \ell^{1/2} \Rightarrow \frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta\ell}{\ell} = \frac{1}{2}\alpha\Delta\theta$$

Assuming clock gives correct time at temperature (माना लीजिये कि घड़ी दिये गये ताप पर सही समय दर्शाती है)

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

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

$$\Rightarrow \alpha = 1.4\times10^{-5}\ °C^{-1}$$

20. 

$$\ell_0\ (1+20\ \alpha_C) = \ell_1\ (1+20\alpha_S) \Rightarrow \ell_1 = \left(\frac{1+20\alpha_C}{1+20\alpha_S}\right)\ell_0$$

21. $\gamma_r = \gamma_1 + 3\alpha_1 = \gamma_2 + 3\alpha_2 \;\Rightarrow\; \alpha_2 = \dfrac{\gamma_1 - \gamma_2 + 3\alpha_1}{3}$

22. Let θ = junction temperature (माना θ = संधि का ताप)

Net heat current at junction is zero (संधि पर कुल ऊष्मा धारा शून्य होती है)

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

23. Newton's law of cooling (न्यूटन के शीतलन नियम से)

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

θ_0 = surrounding's temperature (परिवेश का ताप)

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

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

$\Rightarrow$ t = 48 sec

24. $\because t \propto (x_2^2 - x_1^2)$

For $x_1 = 0$, $x_2 = 1$ cm

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

For x_1 =1cm, x_2 = 2cm

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

25. From Stefan's law (स्टीफन नियम से): $\Delta\dot{Q} = \sigma AT^4$

$$\Rightarrow \frac{1cal}{s-m^2}\times\frac{4.2J}{cal} = 5.67\times10^{-8}\times1\times T^4 \Rightarrow T = 100\ K$$

26. $\dfrac{\text{Power}}{\text{Area}}$ = Intensity (तीव्रता)

Power absorbed by the foil = Intensity at foil   Area of foil (पन्नी द्वारा अवशोषित शक्ति = पन्नी पर तीव्रता   पन्नी का क्षेत्रफल)

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

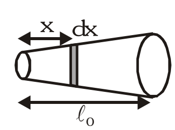
$$\text{Now } P' = \frac{\sigma A_0(2T)^4\times A}{4\pi(2d)^2} = 4P$$

27 $\because \left(\dfrac{\Delta Q}{\Delta t}\right)_A = \left(\dfrac{\Delta Q}{\Delta t}\right)_B$

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

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

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



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

$$= \frac{1}{KA_0\alpha}\ell n(1+\alpha\ell_0)$$

OR

Check dimensionally (विमीय विश्लेषण से जांचे)

29. According to Wien's law (वीन के नियमानुसार)

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

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

(चूंकि वस्तु का ताप बढ़ता है, विकिरण (ν_m) में अधिकतम ऊर्जा के संगत आवृत्ति बढ़ती है। वक्र के अन्तर्गत क्षेत्रफल)

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

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

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

$\Rightarrow$ Area of red star is greater

(लाल तारे का क्षेत्रफल अधिक होगा)

31. Rate of cooling of water = Rate of cooling of alcohol

(पानी के शीतलन की दर = एल्कोहल के शीतलन की दर)

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

$\Rightarrow$ Specific heat of alcohol (एल्कोहॉल की विशिष्ट ऊष्मा)

s = 0.62

32. Amount of energy utilised in climbing

(चढ़ने में उपयोग की गई ऊर्जा की मात्रा)

mgh= 0.28 10 4.2

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

33. Entire KE gets converted into heat.

(सम्पूर्ण गतिज ऊर्जा, ऊष्मा में परिवर्तित हो जाती है)

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

$\Rightarrow \Delta\theta$ = 0.12 C

34. M= mass of hallstone falling

(M= गिर रहे ओले का द्रव्यमान)

m = mass of hallstone melting

(m= पिघल रहे ओले का द्रव्यमान)

As Mgh = mL.

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

35. $H_C = ms\Delta\theta$ = ms (1) C

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

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

$\therefore H_C = H_K > H_F$

36. Heat lost = Heat gained

(ऊष्मा हानि=ऊष्मा वृद्धि)

m_{steam} 540=1100 1 (80–15)+20 1 (80 – 15)

$\therefore$ mass of steam condensed = 0.13 kg

(संघनित भाप का द्रव्यमान)

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

(पानी की विशिष्ट ऊष्मा उच्च होती है तथा इसी के कारण ताप में वृद्धि होने पर यह अधिक ऊष्मा अवशोषित करती है)

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

(जब जल ठंडा बर्फ बनाता है तो ऊर्जा ऊष्मा के रूप में मुक्त होती है, अत: पानी का द्रव्यमान घटता है)

39. If intermolecular forces vanish water behaves as gas.

(यदि अन्तराण्विक बल शून्य है तो पानी गैस की तरह व्यवहार करता है)

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

(पानी के मोलों की संख्या)

Total volume of water at STP

(STP पर पानी का कुल आयतन)

= 22.4 250 10^{-3} m^3 = 5.6 m^3

40. Heat removed in cooling water from 25^{0}C to 0^{0}C

(25^{0}C से 0^{0}C तक ठण्डे पानी में निष्कासित ऊष्मा)

= 100 1 25=2500 cal

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

(0 C पर पानी को बर्फ में बदलने में निष्कासित ऊष्मा)

= 100 80 = 8000 cal

Heat removed in cooling ice from

(ठण्डे बर्फ में निष्कासित ऊष्मा)

0^0 to –15^{0}C = 100 0.5 10 = 500 cal

Total heat removed in1hr 50min

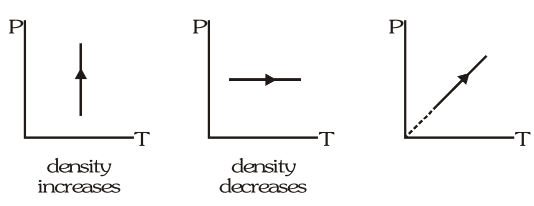
(1 hr 50 min में निष्कासित कुल ऊष्मा)

= 2500 + 8000 + 500=11000 cal

Heat removed per minute (प्रति मिनट निष्कासित ऊष्मा)

$$= \frac{11000}{110} = 100 \text{ cal/min}$$

41.



For equation : $\left(\because P = \frac{\rho RT}{M_w}\right)$

At constant temperature $\rho \propto P$

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

For 2nd graph : $\left(\because P = \frac{\rho RT}{M_w}\right)$

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

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

$\Rightarrow$ density ρ = constant

42. If temperature is doubled, pressure will also be doubled as $P = \frac{\rho RT}{M_w}$ (यदि ताप दुगुना है तो)

$\Rightarrow$ 100% increase $\Rightarrow$ से दाब भी दुगुना होगा

43. Volume can't be negative.
(आयतन ऋणात्मक नहीं हो सकता)

At constant pressure (नियत दाब पर)

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

44. $\frac{3}{4}^{th}$ volume of air at 0 C occupies entire volume at θ ,

(0 C पर वायु का 3/4 आयतन θ ताप पर सम्पूर्ण आयतन घेरता है)

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

45. Ideal gas equation (आदर्श गैस समीकरण): PV = nRT

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

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

46. Number of moles remain constant
(मोलों की संख्या नियत है)

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

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

$\Rightarrow$ T = 273 3 K = (273 3 − 273) C= 546 C

47. Total translational KE(कुल स्थानान्तरित गतिज ऊर्जा)

$= \frac{3}{2} nRT = \frac{3}{2}$ PV

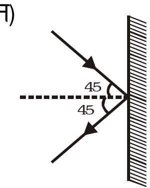
48. $\gamma = \frac{n_1C_{P1} + n_2C_{P2}}{n_1Cv_1 + n_2Cv_2}$

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

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

49. $v_{rms} = \sqrt{\frac{3KT}{m}} \Rightarrow T = \frac{mv_{rms}^2}{3K} \quad \because T \propto mv_{rms}^2$

50. Change in momentum (संवेग में परिवर्तन)



= 2mv cos(45)

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

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

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

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

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

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

53. ΔU_1 = +ve;
ΔU_2 = 0
ΔU_3 = −ve
$\therefore \Delta U_1 > \Delta U_2 > \Delta U_3$
As volume increases, ΔW = +ve.

54. Internal energy and volume depend upon states.
(आन्तरिक ऊर्जा व आयतन अवस्था पर निर्भर करते हैं)

55. PT^{11} = constant & PV =nRT

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

56. $\Delta U = 2P_0\Delta V$ & $W = P_0\Delta V$
So $Q = W + \Delta U = 3P_0\Delta V = 3P_0V_0$

57. When water is heated from 0 C to 4 C, its volume decreases. (जब पानी को 0 C से 4 C तक ऊष्मा दी जाती है तो इसका आयतन घटता है)

$\therefore$ P ΔV is negative (ऋणात्मक)

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

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

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

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

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

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

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

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

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

EXERCISE –II

1. All dimensions increase on heating.
(गरम करने पर सारी विमायें बढ़ती हैं)

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

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

3. A part of liquid will evaporate immediately sucking latent heat from the bulk of liquid. Hence a part of liquid will freeze.(द्रव का एक भाग द्रव के आयतन (परिमाण) से गुप्त ऊष्मा सोखकर उसे शीघ्रता से वाष्प में बदल देता है, अत: द्रव्य का एक भाग जम जायेगा)

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

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

L = latent heat of freezing (जमने की गुप्त ऊष्मा)

m = mass of vapour (वाष्प का द्रव्यमान)

M = mass of freezed (जमा द्रव्यमान)

$\therefore$ Fraction of water which freezed
(पानी का वह भाग जो जम जायेगा)

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

6. Mixture may attain intermediate temperature or terminal temperatures of fusion or vapourisation.
(मिश्रण का ताप मध्यवर्ती ताप के बराबर या गलन या वाष्पन के अन्तिम ताप के बराबर हो सकता है)

7. Water at 4 C has highest density
(4 C पर पानी का घनत्व अत्यधिक होता है)

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

Ratio of specific heats
(विशिष्ट ऊष्माओं का अनुपात)

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

9. $Q = \Delta U + W$

Q = +ve, as heat is absorbed from the atmosphere
(वायुमण्डल से अवशोषित ऊष्मा)

W=–ve as the volume decrease
(जब आयतन घटता है)

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

$\therefore$ Internal energy increases.
(आन्तरिक ऊर्जा बढ़ती है)

10. H_A = (6 cal/s) (6 – 2) s

H_B = (6 cal/s) (6.5 – 4) s

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

12. For insulated chambers (ऊष्मारोधी प्रकोष्ठों के लिये)

$$n_1 + n_2 = n'_1 + n_2'$$

(final pressures become equal)
(अन्तिम दाब बराबर होगा)

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

For left chamber (बांये प्रकोष्ठ के लिये)

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

For right chamber (दांये प्रकोष्ठ के लिये)

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

13. $\frac{P^2}{\rho}$ = constant (नियत)

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

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

$\therefore$ The graph of the above process on the P–T diagram is hyperbola.
(P-T आरेख पर उपरोक्त प्रक्रम का वक्र अतिपरवलयिक होगा)

For the above process (उपरोक्त प्रक्रम के लिये)

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

and

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

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

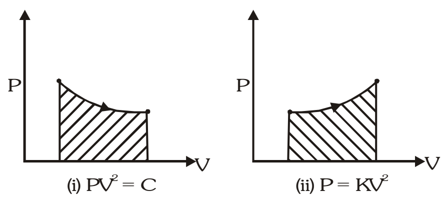
If volume expands temperature decreases.

(यदि आयतन प्रसारित होता है तो ताप घटता है)

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

If volume expands, temperature increases

(यदि आयतन प्रसारित होता है तो ताप बढ़ता है)



$Q = \Delta U + W$

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

15. Ideal gas equation (आदर्श गैस समीकरण) $P = \frac{\rho}{M}.RT$

For state A (अवस्था A के लिये):

$$P_0 = \frac{\rho_0}{M} R\, T_0$$

For state B (अवस्था B के लिए)

$$3P_0 = \frac{\rho}{M} R2T_0 \Rightarrow \rho = \frac{3}{2}\rho_0$$

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

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

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

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

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

(A व B में प्रति अणु औसत गतिज ऊर्जा)

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

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

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

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

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

(पात्र में गैस द्वारा लगया गया दाब पात्र के अन्दर उपस्थित अणुओं की संख्या पर निर्भर करता है)

20. Average speed (औसत चाल)

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

rms speed (वर्ग माध्य मूल चाल)

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

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

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

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

22. Fig A : W_A = +ve Fig B : W_B =+ve

Fig C : W_C = +ve Fig D : W_D = –ve

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

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

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

(ΔU शून्य हो सकता है यदि ΔT शून्य या $Q - W$ शून्य हो)

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

(नियत आयतन पर गैस द्वारा किया गया कार्य शून्य है)

25. For any process (किसी प्रक्रम के लिए) $\Delta U = nC_V\Delta T$

In adiabatic process (रूद्धोष्म प्रक्रम में)

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

For any process (किसी प्रक्रम के लिए)

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

For Q = 0, C = 0 (adiabatic process)
(रूद्धोष्म प्रक्रम)

26. Slope of isothermal process (समतापीय प्रक्रम का ढाल)

$$m_1 = \frac{\Delta P}{\Delta V} = -\frac{P}{V}$$

Slope of adiabatic process (रूद्धोष्म प्रक्रम का ढाल)

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

27. $W_{AB} = (2V_0 - V_0)P_0 = P_0V_0$
[Isobaric process] [समदाबीय प्रक्रम]

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

[Isothermal process] [समतापीय प्रक्रम]

$$\therefore \frac{Q_{AB}}{W_{BC}} = \frac{\frac{3}{2}P_0V_0 + P_0V_0}{2P_0V_0.\ell n2} = \frac{5}{4\ell n2}$$

28. $PV^{\gamma} = C$; $\ell n P + \gamma \ell nV = \ell nC$
$\Rightarrow \ell nP = -\gamma\ell nV + \ell nC \Rightarrow y = mx + c$

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

$\therefore$ The gas is diatomic (गैस द्विपरमाण्विक है)

29. $W_{OBC} = W_{ODA}$
$\therefore$ Net work done (किया गया कुल कार्य)
$= W_{OBC} - W_{ODC} = 0$

30. Final pressure (अन्तिम दाब) $= \frac{kx_0}{S}$

Workdone by gas = P.E. stored in spring = $1/2kx_0^2$
(गैस द्वारा किया गया कार्य = स्प्रिंग में संचित स्थितिज ऊर्जा)
Change in internal energy (आन्तरिक ऊर्जा में परिवर्तन)
$\Delta U = |-\Delta W| = 1/2\ kx_0^2$
As gas expands, ΔT is negative.
(चूंकि गैस प्रसारित होती है, ΔT ऋणात्मक होगा)

31. Work done = Area of ABC with V–axis
(किया गया कार्य = V-अक्ष के साथ ABC का क्षेत्रफल)
$= P_0(2V_0 - V_0) + 0 = P_0V_0 = nRT_0 = RT_0$
Change in internal energy = $nC_V\Delta T$
(आन्तरिक ऊर्जा में परिवर्तन)

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

$\therefore$ Heat absorbed (अवशोषित ऊष्मा)

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

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

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

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

$\Rightarrow$ f = degrees of freedom (स्वतंत्रता की कोटि) = 6

33. For constant pressure process Q
(नियत दाब पर प्रक्रम Q के लिए)
$= nC_P\Delta T = 30nC_P$
For constant volume process Q
(नियत आयतन पर प्रक्रम Q के लिए)

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

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

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

35. **Ans. (C)**
$\Delta U_{CA} = nC_V(T_A - T_C)$

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

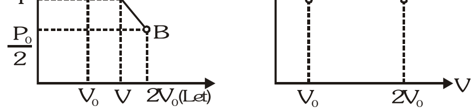
$\Delta U_{AB} = nC_V(T_B - T_A)$

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

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

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

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

36.


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

(माना V_0 = प्रारम्भिक आयतन= $2V_0$ = अन्तिम आयतन)

V = volume of any state

(V=किसी अवस्था का आयतन)

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

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

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

(T-V एक परवलय है जिसका शीर्ष उपरोक्त है)

Hence temperature first increases then decreases.

(अत: पहले ताप बढ़ता है फिर घटता है)

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

(प्रक्रम 1-3 में किया गया कार्य प्रक्रम 1–2 की तुलना में अधिक है जबकि दोनों प्रक्रमों के लिये आन्तरिक ऊर्जा में परिवर्तन समान है)

38. Intensity in first case (प्रथम स्थिति में तीव्रता)

$$I_1 = \frac{P_1}{4\pi R_1^2} = \frac{\sigma A T_1^4}{4\pi d_1^2}$$

Intensity in second case (द्वितीय स्थिति में तीव्रता)

$$I_2 = \frac{P_2}{4\pi R_2^2} = \frac{\sigma A T_2^4}{4\pi d_2^2}$$

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

39. For sphere (गोले के लिए) $kA\left(-\frac{dT}{dr}\right) = P$

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

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

40. For black body (कृष्णिका वस्तु के लिए)

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

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

41. Ans. (A)

For body A (वस्तु A के लिए) $P = \sigma A T^4$

$$\frac{P}{A} = 100 = \sigma \times 300^4$$

For body B (वस्तु B के लिए)

$\frac{P}{A} = (\sigma T^4)\in = (1 - 0.5 - 0.3)$ $[\sigma \quad 300^4]$

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

42. From Stefan's law of cooling :

(स्टीफन के शीतलन नियम से)

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

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

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

43. For surface areas to be same

(समान पृष्ठीय क्षेत्रफल के लिये)

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

Volume ratio (आयतन अनुपात)

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

$\therefore$ (Mass of water in sphere) > (Mass of water in cube)

(गोले में पानी का द्रव्यमान > (घन में पानी का द्रव्यमान)

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

(विकिरण द्वारा ऊर्जा हानि पृष्ठीय क्षेत्रफल पर निर्भर करती है, अत: दोनों प्रकार के क्षेत्रफलों द्वारा ऊर्जा हानि की प्रारम्भिक दर बराबर है। परन्तु गोले के अन्दर पानी का द्रव्यमान अधिक है अत: यह धीरे–धीरे ठण्डा होगा।)

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

(समान ऊष्मा स्थानान्तरण की दर के लिये वस्तु की चालकता उच्च व तापान्तर कम होना चाहिये। यदि बेलन को पहले उच्च चालकता के गर्म पात्र के साथ जोड़ा जाये तो T_b गर्म पात्र के ताप के निकट होगा।)

45. Newton's law of cooling implies that rate of cooling is proportional to temperature difference if the temperature difference between body and surrounding is small. (न्यूटन के शीतलन नियम के अनुसार शीतलन की दर तापान्तर के समानुपाती होती है। यदि वस्तु व परिवेश के मध्य तापान्तर कम है तो)

Then,

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

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

46. From newton's law of cooling.
(न्यूटन के शीतलन नियम से)

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

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

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

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

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

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

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

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

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

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

(where R & R' are thermal resistances).
(जहां R व R' ऊष्मीय प्रतिरोध है)

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

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

49. For the cube, net resistance $= \frac{5R}{6}$
(घन के लिए, कुल प्रतिरोध)
(Where R = thermal resistance of each side)
(जहां R= प्रत्येक भुजा का ऊष्मीय प्रतिरोध है)

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

For side A (भुजा A के लिए)

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

50. Heat current flow rate is uniform everywhere.
(ऊष्मा प्रवाह की दर सभी जगह एकसमान होती है)

51. Heat lost (ऊष्मा हानि)

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

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

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

$\Rightarrow$ radius decreases with time
(त्रिज्या समय के साथ घटती है)

52. $T_P = 50\ C;\ T_Q = 45\ C$
$\therefore$ Heat will flow from P to Q.
(ऊष्मा P से Q बहती है)

53. For same power of radiation
(समान उत्सर्जित शक्ति के लिए)

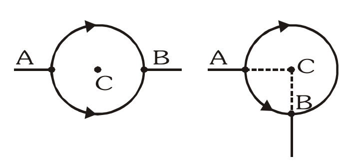
$$P_A = P_B = P_C \Rightarrow e_A\sigma AT_A^4 = e_B\sigma A\ T_B^4 = e_C\sigma AT_C^4$$

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

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

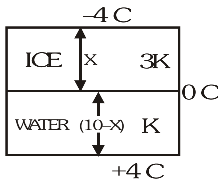
54. $$R = \frac{1}{\frac{KA}{L/2} + \frac{KA}{L/2}} = \frac{KA}{4L};\ R' = \frac{1}{\frac{KA}{3L/4} + \frac{KA}{L/4}} = \frac{3}{4}R$$

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



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

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



57. Rate of cooling (शीतलन की दर)

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

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

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

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

58. For a grey body (एक सामान्य वस्तु के लिए)

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

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

The body is opaque (अत: वस्तु अपरादर्शक होगी)

59. Wien's displacement law.(वीन विस्थापन नियम से)

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

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

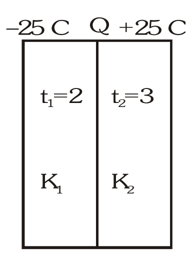
$\Rightarrow \lambda_1 = 1\ \mu m$ & $[\lambda_2 - \lambda_1] = 9\ \mu m$

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

$\Rightarrow T_2 = 300$ K

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

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



(ii) $\dot{Q} = \frac{K_1 A(\theta + 25)}{t_1} = \frac{K_2 A(25 - \theta)}{t_2}$

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

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

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

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

62. $\dot{Q} = \frac{T_A - T_B}{\frac{L}{k_3 A}} = \frac{T_A - T_B}{\frac{L}{k_1 A} + \frac{L}{k_2 A}} \Rightarrow k_3 = \frac{k_1 . k_2}{k_1 + k_2}$

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

then $f = 1/3$

64. For an elemental spherical shells,
(गोलीय कोश के लिए)

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

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

65. $P = P_0 - aV^2$

From ideal gas equation (आदर्श गैस समीकरण से)

$PV = nRT$

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

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

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

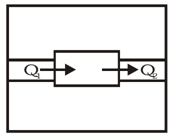
$\therefore T_{max} = \frac{(P_0 - aV^2)V}{R} = \frac{2P_0}{3R}\sqrt{\frac{P_0}{3a}}$

66. Let x= percentage of water solidified
then heat lost = Heat gained
(माना x= जमे हुए पानी की प्रतिशत मात्रा तो
ऊष्मा हानि = ऊष्मा वृद्धि)

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

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

67. $Q_1 + 36 = Q_2$



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

$\Rightarrow \theta = 76$ C

68. He and Ne are monatomic gas.
(He व Ne एकपरमाणुक गैस है)

69. $Q = W = nRT\ \ell n \frac{V_f}{V_i}$

$$T = \frac{Q}{nR\ell nV_f/V_i} = \frac{1500}{0.5 \times 25/3 \times \ell n3}$$

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

70. Area under the curve is equal to number of molecules of the gas sample.
(वक्र के अन्तर्गत क्षेत्रफल प्रतिदर्श गैस के अणुओं की संख्या के बराबर होते हैं।)

Hence $N = \frac{1}{2} a V_0 \Rightarrow aV_0 = 2N$

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

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

$$V_{rms}^2 = \frac{1}{N}\int_0^{\infty} V^2N(V)dV = \frac{1}{N}\int_0^{v_0} V^2\left(\frac{a}{V_0}V\right)dV = \frac{V_0^2}{2}$$

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

Area under the curve from 0.5 V_0 to V_0 is 3/4 of total area (0.5 V_0 से V_0 तक वक्र के अन्तर्गत क्षेत्रफल, कुल क्षेत्रफल का 3/4 होता है)

71. Length (लम्बाई)

$\ell = \ell_0(1+\alpha\Delta T) = \ell_0\ (1+20\alpha)$

Area (क्षेत्रफल)

$A = A_0\ (1+\beta\Delta T) = 6\ell_0^2\ (1+40\alpha)$

Volume (आयतन)

$V = V_0\ (1+\gamma\Delta T) = \ell_0^3\ (1+3\alpha\Delta T) = \ell_0^3\ (1+60\alpha)$

Density (घनत्व)

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

72. At 30 true length is given by (30 पर वास्तविक लम्बाई)

$= SR\ (1+\alpha_{zinc}\ \Delta T)$

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

At 0 , True length is given by (0 पर वास्तविक लम्बाई)

$$= \frac{SR(1+\alpha_{zinc}\Delta T)}{(1+\alpha_{glass}\Delta T)} = \frac{100.078}{(1+8\times10^{-6}\times30)}$$

$=100.054$ cm

73. Tensile Stress (तनन प्रतिबल)

$$= (Y_{steel})\left(\frac{\Delta\ell}{\ell}\right) = Y_S(\alpha_b - \alpha_S)\Delta T$$

$= 200\quad 10^9\ (0.8\quad 10^{-5})\ (200) = 3.2\quad 10^8\ Nm^{-2}$

$= 0.32\ GNm^{-2}$

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

75.

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

So available heat is more than required heat therefore final temperature will be 100^0C.
(उपलब्ध ऊष्मा आवश्यक ऊष्मा से अधिक है अत: अन्तिम ताप 100 C होगा)

Mass of vapour condensed (संघनित वाष्प का द्रव्यमान)

$$= \frac{800+1000}{540} = \frac{10}{3}\ g$$

Total mass of water (पानी का कुल द्रव्यमान)

$$= 10 + \frac{10}{3} = \frac{40}{3} = 13\frac{1}{3}\ g$$

Total mass of steam (भाप का कुल द्रव्यमान)

$$= 5 - \frac{10}{3} = \frac{5}{3} = 1\frac{2}{3}\ g$$

76. At normal temperature (सामान्य ताप पर)

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

At any temperature (किसी भी ताप पर)

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

from process (प्रक्रम से) $T = k_1V^2$

and

ideal gas equation (आदर्श गैस समी.) $PV = nRT$

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

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

At normal temperature (सामान्य ताप पर)

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

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

$\Rightarrow$ Bulk modulus (आयतन प्रत्यास्थता गुणांक)

$$K = \frac{\Delta P}{-\frac{\Delta V}{V}} = 2P$$

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

78. $C_{P_{mix}} = \frac{n_1Cp_1 + n_2Cp_2 + n_3Cp_3}{n_1 + n_2 + n_3}$

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

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

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

EXERCISE –III

True/False

1. $v_{rms} = \sqrt{\frac{3RT}{M_w}}$ (False)

2. $v_{rms} = \sqrt{\frac{3RT}{M_w}}, v'_{rms} = \sqrt{\frac{3R(2T)}{M_{w/2}}} = 2\sqrt{\frac{3RT}{M_w}} = 2v_{rms}$(False)

3. $C_p - C_v = R \Rightarrow C_p > C_v$ (Ans $\rightarrow$ True)

4. Energy radiated per second = σAT^4
(प्रति सेकण्ड उत्सर्जित ऊर्जा)

$$\frac{Q_1}{Q_2} = \left(\frac{1}{4}\right)^2\left(\frac{4000}{2000}\right)^4 = \left(\frac{1}{16}\right)(16) = 1 \quad (\text{Ans} \rightarrow F)$$

5. $(PE)_{rared} > (PE)_{compressed}$ (Ans – True)

6. Equal volume at NTP contains equal molecules.
(NTP पर समान अणुओं के आयतन समान होते हैं)

7. Higher temperature means higher internal energy
(उच्च ताप का अर्थ है उच्च आन्तरिक ऊर्जा)

Match the column

1. When A & B are mixed (जब A व B को मिलाते हैं)

ms (T – 20) = (2m) s (40 – T) $\Rightarrow T = \frac{100}{3}$ = 33.3 C

When A & C are mixed (जब A व C को मिलाते हैं)

ms(T – 20) = (3m) s (60–T) $\Rightarrow$ T = 50 C

When B & C are mixed (जब B व C को मिलाते हैं)

(2m) s (T –40) = (3m) s (60 –T) $\Rightarrow$ T = 52 C

When A, B & C are mixed (जब A,B व C को मिलाते हैं)

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

2. Isobaric process (समदाबीय प्रक्रम)

$\Rightarrow$ P = constant (नियत)

Isothermal process (समतापी प्रक्रम):

$\Rightarrow$ T = constant (नियत)

$\Rightarrow \Delta U=0 \Rightarrow U$=constant (नियत)

Isoentropy process (समएन्ट्रॉपी प्रक्रम):

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

No heat exchange (कोई ऊष्मा परिवर्तित नहीं होगी)

Isochoric process (समआयतनिक प्रक्रम):

$\Rightarrow$ V = constant (नियत) $\Rightarrow$ dW = PdV = 0

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

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

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

4. **For(A)**

as PV = $\frac{1}{3}mNv^2_{rms}$ = $\frac{2}{3}E$ so in P = $\frac{2}{3}E$,

E is transtational kinetic energy of unit volume.

(E इकाई आयतन की स्थानान्तरित गतिज ऊर्जा है)

For (B):

In U = 3RT, U is not internal energy of one mole as for monoatomic gas U = 3/2 nRT (U एकल परमाण्विक गैस के लिये एक मोल की आन्तरिक ऊर्जा नहीं है)

For (C):

In W= P(V_f – V_i); w is work done in isobaric process. (w समदाबीय प्रक्रम में किया गया कार्य है)

For (D) :

In $\Delta U = nC_v\Delta T$

ΔU is change in internal energy for every process.

(ΔU प्रत्येक प्रक्रम के लिये आन्तरिक ऊर्जा में परिवर्तन है)

5. From given V–T graph we cannot tell the nature of gas (दिए गए V-T ग्राफ से गैस की प्रकृति नहीं बता सकते)

slope of V–T graph (V-T ग्राफ का ढाल)=$\frac{nR}{P}$

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

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

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

(समतापीय प्रत्यास्थता गुणांक)

Adiabalic bulk modulus = γP= $\frac{5RT}{3V}$

(रूद्धोष्म प्रत्यास्थता गुणांक)

Slope of PV graph in isothermal process

(समतापीय प्रक्रम में PV वक्र का ढाल =$-\frac{P}{V}=-\frac{RT}{V^2}$

Slope of P–V graph in adiabatic process

(रूद्धोष्म प्रक्रम में PV वक्र का ढाल) =$-\frac{\gamma P}{V}=-\frac{5P}{3V}$

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

(A पर प्रारम्भिक ऊष्मा प्रवाह की दर अधिकतम होगी तथा B पर न्यूनतम होगी, जबकि अनुप्रस्थ भाग B पर बाह्य कोई तापान्तर नहीं होगा ।)

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

(स्थायी अवस्था में $\frac{dQ}{dt}$ समान होगा)

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

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

will be maximum at B & minimum at A

(B पर अधिकतम तथा A पर न्यूनतम होगा)

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

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

(अत: मोलर ऊष्मा नियतांक C, किसी गैस के ताप के परिवर्तन की दर के लिये निर्धारक गुणांक है क्योंकि उसे ऊष्मा प्रदान की गई है। यह एक परमाणुक गैस $\left(C_V=\frac{3}{2}R\right)$ के समआयतनिक प्रक्रम के लिये न्यूनतम है। जिसके कारण सबसे अधिक ढाल $\left(\frac{dT}{Q}\right)$ प्राप्त होता है अर्थात् वक्र 1)

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

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

(एक परमाण्विक गैस के समदाबीय तथा द्विपरमाण्विक गैस के समआयतनिक प्रक्रम के लिये इनकी ऊष्मा धारिता $\left(\frac{5}{2}R\right)$ समान

होगी। अत: दोनों वक्र 2 द्वारा प्रदर्शित है। द्विपरमाण्विक गैस के समदाबीय प्रक्रम के लिये $C_P = \frac{7}{2}R$ यह वक्र 3 द्वारा प्रदर्शित है। अक्ष Q समआयतनिक प्रक्रम को प्रदर्शित करता है तथा ΔT रूद्धोष्म प्रक्रम को प्रदर्शित करता है)

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

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

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

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

$= 75$ units

Q = 75 + 15 = 90 units

Molar heat capacity (मोलर ऊष्माधारिता) :

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

$= 3 \quad \frac{25}{3} = 25$ units

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

For (A) :

For AB $P \propto V \Rightarrow T \propto V^2 \Rightarrow T \propto \rho^{-2}$

For BC V = constant $\Rightarrow \rho$ = constant

For CA P = constant $\Rightarrow \rho T$ = constant

For (B)

For AB $P \propto T \Rightarrow \rho$ = constant

For BC T = constant $\Rightarrow P \propto \rho$

For CA P = constant $\Rightarrow \rho T$ = constant

For (C)

For AB P = constant $\Rightarrow \rho T$ = constant

For BC T = constant $\Rightarrow P \propto \rho$

For CA V = constant $\Rightarrow \rho$ = constant

For (D)

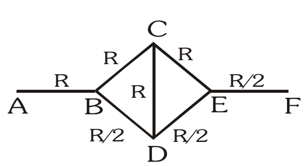
For AB $\rho \propto T \Rightarrow P \propto T^2$

For BC T = constant $\Rightarrow P \propto \rho$

For A ρ = constant $\Rightarrow P \propto T$

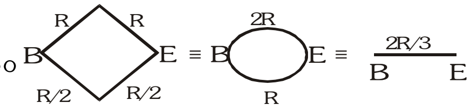
11. For (A)

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



No heat current flows through rod CD

(छड़ CD से होकर कोई ऊष्मा धारा का प्रवाह नहीं होगा)

So


For (B)

For (C)

Total heat current form A to F,

(A से F तक कुल ऊष्मा धारा)

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

Let temperature of B be T_B then

(माना B का ताप T_B है तो)

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

For (D)

As heat current is inversely proportional to heat resistance.

(चूंकि ऊष्मा धारा ऊष्मीय प्रतिरोध के व्युत्क्रमानुपाती होती है)

So heat current in BD (अत: BD में ऊष्मा धारा)

$$= \left(\frac{2R}{R+2R}\right)I = \frac{2}{3}I$$

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

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

Comprehension Based Questions

Comprehension#1

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

(माना कि ऊष्मा k_1 cal/min की दर से दी जाती है तो)

$k_1 \quad 1 = m(0.5)\theta_1$

$k_1 \quad 4 = m(80) \quad k_1 \quad 2 = m(1)\ (\theta_2)$

$\Rightarrow k_1 = 20\ m \Rightarrow \theta_1 = 40\ C,\ \theta_2 = 40\ C$

Therefore initial temperature = –40 C

(अत: प्रारम्भिक ताप)

Final temperature (अन्तिम ताप) = +40 C

Comprehension#2

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

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

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

Comprehension#3

1. Since P is constant = 1 atm, heat added will cause temperature rise.From the phase diagram, A will sublime while B will first melt and then boils.
(चूंकि P नियत है =1 atm, अवस्था आरेख से, A ऊर्ध्वपतित होगा, जबकि B पहले पिघलेगा फिर उबलेगा।)

2. From the phase diagram, at 2 atm & 220 K, A is gas & B is solid.(अवस्था आरेख से 2 atm व 220 K ताप पर, A गैस है तथा B ठोस है।)

Comprehension#4

1. Let M be the mass of solid (माना ठोस का द्रव्यमान M है)

$\therefore$ Volume displaced (निष्कासित आयतन) = $\dfrac{1 \times M}{2 \times \rho_s}$

Thrust force (प्रणोद बल)= $\rho_L \times \dfrac{M}{2\rho_s} g = Mg \quad \therefore \rho_L = 2\rho_S$

2. If $\gamma_{Liq} > \gamma_{solid}$ Also $\rho_L Vg = Mg$
As $T\uparrow$, $\rho_L\downarrow$, so V displaced $\uparrow$
(चूंकि $T\uparrow$, $\rho_L\downarrow$, अतः V निष्कासित $\uparrow$)
Fraction of solid submerged should increased.
(डुबे हुए ठोस का अंश बढ़ेगा)

3. If fraction of solid submerged doesn't change, then
(यदि डुबे हुए ठोस के अंश में कोई परिवर्तन नहीं हो तो)

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

4. If h doesn't change (यदि h में कोई परिवर्तन नहीं हो)
$V = Ah \therefore \gamma_L = 2\alpha_S$

5. If volume change in solid is zero.
(यदि ठोस में आयतन परिवर्तन शून्य है)
Let at T', solid sinks (माना T पर ठोस डुबता है)

$$\Rightarrow \rho_0 \frac{V}{2} g = V\rho_S g \,(\text{Initially}) \quad (\text{प्रारम्भिक})$$

Finally (अन्तिम) $\rho_T Vg = V\rho_S g = \dfrac{\rho_0}{2}$

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

$\therefore$ Temperature= $T + \dfrac{1}{\gamma_L}$

Comprehension#5

1. On increasing temperature (giving heat), U increases. Now r_{avg} increases for A while decreases for B.
(ऊष्मा देने पर, ताप में वृद्धि करने पर, U बढ़ेगा। अब A के लिये r_{avg} बढ़ता है जबकि B के लिये r_{avg} घटता है।

2. The equilibrium remain unchanged but average distance increases.
(साम्य स्थिति अपरिवर्तित रहती है लेकिन औसत दूरी बढ़ती है)

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

(from equilibrium position) (साम्यावस्था स्थिति से)

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

Comprehension#6

2. **Ans. (D)**

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

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

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

$$\Rightarrow \ell n\left(\frac{20}{40}\right) = -\frac{1}{400}t \Rightarrow t = 277\,s$$

Comprehension#7

1. As $Q = n_A C_{vA} \Delta T = n_B C_{vB} \Delta T \Rightarrow n_A C_{vA} = n_B C_{vB}$
But volume is constant (लेकिन आयतन नियत है)
So $\Delta P_A V_A = n_A R\Delta T$ & $\Delta P_B V_B = n_B R\Delta T$

$$\Rightarrow \frac{n_A}{n_B} = \frac{\Delta P_A}{\Delta P_B} = \frac{2.5}{1.5} = \frac{5}{3} \Rightarrow \frac{C_{vB}}{C_{vA}} = \frac{5}{3} = \frac{5/2R}{3/2R}$$

$\Rightarrow$ Gas B is diatomic & gas A is monoatomic
(गैस B द्विपरमाण्विक तथा गैस A एकल परमाण्विक है)

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

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

3. Number of molecules in A (A में अणुओं की संख्या)

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

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

Comprehension#8

1. At temperature above 4 C, temperature of water above is less as compared to below as water is heated by radiation of longer wavelength. (4 C से ऊपर ताप पर, ऊपरी पानी का ताप निचले पानी की तुलना में कम होगा तथा लम्बी तरंगदैर्ध्य की विकिरण द्वारा ऊष्मा दी जाती है)

2. At temperature below 4 C, temperature above is less as compared to below & thus water remain is it is due to higher volume at the upper surface.
(4 C से नीचे ताप पर ऊपरी ताप निचले की तुलना में कम होगा तथा ऊपरी सतह पर उच्च आयतन के कारण यह पानी ही रहेगा)

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

$\therefore \frac{L\rho A dx}{dt} = \frac{\Delta T kA}{x} = L\rho \frac{x^2}{2} = \Delta Tk \cdot t$

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

4. Transition of ice starts from the top & decreases below to the bottom.
(शीर्ष से बर्फ में परिवर्तन प्रारम्भ होता है तथा तल के नीचे घटता है)

Comprehension#9

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

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

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

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

4. Internal energy (आन्तरिक ऊर्जा) He = 100 J
Internal energy (आन्तरिक ऊर्जा) H = 200 J
while mixing, they don't interact
(जब इन्हें मिलाते हैं तो ये कोई क्रिया नहीं करते हैं)
Internal energy of mix (मिश्रण की आन्तरिक ऊर्जा)
= (100 + 200) J = 300 J

Comprehension#10

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

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

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

Comprehension#11

1. Change is entropy (एन्ट्रॉपी में परिवर्तन)$\Delta S = \frac{\Delta Q}{T}$

$\Rightarrow$ Unit of entropy (एन्ट्रॉपी की इकाई)= JK^{-1}

2. When milk is heated, its entropy increases as it is irreversible process. (जब दूध गर्म करते हैं तो इसकी एन्ट्रॉपी बढ़ती है चूंकि अनुत्क्रमणीय प्रक्रम है)

3. After a long time disorder is increased.
(लम्बे समय बाद अव्यवस्था बढ़ती है)

Comprehension#12

1. Stress developed at junction are same
(संधि पर उत्पन्न प्रतिबल समान है)
$Y_1 \alpha_1 \ell_1 \Delta T = Y_2 \alpha_2 \ell_2 \Delta T \Rightarrow Y_1 \alpha_1 \ell_1 = Y_2 \alpha_2 \ell_2$

2. As cross sectional area is same & equal and opposite force acting on both rods.
(चूंकि अनुप्रस्थ काट क्षेत्रफल समान है तथा बराबर है व दोनों छड़ों पर आरोपित बल विपरीत है)
So F/A= same.

3. Let shifting in junction be x towards right then

(माना दांयी ओर संधि में विस्थापन x है तो)

$$\left(\frac{\Delta\ell}{\ell}\right)_1 = \frac{\ell_1\alpha_1\Delta T - x}{\ell_1}, \left(\frac{\Delta\ell}{\ell}\right)_2 = \frac{\ell_2\alpha_2\Delta T + x}{\ell_2}$$

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

So $x = \frac{\ell_1\ell_2(Y_1\alpha_1 - Y_2\alpha_2)\Delta T}{Y_1\ell_2 + Y_2\ell_1}$

Comprehension#13

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

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

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

Comprehension#14

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

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

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

Comprehension#15

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

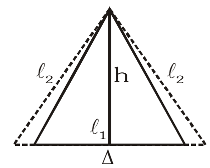
   $\eta' = 0.7 = \frac{T_1' - T_2}{T_1'} = \frac{T_1' - 280}{T_1'} \Rightarrow \frac{2800}{3}$

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

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

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

EXERCISE –IV A

1. 

   $h^2 = L_2^2 - \frac{\ell_1^2}{4}$ = constant

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

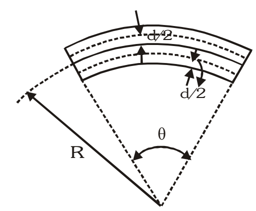
   $\Rightarrow 4L_2\ (L_2\alpha_2\Delta T) = L_1(L_1\ \alpha_1\Delta T)$

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

2. Here:

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

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



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

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

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

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

   (ऊष्मीय धारा $= \frac{\text{तापान्तर}}{R_H}$)

   where $\frac{1}{R_H} = \frac{K_1 A}{\ell} + \frac{K_2 A}{\ell} = \frac{(K_1 + K_2)a^2}{a}$

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

   $\Rightarrow$ Thermal current (ऊष्मीय धारा)

   $= 80\ \ 3 = 240$ W

   (ii) Ratio of thermal currents (ऊष्मीय धाराओं का अनुपात)

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

4. In steady state rate of flow of heat in the whole system will be same.
   (स्थायी अवस्था में सम्पूर्ण निकाय में ऊष्मा प्रवाह की दर समान होगी)

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

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

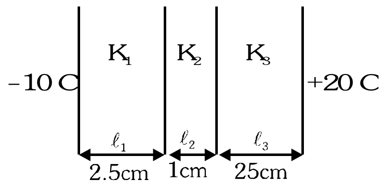
   $\Rightarrow \theta_1 = 116$ C, $\theta_2 = 74$ C

5. $Q = KA\dfrac{(\theta_1-\theta_2)t}{\ell} = mL \Rightarrow \quad m \quad 335 \quad 10^3$

$= 0.01 \quad \dfrac{0.54\times45\times6\times60\times60}{5\times10^{-2}} \Rightarrow m = 0.261$ kg

Therefore mass of ice left in the box after 6 hours
(अत: 6 घण्टे बाद बॉक्स में बांयी ओर बर्फ का द्रव्यमान)
$= (4 - 0.261)$ kg $= 3.739$ kg

6.



Power required (आवश्यक शक्ति)

$= \dfrac{K_{eq}A(T_1-T_2)}{\ell}$

$= \dfrac{\ell}{\left(\dfrac{\ell_1}{K_1}+\dfrac{\ell_2}{K_2}+\dfrac{\ell_3}{K_3}\right)}\left[\dfrac{A(T_1-T_2)}{\ell}\right]$

$= \dfrac{A(T_1-T_2)}{\dfrac{\ell_1}{k_1}+\dfrac{\ell_2}{k_2}+\dfrac{\ell_3}{k_3}}$

$= \dfrac{(137)(30)}{\left(\dfrac{2.5}{0.125}+\dfrac{1}{1.5}+\dfrac{25}{1}\right)\times10^{-2}} = 9000$ W

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

$\Rightarrow 2\theta = 10 \Rightarrow \theta = 5$ C

8. (i) Temperature gradient (ताप प्रवणता)

$= \dfrac{T_1-T_2}{\ell} = \dfrac{100-0}{1} = 100$ C/m

(ii) Steady state temperature of element dx :
(स्थायी अवस्था में अल्पांश dx का ताप)
$T = 100\,(1-x)$
Heat absorbed by the element to reach steady state
(स्थायी अवस्था तक पहुंचने के लिये अल्पांश द्वारा अवशोषित ऊष्मा)

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

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

Total heat absorbed by the rod
(छड़ द्वारा अवशोषित कुल ऊष्मा)

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

9. By using Wien's displacement law
(वीन के विस्थापन नियम द्वारा)

$T = \dfrac{b}{\lambda_m} = \dfrac{2.89\times10^{-3}}{1.5\times10^{-6}} = 1927$ K

10. (i) $\because P_A = P_B$
$\therefore e_A\,\sigma A_A\,T_A^4 = e_B\,\sigma A_B T_B^4$

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

(ii) According to Wein's displacement law
(वीन के विस्थापन नियमानुसार)

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

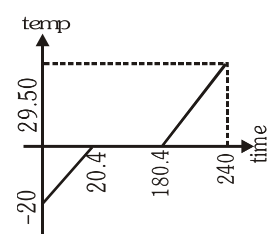
Also $\lambda_B - \lambda_A = 1\ \mu m \Rightarrow \lambda_B - \dfrac{\lambda_B}{3} = 1\mu m \Rightarrow \lambda_B = 1.5\ \mu m$

12. Let m = mass of steam required per hour
(माना m= प्रति घण्टे आवश्यक भाप का द्रव्यमान)
Heat needed (आवश्यक ऊष्मा)
= (10 1000 kg) (1cal/g) (80–20)
= 60 10^4 cal/hour
Heat supplied (दी गई ऊष्मा)
= m 1 (150–100) + m 540 + m 1 (100 – 90)
Heat needed = Heat supplied
(आवश्यक ऊष्मा = दी गई ऊष्मा)
$\Rightarrow$ 60 10^4 = 600 m = 1000 gm = 1 kg

13. Heat needed to bring ice to freezing point
(बर्फ को जमाव बिन्दु तक ले जाने में आवश्यक ऊष्मा)
= 10 0.2 20 + 200 0.5 20
= 40+2000 = 2040 cal

Time taken to reach 0 C $= \dfrac{2040}{100}$ s = 20.4 s

(0 C तक पहुंचने में लिया गया समय)
Heat needed to melt ice
(बर्फ को पिघलाने में आवश्यक ऊष्मा)
=2040 + 200 80 =18040 cal



Time taken to melt ice (बर्फ को पिघलने में लगा समय)

$= \dfrac{18040}{100} = 180.4$ sec

Heat taken in 4 min (4 मिनिट में ली गई ऊष्मा)

$= 100 \quad 4 \quad 60 = 24{,}000$ cal

Let (माना)

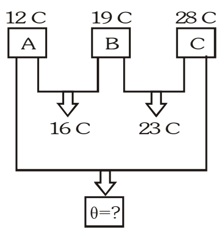
θ = final temperature then (अन्तिम ताप तो)

heat lost = heat gained (ऊष्मा हानि =ऊष्मा वृद्धि)

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

$\Rightarrow \theta = \dfrac{24000-18040}{202} = 29.50$ C

14. When A & B are mixed (जब A व B मिलाते हैं)



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

When B & C are mixed (जब B व C मिलाते हैं)

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

when A & C are mixed (जब A व C मिलाते हैं)

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

15. Heat lost (ऊष्मा हानि) $= \dfrac{3}{4}\left(\dfrac{1}{2}mv^2\right)$

Heat gained (ऊष्मा वृद्धि) = ms(327–27) + mL

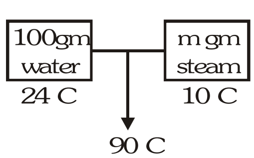
As heat lost = Heat gained (ऊष्मा हानि =ऊष्मा वृद्धि)

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

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

$\Rightarrow v = 12.96$ m/s

16. Heat gained = Heat lost (ऊष्मा वृद्धि =ऊष्मा हानि)



$100 \quad 1 \quad (90-24) = m \quad 540 + m\ 1 \quad (100-90)$

$\Rightarrow m = 12$ g

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

(त्रिक बिन्दु पर (ताप= –56.6 C) व दाब = 5.11 वायुमण्डलीय दाब), CO_2 के ठोस, द्रव व वाष्प कला सह उपस्थित होंगे)

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

(संलयन तथा क्वथनांक बिन्दु दोनों बिन्दुओं पर दाब घटता है)

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

(क्रान्तिक ताप 31.1 C व क्रान्तिक दाब 73.0 वायुमण्डलीय दाब। क्रान्तिक ताप से अधिक ताप पर इसे द्रवित नहीं किया जा सकता है)

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

(A) वाष्प (B) ठोस (C) द्रव

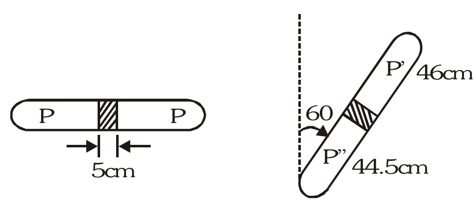
18. No. of moles (initially) = No. of moles (finally)

(मोलों की संख्या (प्रारम्भ में) = मोलों की संख्या (अन्तिम)

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

$\Rightarrow P = 83.83$ cm of Hg

19. P" = P' + 5 cos 60 = (P' + 2.5) cm of Hg



For constant temperature process :

(नियत ताप प्रक्रम के लिये)

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

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

20. Let m = mass of neon gas then

(माना m= निऑन गैस का द्रव्यमान)

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

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

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

21. No. of moles withdrawn (निकाले गये मोलों की संख्या)

$= n_1 - n_2 = \dfrac{\Delta m}{M}$

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

$= 32\left[\dfrac{15\times10^5\times30\times10^{-3}}{300\times8.314} - \dfrac{11\times10^5\times30\times10^{-3}}{290\times8.314}\right]$

$=0.139$ kg

22. (i) Dotted lines correspond to ideal gas (बिन्दुकित् रेखायें आदर्श गैस को बताती है)

(ii) $T_1 > T_2$
(On high temp. real gas behaves as ideal gas)
(उच्च ताप पर वास्तविक गैस, आदर्श गैस की भांति व्यवहार करती है)

(iii) $\dfrac{PV}{T} = \dfrac{m}{M}.R = \dfrac{10^{-3}}{32\times10^{-3}}\ \ 8.314 = 0.26$ J/K

23. $\dfrac{R}{C_P} = 0.4 \Rightarrow C_P = \dfrac{R}{0.4} = \dfrac{5}{2}R \Rightarrow C_v = C_P - R = \dfrac{3}{2}R$

(i) Atomicity = Monatomic,
(परमाणुकता = एकल परमाणुक)
Degree of freedom = 3
(स्वतंत्रता की कोटि =3)

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

(iii) Mean gram-molecular kinetic energy
(माध्य ग्राम अणुक गतिज ऊर्जा)

$= \dfrac{3}{2}R\ \ 300 = 450$ R

24. (i) Let $\dot{n}$ = number of collisions per second per unit area, (माना $\dot{n}$ = एकांक क्षेत्रफल पर प्रति सेकण्ड टक्करों की संख्या)

change in momentum (संवेग में परिवर्तन)

$= 2mv$

$\therefore$ Pressure exerted on wall (दीवार पर आरोपित दाब)

$= \dot{n}(2mv) = P_0$

$\Rightarrow \dfrac{\dot{n}\times2\times32\times10^{-3}}{6.02\times10^{23}}\times\sqrt{\dfrac{3\times8.3\times300}{0.032}} = 10^5$

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

(ii) If vessel is suddenly stopped then KE will utilized in increase in temperature. (यदि पात्र अचानक रूक जाता है तो गतिज ऊर्जा ताप में वृद्धि करने में काम आती है।)

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

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

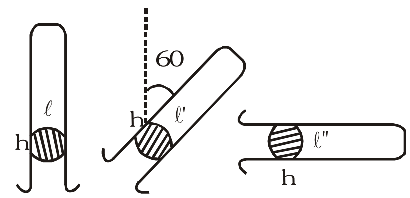
25. For gas trapped in the tube (नली में बंद गैस के लिए)

$P_1V_1 = P_2V_2 = P_3V_3$

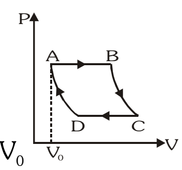
$\Rightarrow (76-h)\ A\ell = (76-h\cos60\ )\ A\ell' = 76\ \ \ A\ell$

$\Rightarrow 66\ \ \ 40 = 71\ \ \ell' = \ 76\ \ \ \ell''$

$\ell = 37.2$ cm & $\ell'' = 34.7$ cm



26. $V_A = V_0 = \dfrac{nRT_A}{P_A} = \dfrac{2R\times300}{2} = 300R$



$V_B = \dfrac{nRT_B}{P_B} = \dfrac{2R\times400}{2} = 400R = \dfrac{4}{3}V_0$

$V_C = \dfrac{nRT_C}{P_C} = \dfrac{2R\times400}{1} = 800\ R = \dfrac{8}{3}V_0$

$V_D = \dfrac{nRT_D}{P_D} = \dfrac{2R\times300}{1} = 600\ R = 2V_0$

For cyclic process (चक्रीय प्रक्रम के लिए)

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

$W_{A\to B} = P_A\ (V_B - V_A) = 2\left(\dfrac{4V_0}{3} - V_0\right)\times10^5 = \dfrac{2V_0}{3}\times10^5$

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

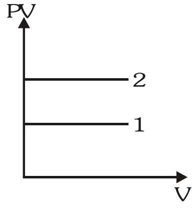
$W_{C\to D} = P_C(V_D - V_C) = 10^5\left(2V_0 - \dfrac{8V_0}{3}\right) = -\dfrac{2V_0}{3}\times10^5$

$W_{D\to A} = -P_DV_D.\ \ell n2 = -\ 10^5\ \ \ 2\ \ \ \ell n2$

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

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

27. (i) $P_1V_1 = nRT_1$ and $P_2V_2 = nRT_2$



$\because\ P_2V_2 > P_1V_1$

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

For same volume, $P_1V = nRT_1$

$\because\ T_1 < T_2\ \&\ P_2V = nRT_2$

$\Rightarrow P_1 < P_2$

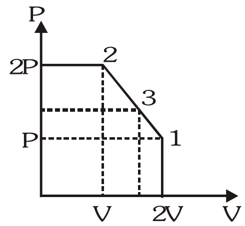
(ii) $P_2V_2 = P_1V_1 = 2PV = P2V \Rightarrow T_1 = T_2$

For state 3:

Let $V_3 = 3V/2$

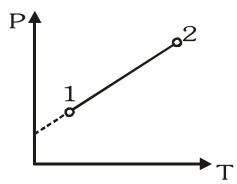
$P_3 = 3P/2$ then

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



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

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



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

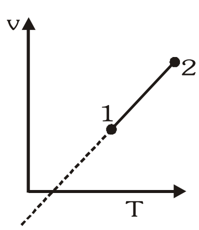
From ideal gas equation

(आदर्श गैस समीकरण से)

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

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

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



then $P_1V_1 = nRT_1$

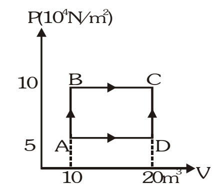
$P_2V_2 = nRT_2 \Rightarrow \dfrac{P_1V_1}{P_2V_2} = \dfrac{nRT_1}{nRT_2}$

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

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

28. (i) $T_A = \dfrac{P_AV_A}{nR} = \dfrac{5 \times 10^4 \times 10}{\left(\dfrac{2000}{4}\right) \times 8.314} = 120.3°K$

$T_B = \dfrac{P_BV_B}{nR} = 2T_A = 240.6\ \ K$



$T_C = \dfrac{P_CV_C}{nR} = 2T_B = 481.3\ \ K$

$T_D = \dfrac{P_DV_D}{nR} = T_B = 240.6\ K$

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

(नहीं, हम अभिक्रिया की दिशा ज्ञात नहीं कर सकते हैं)

(iii) Process ABC :

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

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

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

Process ADC $\rightarrow$

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

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

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

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

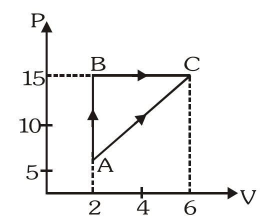
(PV वक्र के अन्तर्गत क्षेत्रफल कार्य द्वारा दिया जाता है)

(ii) $U_A = 10$J

$Q_{AC} = 200$ J

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

$= \dfrac{4 \times 20}{2} = 40$ J



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

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

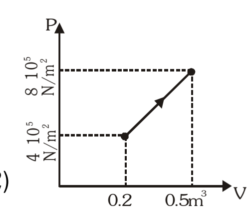
(iii) $Q_{AB} = \Delta U_{AB} + W_{AB} = (U_B - U_A) + W_{A\rightarrow B}$

$= (20 - 10) + 0 = 10$ J

30. (i) Work done by gas

(गैस द्वारा किया गया कार्य)

$= \dfrac{1}{2}(4+8)\quad 10^5\quad (0.5-0.2)$



$= 1.8\quad 10^5$ J

(ii) Increase in internal energy

(आन्तरिक ऊर्जा में वृद्धि)

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

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

(iii) Amount of heat supplied (दी गई ऊष्मा की मात्रा)

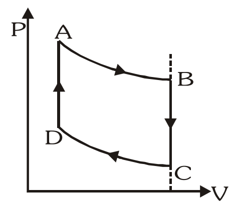
$Q = \Delta U + W = 6.6 \quad 10^5$ J

(iv) Molar specific heat of the gas

(गैस की मोलर विशिष्ट ऊष्मा)

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

31. Given that



$T_A = 1000$ K $\qquad n = 1$

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

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

For process A→B (प्रक्रम A→B के लिए)

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

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

$$= 1000 \quad 0.85 = 850\ k$$

For Process B → C (प्रक्रम B→C के लिए)

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

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

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

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

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

$= -5300.175$ J

(iii) For process A → B (प्रक्रम A→B के लिए)

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

For Process C → D (प्रक्रम C→D के लिए)

$P_C V_C^{\gamma} = P_D V_D^{\gamma}$

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

At end points A and D ((बिन्दु A व D सिरों पर)

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

32. (i) For adiabatic process (रूद्धोष्म प्रक्रम के लिए)

$T_1 V_1^{\gamma-1} = T_2 . V_2^{\gamma-1}$

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

(ii) Change in internal energy (आन्तरिक ऊर्जा में परिवर्तन)

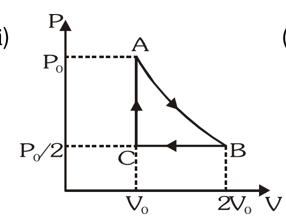
$$\Delta U = nC_V\Delta T = n\frac{3}{2}R(T_2 - T_1)$$

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

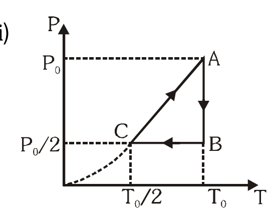
(iii) Work done by gas (गैस द्वारा किया गया कार्य)

$$= \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{nR(T_1 - T_2)}{\gamma - 1} = 2767\ J$$

33. (i)



(ii)



(iii) Work done by gas (गैस द्वारा किया गया कार्य)

$$W_{AB} = nR(T_A)\ \ell n\ \frac{V_B}{V_A} = 3RT_A \ell n2$$

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

$$= -\frac{P_0V_0}{2} = \frac{-nRT_A}{2} = -\frac{3}{2}RT_A$$

$W_{CA} = 0$

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

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

34. For polytropic process (बहुदेशिक प्रक्रम के लिए)

$$T_1V_1^{n-1} = T_2V_2^{n-1} \Rightarrow TV^{n-1} = \frac{T}{2}(5.66V)^{n-1} \Rightarrow 2 = 5.66^{n-1}$$

Taking log both sides (दोनों पक्षों का लघुगुणक लेने पर)

$\ell n2 = (n-1)\ \ell n\ 5.66$

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

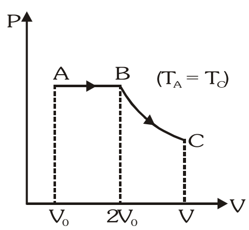
(i) $\therefore$ Degrees of freedom (स्वतंत्रता की कोटि)= 5

(ii) Work done by gas (गैस द्वारा किया गया कार्य)

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

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

35. (i)



(ii) **Process AB (प्रक्रम AB):**

$$\frac{V_A}{T_A} = \frac{V_B}{T_B}$$

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

Process BC (प्रक्रम BC):

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

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

For end states A & C (अवस्था A व C के लिए)

$$\frac{P_A.V_A}{T_A} = \frac{P_CV_C}{T_C} = nR \Rightarrow P_C = 0.44\ \ \ 10^5\ N/m^2$$

(iii) Work done (किया गया कार्य)

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

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

36. Number of moles (मोलों की संख्या)

$$n = \frac{PV}{RT} = \frac{(1.6 \times 10^6)(0.0083)}{(8.3)(300)} = \frac{16}{3}$$

Heat is supplied at cosntant volume

(ऊष्मा, नियत आयतन पर दी जाती है)

so $Q = nC_V\Delta T$

$$\Rightarrow T_2 = T_1 + \frac{Q}{nC_V} = 300 + \frac{2.49 \times 10^4}{\left(\frac{16}{3}\right)\left(\frac{3R}{2}\right)}$$

$= 300 + 375 = 675\ K$

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

$$\Rightarrow P_2 = \left(\frac{675}{300}\right)(1.6\ \ \ 10^6) = 3.6\ \ \ 10^6\ Nm^{-2}$$

37. PV^{γ} = constant $\Rightarrow (10^5)\ (6)^{5/3} = (P_2)\ (2)^{5/3}$

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

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

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

38. $$\gamma_{mix} = \frac{n_AC_{P_A} + n_BC_{P_B}}{n_AC_{V_A} + n_BC_{V_B}}$$

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

39. (i) For a cyclic process (चक्रीय प्रक्रम के लिए)

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

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

$= 5960 - 5585 - 2980 + 3645 - 2200 + 825 + 1100$

$= 765$ J

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

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

40. PT = constant $\Rightarrow P^2V$ = constant $\Rightarrow PV^{1/2}$ = constant

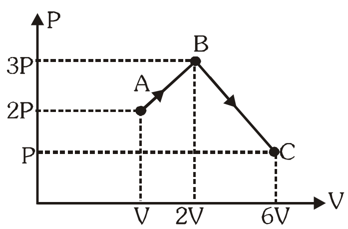
For this process $C = C_V + \dfrac{R}{1-1/2} = C_V + 2R$

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

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

41. The maximum temperature of the gas will be during process BC.
(गैस का अधिकतम ताप प्रक्रम BC के दौरान होगा)
Process BC can be represented by straight line,
$y = mx + C$
(प्रक्रम BC को सरल रेखा y = mx + C द्वारा प्रदर्शित कर सकते हैं)
So P = mV + C
Putting point B & C gives
3P = 2mV + C ...(i)   P = 6 mV + C ...(ii)

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



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

Hence we get equation as (अतः समीकरण से)

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

where y is pressure and x is volume of gas.
(जहां y गैस का दाब तथा x गैस का आयतन है)
Putting y from above. Now we have

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

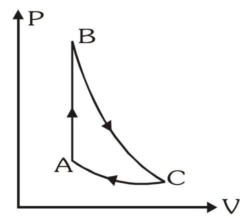
For maximum temperature (अधिकतम ताप के लिए)

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

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

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

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



For process AB (प्रक्रम AB के लिए)

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

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

For process BC (प्रक्रम BC के लिए)

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

$= 148.5$ J and $\Delta U = -W = -148.5$J

For process CA (प्रक्रम CA के लिए)

$\Delta U = 0$

$W = nRT\ \ell n\left(\dfrac{V_A}{V_C}\right) = -6.9$ J and Q = W = – 6.9 J

Thermal efficiency (ऊष्मीय दक्षता)

$= \dfrac{W_{net}}{Q_{supplied}} = \dfrac{148.5 - 6.9}{148.5} = 0.954$

43. Slope (ढाल)

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

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

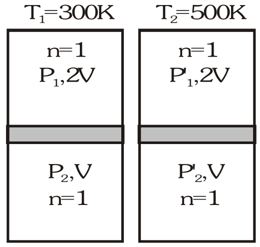
44. $\Delta U = nC_V\Delta T$, $Q = nC_P\Delta T$ and

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

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

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

45. $P_1A + Mg = P_2A$



Extra force needed
(आवश्यक अतिरिक्त बल)

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

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

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

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

47. New length of gas column (गैस स्तम्भ की नई लम्बाई)

$= \frac{h}{2} + \frac{h}{16} = \frac{9}{16}h$

New volume of gas (गैस का नया आयतन)

$= \left(\frac{9}{16}h\right) A = \frac{9}{16}V_0$

$P = P_0 + kx$

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

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

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

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

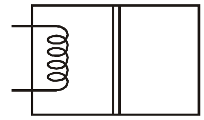
$\Rightarrow (273)\ (V_0)^{0.5} = (T_2)\left(\frac{9}{16}V_0\right)^{0.5}$

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

EXERCISE –IV B

1. (i) For the right chamber (बांये प्रकोष्ठ के लिए)

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



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

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

For the left chamber (बांये प्रकोष्ठ के लिए)

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

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

$\Rightarrow T_1 = \frac{T_0}{P_0V_0}\times\left(\frac{243}{32}P_0\right)\left(\frac{46}{27}V_0\right) = \frac{9\times23}{16}T_0$

$= 12.94\ T_0$

(ii) Work done by the gas in the right chamber :
(बांये प्रकोष्ठ में गैस द्वारा किया गया कार्य)

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

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

2. Final volume of chamber (प्रकोष्ठ का अन्तिम आयतन)

$= V_0 + Ax = 3.2\ \ 10^{-3}\ m^3$

Final pressure in chamber (प्रकोष्ठ में अन्तिम दाब)

$= P_0 + \frac{kx}{A} = 2\ \ 10^5 N/m^2$

From ideal gas equation (आदर्श गैस समीकरण से)

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

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

Work done by gas (गैस द्वारा किया गया कार्य)

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

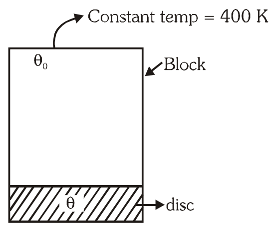
Change in internal energy (आन्तरिक ऊर्जा में परिवर्तन)

$\Delta U = nC_v \,\Delta T$

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

$\therefore$ Heat Supplied (दी गई ऊष्मा)= 120 + 600 = 720 J

3.



θ = temperature of disc (चकती का ताप)

θ_0 = constant temperature (नियत ताप)

Heat input to disc (चकती को निवेशी ऊष्मा)= $\dfrac{KA(\theta_0-\theta)}{L}$

Heat utilised by disc (चकती द्वारा व्ययित ऊष्मा)= $ms\dfrac{d\theta}{dt}$

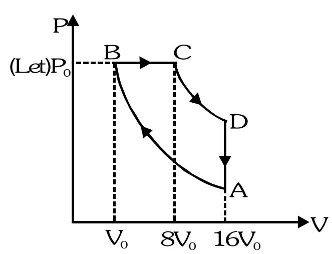
(where s = specific heat of disc)

(जहां s= चकती की विशिष्ट ऊष्मा)

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

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

4. Let $V_B = V_0$



Process A $\rightarrow$ B

$T_A V_A^{\gamma-1} = T_B V^{\gamma-1}$

$\Rightarrow T_B$ = 909 K

Process B $\rightarrow$ C

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

Process C $\rightarrow$ D :

$T_C V_C^{\gamma-1} = T_D V_D^{\gamma-1} \Rightarrow T_D$ = 5511.15 K

Heat flow (ऊष्मा प्रवाह)

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

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

$= 1 \quad \dfrac{7}{2}R\,(T_C - T_B)$

= 185156.937J

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

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

$= 1\left(\dfrac{5}{2}R\right)(T_A - T_D)$

= –108313.753 J

$\therefore$ Efficiency (दक्षता)

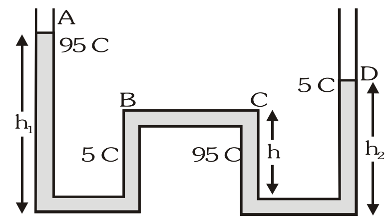
$$\eta = \frac{\text{work output}}{\text{Heat input}} = \frac{Q_{in}-Q_{out}}{Q_{in}}$$

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

η = 41.50%

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

5.



Pressure at the bottom of A – B limb :

(भुजा A-B के तल पर दाब)

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

Pressure at the bottom of C–D limb :

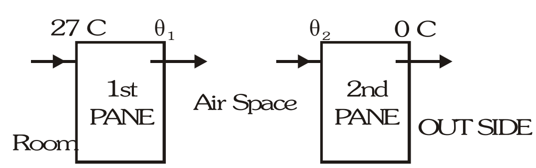
(भुजा C-D के तल पर दाब)

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

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

6. Heat flow for three sections will be same.

(तीनों भागों के लिये ऊष्मा का प्रवाह समान होगा)

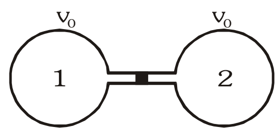


$$\therefore \frac{27-\theta_1}{\left(\dfrac{L}{KA}\right)_{1st\,Pane}} = \frac{\theta_1-\theta_2}{\left(\dfrac{L}{KA}\right)_{A.S.}} = \frac{\theta_2-0}{\left(\dfrac{L}{KA}\right)_{2nd\,Pane}}$$

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

Heat flow rate (ऊष्मा प्रवाह की दर)

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

7. 

Let (माना)

n_1= no. of moles in vessel–1

(n_1= पात्र 1 में मोलों की संख्या)

n_2 = no. of moles in vessel–2

(n_1= पात्र 2 में मोलों की संख्या)

P_1 = initial pressure in both vessels

(P_1 =दोनों पात्रों में प्रारम्भिक दाब)

P_2 = final pressure in both vessels.

(P_1 =दोनों पात्रों में अन्तिम दाब)

Initially (प्रारम्भ में)

volume of vessel–1 = volume of vessel–2

(पात्र –1 का आयतन= पात्र –2 का आयतन)

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

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

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

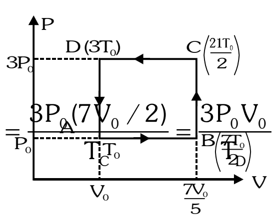
Displacement of mercury droplets

(पारे की बूंदों का विस्थापन)

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

8. For each state

(प्रत्येक अवस्था के लिए)



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

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

$T_D = 3T_0$.

$\therefore$ Heat absorbed (अवशोषित ऊष्मा)

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

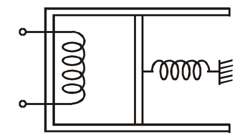
$= n4R\left(\frac{5}{2}T_0\right) + n\ 3R(7T_0) = 31.nR\ T_0 = 31P_0V_0$

Work done (किया गया कार्य)= $(3P_0 - P_0)(V_0 - \frac{7}{2}V_0)$

$= -5P_0V_0$

9. Work done by gas (गैस द्वारा किया गया कार्य)

$$= \int_0^x P_0Adx + \int_0^x kx.dx$$



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

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

Spring constant (स्प्रिंग नियतांक)$\Rightarrow$ k = 2000 N/m

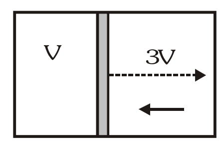
Heat supplied (दी गई ऊष्मा)

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

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

10. In free expansion, temperature remains constant

(मुक्त प्रसार में ताप नियत होगा)



Initial temperature (प्रारम्भिक ताप) $T_0 = \frac{P_0V_0}{nR}$

After compression (सम्पीड़न के बाद)

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

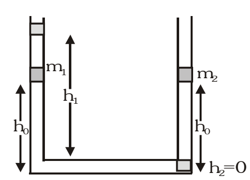
Change in internal energy (आन्तरिक ऊर्जा में परिवर्तन)

$$\Delta U = nC_V.\Delta T = n\left(\frac{R}{\gamma - 1}\right)$$

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

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

11. For equilibrium (साम्यावस्था के लिए)



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

$$m_1 = 2\text{kg}, m_2 = 1\text{kg} \Rightarrow \frac{2}{A_1} = \frac{1}{A_2}$$

For final equilibrium (अन्तिम साम्यावस्था के लिए)

$$\frac{m_1 g}{A_2} > \frac{m_2 g}{A_1}$$

$\therefore$ m_1 block will fall down (ब्लॉक m_1 नीचे गिरेगा)

For constant temperature forcess and pressure being constant (नियत ताप के लिए बल व दाब के मान नियत होते हैं)

$$V_{initial} = V_{final}$$

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

12. Let h_i = empty space over Hg–column

(माना h_1= Hg स्तम्भ के ऊपर रिक्त स्थान)

For constant temperature process

(नियत ताप प्रक्रम के लिए)

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

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

True Reading	Faulty Reading
73	69
75	70
74	x

(i) Total length of tube (नली की कुल लम्बाई)

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

(ii) When faulty barometer reads 69.5 cm.

(जब त्रुटिपूर्ण बेरोमीटर का पाठ्यांक 69.5 cm है)

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

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

(iii) When the barometer reads 74 cm

(जब बेरोमीटर का पाठ्यांक 74 cm है)

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

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

H_2	He	CO_2
ℓ	ℓ	ℓ

For the H_2 gas (H_2 गैस के लिए)

$$\frac{P_1V_1}{RT_1} = \frac{P_2V_2}{RT_2} \Rightarrow \frac{P_0A\ell}{645R} = \frac{P \times A\ell_1}{TR} \quad \ldots(i)$$

For the He gas (He गैस के लिए)

$$\frac{P_0A\ell}{258R} = \frac{P \times A\ell_2}{TR} \quad \ldots(ii)$$

For the CO_2 gas (CO_2 गैस के लिए)

$$\frac{P_0A\ell}{430R} = \frac{P \times A\ell_3}{TR} \quad \ldots(iii)$$

$$\Rightarrow \frac{\ell_1}{\ell_2} = \frac{258}{645} = \frac{1}{2.5} \;\&\; \frac{\ell_1}{\ell_3} = \frac{430}{645} = \frac{1}{1.5}$$

$\Rightarrow \ell_1 + \ell_2 + \ell_3 = 3\ell \Rightarrow \ell_1(1 + 2.5 + 1.5) = 3\ell$

$\Rightarrow \ell_1 = 0.6\ \ell$ and $\ell_2 = 2.5\ \ell_1 = 1.5\ell$

$\ell_3 = 1.5 \quad 0.6\ell = 0.9\ell$

For the entire system (सम्पूर्ण निकाय के लिए)

$\Delta U_1 + \Delta U_2 + \Delta U_3 = 0$

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

$$\Rightarrow \frac{P \times 0.6\ell - P_0\ell}{\left(\frac{7}{5} - 1\right)} + \frac{(P \times 1.5\ell - P_0\ell)}{\left(\frac{5}{3} - 1\right)} + \frac{(P \times 0.9\ell - P_0\ell)}{\left(\frac{7}{5} - 1\right)} = 0$$

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

14. For compartment C (भाग C के लिए)

$$P_0V_0^{\gamma} = P\left(\frac{4V_0}{9}\right)^{\gamma} \quad \Rightarrow P = \frac{27}{8}P_0$$

$$\Rightarrow P_0.T_0^{\gamma/1-\gamma} = P.T^{\gamma/1-\gamma}$$

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

For compartment A (भाग A के लिए)

$$P_A = \frac{27}{8}P_0$$

$$\frac{P_0V_0}{RT_0} = \frac{P_1V_1}{RT_1}$$

$$\Rightarrow T_1 = \frac{\frac{27}{8}P_0\left(2V_0 - \frac{4V_0}{9}\right)}{R} \times \frac{RT_0}{P_0V_0} = T_1 = \frac{21}{4}T_0$$

For compartment B (भाग B के लिए)

$$\frac{P_0V_0}{T_0}=\frac{P_1V_1}{T_1}\Rightarrow\frac{P_0V_0}{T_0}=\frac{P_1V_0}{\left(\frac{21}{4}T_0\right)}\Rightarrow P_1=\frac{21}{4}P_0$$

(i) Final pressure in A (A में अन्तिम दाब) $\frac{27}{8}P_0$

Final pressure in B (B में अन्तिम दाब) $\frac{21}{4}P_0$

Final pressure in C (C में अन्तिम दाब) $\frac{3}{2}P_0$

(ii) Final temperature in A (A में अन्तिम ताप) = $\frac{21}{4}T_0$

Final temperature in B (B में अन्तिम ताप)= $\frac{21}{4}T_0$

Final temperature in C (C में अन्तिम ताप)= $\frac{3}{2}T_0$

(iii) Heat supplied by heater = (ΔU + W) all chambers

(हीटर द्वारा दी गई ऊष्मा = (ΔU + W) सभी प्रकोष्ठों)

$Q = (\Delta U_1 + W_1) + (\Delta U_2 + W_2) + 0$

$= (\Delta U_1 - W_3) + (\Delta U_2 + 0)$

$= \Delta U_1 + \Delta U_2 - W_3$

$$=\frac{n_1R\Delta T}{\gamma_1-1}+\frac{n_2R\Delta T}{\gamma_2-1}-\left(\frac{n_3R\Delta T}{\gamma_3-1}\right)$$

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

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

(प्रकोष्ठ B में गैस द्वारा किया गया कार्य शून्य है)

Work done by gas in chamber C

(प्रकोष्ठ C में गैस द्वारा किया गया कार्य)

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

Work done by gas in chamber A

(प्रकोष्ठ A में गैस द्वारा किया गया कार्य)

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

(v) Heat flowing across piston –I

(पिस्टन -I के सिरों पर प्रवाहित ऊष्मा)

$$=\Delta U_2=\frac{17}{2}P_0V_0$$

15. For the process (इस प्रक्रम के लिए)

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

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

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

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

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

(i) W = 80J

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

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

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

EXERCISE –V-A

1. The temperature of gas molecules depends on the average kinetic energy associated with the disorderly motion (i.e., random motion) of the gas molecules. The orderly kinetic energy of the molecules of the gas container will increase in the lorry, whereas disorderly kinetic energy will still remain the same; hence the temperature of the gas molecules will remain unchanged.
(गैस अणुओं का ताप, गैस अणुओं की अनियमित गति के साथ सम्बन्धित औसत गतिज ऊर्जा पर निर्भर करता है। ट्रक में गैस सिलिंडर के अणुओं की नियमित गतिज ऊर्जा का मान बढ़ेगा जबकि अनियमित गतिज ऊर्जा का मान समान ही रहेगा। अत: गैस अणुओं का ताप अपरिवर्तित रहेगा।)

2. $v_{rms} = \sqrt{\dfrac{3RT}{M}}$
Where T is the temperature of the gas molecules in kelvin and M is the molecular mass of the gas
(जहां T (केल्विन में) गैस के अणुओं का ताप है तथा M गैस के अणुओं का द्रव्यमान है)

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

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

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

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

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

4. Given $P \propto T^3$
$\because PV = \mu RT$
$\therefore P \propto (PV)^3 \Rightarrow P^3V^3 \propto P \Rightarrow P^2V^3 =$ constant

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

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

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

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

6. $$\frac{n_1+n_2}{\gamma_{mix}-1} = \frac{n_1}{\gamma_1-1} + \frac{n_2}{\gamma_2-1}$$
Number of moles in 16 g He =4
(16 g, He में मोलों की संख्या =4)
Number of moles in 16 g O_2 = 0.5
(16 g, O_2 में मोलों की संख्या = 0.5)

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

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

$$\gamma_{mix} = 1.62$$

7. We have, molar heat capacity = molar mass specific heat capacity per unit mass
(ग्राम अणुक ऊष्मा धारिता = ग्राम अणुक द्रव्यमान x एकांक द्रव्यमान की विशिष्ट ऊष्मा धारिता)
$\therefore C_p = 28\ c_p$ (for nitrogen) and $C_V = 28\ c_V$
Now $C_p - C_V = R$ or $28c_p - 28\ c_v = R$

$$\Rightarrow c_p - c_v = \frac{R}{28}$$

8. $U = U_1 + U_2 \Rightarrow (n_1+n_2)\ C_vT = n_1C_vT_1 + n_2C_vT_2$

$$\Rightarrow T = \frac{(P_1V_1 + P_2V_2)T_1T_2}{(P_1V_1T_2 + P_2V_2T_2)}$$

9. $$v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{\gamma_1 M_2}{\gamma_2 M_1}} = \sqrt{\frac{\frac{7}{5}\times 4}{\frac{5}{3}\times 32}}$$

$$\Rightarrow \frac{460}{v_2} = \sqrt{\frac{21}{25\times 8}} \Rightarrow v_2 = 460\sqrt{\frac{200}{21}}\ \text{m/s}$$

10. **Ans. (4)**
Energy of the diatomic gas
(द्विपरमाणुक गैस की ऊर्जा)

$$\frac{5}{2}nRT = \frac{5}{2}PV = \frac{5}{2}\times 8\times 10^4 \times \frac{1}{4} = 5 \quad 10^4\ J$$

11. $Q = ms\Delta\theta = 0.1 \quad 4184 \quad 20 = 8.4$ kJ

12. $$\left(n_1C_{v_1}T_1 + n_2C_{v_2}T_2 + n_3C_{v_3}T_3\right)$$

$$=(n_1 + n_2 + n_3)\ C_{V_{mix}}T$$

As $C_{V_1} = C_{V_2}$ so $T = \dfrac{n_1T_1 + n_2T_2 + n_3T_3}{n_1 + n_2 + n_3}$

13. Specific heat at low temperature is
(निम्न ताप पर विशिष्ट ऊष्मा)

$$C_p = 32\left(\frac{T}{400}\right)^3$$

$$Q = \int m.c.dT$$

$$= \int_{20}^{4} \frac{100}{1000} \times 32\left(\frac{T}{400}\right)^3 dT$$

$$= \frac{32}{10} \times \frac{1}{(400)^3}\left(\frac{T^4}{4}\right)$$

$$= \frac{32}{10 \times (400)^3} \times \frac{1}{4}\left(20^4 - 4^4\right)$$

$$= \frac{32}{10 \times (400)^3} \times \frac{1}{4} \times (160000 - 256)$$

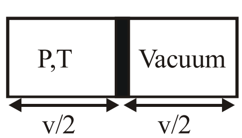
$= 0.002$ kJ

$$\beta = \frac{T_2}{T_1 - T_2} = \frac{Q_2}{W}$$

$$\Rightarrow \frac{20}{300-20} = \frac{0.02}{W} \Rightarrow W = 0.028 \text{ kJ}$$

$$\Rightarrow \frac{4}{300-4} = \frac{0.002}{W} \Rightarrow W = 0.0148 \text{ kJ}$$

14. This is free expansion of the gas in which temperature will remain constant i.e. on the other side temperature will T.
(यह गैस का मुक्त प्रसार है जिसमें ताप नियत होता है अर्थात् अन्य भुजा पर ताप T होंगे)



Number of moles (मोलों की सं.) $n_1 = \frac{PV/2}{KT}$

Finally number of moles $n_2 = \frac{P'V}{KT}$

(मोलों की अन्तिम संख्या)

$n_1 = n_2$

$$\frac{PV}{2} = \frac{P^1V}{KT} \Rightarrow P' = \frac{P}{2}$$

15. All reversible engines work for different values of temperature of source and sink hence the efficiencies of all such engines are different.The incorrect statement is all reversible cycles have same efficiency.
(सभी उत्क्रमणीय प्रक्रम स्रोत व पात्र के ताप के भिन्न मानों के लिये कार्य करते हैं। अत: सभी की दक्षतायें इंजन से भिन्न होगी, सभी उत्क्रमणीय चक्रों की दक्षता समान होती है, असत्य कथन है)

16. **Ans. (3)**
When water is cooled to form ice, the energy is released as heat so mass of water decreases.
(जब जल ठंडा बर्फ बनता है तो ऊर्जा ऊष्मा के रूप में मुक्त होती है, अत: पानी का द्रव्यमान घटता है)

17. $\eta = 1 - \frac{T_2}{T_1} = 1 \Rightarrow \frac{T_2}{T_1} = 0 \Rightarrow T_2 = 0$ or $T = \infty$

Which is not possible (जो कि सम्भव नहीं है)

18. Heat can't flow from the body at lower temperature to body at higher temperature is a consequences of second law of thermodynamics. (ऊष्मा स्वत: ही कम ताप वाली वस्तु से अधिक ताप वाली वस्तु की ओर प्रवाहित नहीं हो सकती है यह कथन ऊष्मागतिकी का द्वितीय नियम है)

19. The instantaneous thermodynamic state of matter is denoted by pressure, volume and temperature. (पदार्थ की तात्क्षणिक ऊष्मागतिक अवस्था को दाब, आयतन तथा ताप के द्वारा प्रदर्शित करते हैं)

20. $T_{source} = 627°C = 627 + 273 = 900K$

$T_{sink} = 27°C = 27 + 273 = 300K$

Efficiency (दक्षता)

$$(\eta) = 1 - \frac{T_{sink}}{T_{source}} = 1 - \frac{300}{900} = 1 - \frac{1}{3}$$

$$(\eta) = \frac{2}{3} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Work}}{\text{Heat Input}}$$

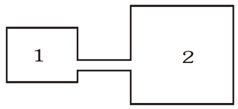
$\Rightarrow \frac{2}{3}$ Heat Input = Work

$\Rightarrow \frac{2}{3}$ 3 10^6 4.2 = Work

$\Rightarrow$ Work = 8.4 10^6 J

21. Internal energy and entropy are state functions and not path functions.
(आन्तरिक ऊर्जा व एन्ट्रॉपी अवस्था फलन होते हैं न कि पथ फलन)

22. Assume $T_1 > T_2$



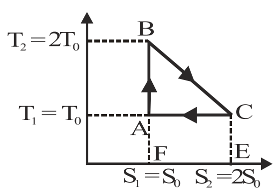
Heat given = Heat taken

$\mu_1 C_{v_1}(T_1 - T) = \mu_2 C_{v_2}(T - T_2)$

Here $C_{v_1} = C_{v_2}$ & $\mu_1 = \frac{P_1V_1}{T_1}$, $\mu_2 = \frac{P_2V_2}{T_2}$

23. The first law of thermodynamics does not introduce the concept of entropy.
(ऊष्मागतिकी का प्रथम नियम की अवधारणा एक एन्ट्रॉपी की संकल्पना को प्रस्तावित नहीं करता है)

24. Heat supplied Q = Area FBCEF
(दी गई ऊष्मा Q =FBCEF क्षेत्रफल)



$= T(S_2 - S_1) + \frac{1}{2}(T_2 - T_1)(S_2 - S_1)$

Work done W = Area ABC
(किया गया कार्य W=ABC क्षेत्रफल)

$$= \frac{1}{2}(T_2 - T_1)(S_2 - S_1)$$

$$\eta = \frac{W}{Q} = \frac{\frac{1}{2}(T_2 - T_1)(S_2 - S_1)}{T_1(S_2 - S_1) + \frac{1}{2}(T_2 - T_1)(S_2 - S_1)}$$

$$= \frac{T_2 - T_1}{T_2 + T_1} = \frac{2T_0 - T_0}{2T_0 + T_0} = \frac{1}{3}$$

25. The internal energy of a system is a state function, i.e., change in internal energy only depends on the initial and the final position and not on the path chosen.
(निकाय की आन्तरिक ऊर्जा एक अवस्था फलन है। अर्थात् आन्तरिक ऊर्जा में परिवर्तन केवल प्रारम्भिक व अन्तिम स्थिति पर निर्भर करती है। चयनित पथ पर नहीं।)
Hence $\Delta U_1 = \Delta U_2$

26. $\because n_1 C_{v_1} T_1 + n_2 C_{v_2} T_2 = \left(n_1 C_{v_1} + n_2 C_{v_2}\right) T_f$

$$\therefore T_f = \frac{n_1 C_{v_1} T_1 + n_2 C_{v_2} T_2}{n_1 C_{v_1} + n_2 C_{v_2}}$$

$$= \frac{1 \times \frac{5}{2} RT_0 + 1 \times \frac{3}{2} R\left(\frac{7}{3} T_0\right)}{1 \times \frac{5}{2} R + 1 \times \frac{3}{2} R} = \frac{6RT_0}{4R} = \frac{3}{2} T_0$$

27. Work done in adiabatic process
(रूद्धोष्म प्रक्रम में किया गया कार्य)

$$W = \frac{\mu R(T_1 - T_2)}{\gamma - 1} \Rightarrow \gamma = 1 + \frac{R(T_2 - T_1)}{W}$$

$$= 1 + \frac{10^3 \times 8.3(7)}{146 \times 10^3} = 1 + 0.40 = 1.40$$

$\therefore$ The gas must be diatomic
(अतः गैस द्विपरमाण्विक होगी)

28. Let η is the efficiency of heat engine and β is the corresponding coefficient of performance of a refrigerator working between the same temperature.
(माना η ऊष्मा इंजन की दक्षता तथा β इसके संगत समान ताप के मध्य क्रियाशील रेफ्रिजरेटर का कार्य गुणांक β है)
The relation between η and β is
(η व β के मध्य सम्बन्ध)

$$\beta = \frac{1}{\eta} - 1 = 10 - 1 = 9 \text{ Also } \beta = \frac{\text{Output}}{\text{Input}}$$

$$= \frac{\text{Energy absorbed from the reservoir at lower temperature}}{\text{Work done on the system}}$$

$$\left(\frac{\text{न्यून ताप पर कुण्ड से अवशोषित ऊर्जा}}{\text{निकाय पर किया गया कार्य}}\right)$$

$$\beta = 9 = \frac{\text{Energy absorbed}}{10\text{J}}$$

So, energy absorbed (अवशोषित ऊर्जा)= 90 J

29. As a thermodynamic system is taken from state *i* to state *f*; then the internal energy of the system remains the same irrespective of the path followed
(चूंकि ऊष्मागतिक निकाय अवस्था i से अवस्था f तक लिया जाता है। अतः बिना पथ का अनुसरण करते हुए निकाय की आन्तरिक ऊर्जा समान होगी)

$(Q - W)_{iaf} = (Q - W)_{ibf} \Rightarrow 50 - 20 = 36 - W$

$\Rightarrow W = 6$ cal

30. W_{AB} = Work done in isobaric process
(समदाबीय प्रक्रम में किया गया कार्य)
$= \mu R \Delta T = 2R \quad (500 - 300) = 400R$
Work done on the gas = – 400R
(गैस द्वारा किया गया कार्य)

31. W_{DA} = Work done in isothermal process
(समतापीय प्रक्रम में किया गया कार्य)

$$= 2.303\ \mu RT \log \frac{P_1}{P_2}$$

$$= 2.303 \quad 2R \quad 300 \log \frac{1 \times 10^5}{2 \times 10^5}$$

$$= 2.303 \quad 2R \quad 300 \quad (-0.3010) = -414R$$

Word done on the gas (गैस पर किया गया कार्य)
$= -(-414\ R) = 414\ R$

32. $W_{ABCDA} = W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$$= \mu R(500-300) + 2.303\mu R\ (500) \log \frac{2}{2}$$

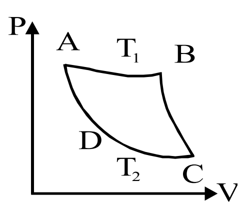
$$+ \mu R(300-500) + 2.303\ \mu R(300) \log \frac{1}{2}$$

$= 276R$

Work done on the gas (गैस पर किया गया कार्य)
$= -276\ R$

33. $T_B = T_1,\ T_C = T_2,\ \gamma = 1.4$
$V_B = V,\ V_C = 32\ V$

$$T_B V_B^{\gamma-1} = T_C V_C^{\gamma-1}$$



$$\frac{T_C}{T_B} = \frac{T_2}{T_1} = \left(\frac{V_B}{V_C}\right)^{\gamma-1}$$

$$= \left(\frac{1}{32}\right)^{\gamma-1} = \frac{1}{4}$$

$$\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{1}{4} = \frac{3}{4} = 0.75$$

34. $\frac{1}{2}Mv^2 = \frac{f}{2}R\Delta T$ and

$$\gamma = 1 + \frac{2}{f} \Rightarrow \Delta T = \frac{(\gamma - 1)}{2R} Mv^2$$

35. $1 - \frac{T_2}{T_1} = \frac{1}{6} \Rightarrow \frac{T_2}{T_1} = \frac{5}{6}$ ... (1)

and $1 - \frac{T_2 - 62}{T_1} = \frac{1}{3} \Rightarrow \frac{T_2 - 62}{T_1} = \frac{2}{3}$ ... (2)

By solving equation (1) and (2)
$T_1 = 372$ K and $T_2 = 310$ K

36. $\Delta V = V_0(3\alpha)\Delta\theta$

$$= \frac{4}{3}(3.14)(10)^3\ [3 \quad 23 \quad 10^{-6}]\ [100-0]$$

= 28.9 cc

37. $\text{Strain} = \frac{\ell_2 - \ell_1}{\ell_1} = \alpha t$ and $Y = \frac{\text{Stress}}{\text{Strain}}$

$\Rightarrow$ Stress = Y α t

38. W = Area bounded by curve = P_0V_0
(वक्र द्वारा परिबद्ध क्षेत्रफल)

$$Q_{AB} = nC_V\Delta T = n \quad \frac{3}{2}R \quad \Delta T = \frac{3}{2}P_0V_0$$

$$Q_{BC} = nC_P\ \Delta T = n \quad \frac{5}{2}R \quad \Delta T = 5\ P_0V_0$$

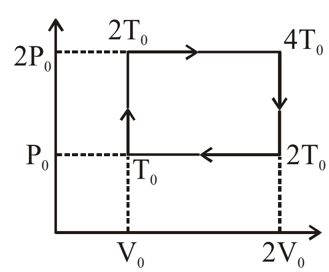
Total heat supplied (दी गई कुल ऊष्मा)

$$= \frac{3}{2}P_0V_0 + 5P_0V_0 = \frac{13}{2}P_0V_0$$

$$\eta = \frac{W}{Q} \quad 100 = \frac{P_0V_0}{13P_0V_0} \quad 100 = 15.4\%$$

40. $\eta = \left(1 - \frac{T_2}{T_1}\right) \quad 100 \Rightarrow \frac{40}{100} = 1 - \frac{T_2}{500} \Rightarrow T_2 = 300$ K

Again $\frac{60}{100} = 1 - \frac{300}{T_1} \Rightarrow T_1 = 750$ K



$$\text{heat supplied} = nC_v(2T_0 - T_0) + nC_p(4T_0 - 2T_0)$$

$$= \frac{n.3RT_0}{2} + \frac{D5R}{2}(2T_0) = \frac{13}{2}nRT_0 = \frac{13}{2}P_0V_0$$

41. Amount of heat required by a body of any mass of undergo a unity change in temperature is known as heat capacity or thermal capacity of the substance. (ताप में इकाई परिवर्तन के कोई द्रव्यमान की वस्तु द्वारा आवश्यक ऊष्मा की मात्रा को पदार्थ की ऊष्मा धारिता या तापीय धारिता कहते हैं)

42. Black board paint is more close to a black body. (ब्लैक बोर्ड पेन्ट, कृष्णिका के ज्यादा निकट है)

43. Infrared radiations are detected by pyrometer. (पाइरोमीटर द्वारा अवरक्त विकिरणों का पता लगाया जाता है)

44. The power radiated by a sphere of radius R at temperature T is
(ताप T पर R त्रिज्या के गोले द्वारा उत्सर्जित शक्ति)

$P = \varepsilon\sigma T^4(4\pi R^2)$

Where (जहां)

ε = emissivity of the material of sphere.

(ε = गोले के पदार्थ की उत्सर्जकता है)

σ = Stefan's constant (स्टीफन नियतांक)

T = Absolute temperature (वास्तविक ताप)

R = Radius of the sphere (गोले की त्रिज्या)

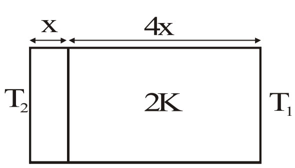
$$\Rightarrow \frac{P_1}{P_2} = \frac{T_1^4R_1^2}{T_1^4R_2^2} = \left(\frac{4000}{2000}\right)^4\left(\frac{1}{4}\right)^2 = (2^4)\times\frac{1}{4^2} = \frac{16}{16} = 1$$

45. According to Stefan's law, power radiated by a perfectly black body is
(स्टीफन नियम के अनुसार पूर्ण कृष्णिका द्वारा उत्सर्जित शक्ति)

$P = \sigma AT^4;\ P = \sigma 4\pi R^2T^4$

$$\frac{P_2}{P_1} = \left(\frac{R_2}{R_1}\right)^2\left(\frac{T_2}{T_1}\right)^4 \Rightarrow P_2 = 64P_1$$

46.



R_1=Resistance of left part $= \frac{x}{KA}$

(R_1 = बांये भाग का प्रतिरोध)

R_2=Resistance of right part $= \frac{4x}{2KA} = \frac{2x}{KA}$

(R_2 =दांये भाग का प्रतिरोध)

Total Resistance (कुल प्रतिरोध)

$$R_1 + R_2 = \frac{x}{KA} + \frac{2x}{KA} = \frac{3x}{KA}$$

Thermal current (ऊष्मीय धारा)

$$= \frac{T_2 - T_1}{R} = \frac{K(T_2 - T_1)A}{3x}$$

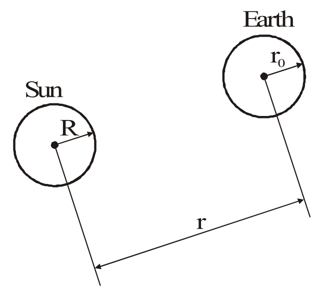
Comparing with the given result $f = \frac{1}{3}$

(दिये गये परिणाम से तुलना करने पर)

47. Rate of flow of heat (ऊष्मा प्रवाह की दर)

$$= KA\left(\frac{\Delta T}{\Delta x}\right) = K\ (4\pi r_1 r_2)\left(\frac{T_1 - T_2}{r_2 - r_1}\right)$$

48. According to Stefan's law (स्टीफन नियमानुसार)



Power radiated by Sun (सूर्य द्वारा विकिरित शक्ति)

$=\sigma(4\pi R^2)T^4$

Intensity of the sun received by the earth (पृथ्वी द्वारा प्राप्त सूर्य की तीव्रता)

$$= \frac{\text{Power of the sun}}{4\pi r^2}$$

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

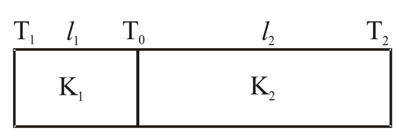
Radiant power incident on the earth $= I(\pi r_0^2)$

(पृथ्वी पर आपतित विकिरित शक्ति)

where (πr_0^2) is the projection of the earth's area receiving the energy from the sun.(जहां (πr_0^2) पृथ्वी का प्रक्षेप्य, सूर्य से ऊर्जा का प्राप्त क्षेत्रफल है)

$$P = \frac{\sigma R^2T^4}{r^2}(\pi r_0^2)$$

49. Let the temperature of the interface be T_0. (माना अन्तरापृष्ठ का ताप T_0 है)



Thermal current (I) (ऊष्मीय धारा)

$$= \frac{\text{Temperature difference}}{\text{Thermal resitance}}$$

Thermal resistance (ऊष्मीय प्रतिरोध) = $\frac{1}{K}\frac{\ell}{A}$

$$\Rightarrow \frac{T_1 - T_0}{\ell_1 / K_1 A} = \frac{T_0 - T_2}{\ell_2 / K_2 A}$$

$$\Rightarrow T_0 = \frac{K_1\ell_2 T_1 + K_2\ell_1 T_2}{K_1\ell_2 + K_2\ell_1}$$

50. In steady state, temperature decreases linearly along the bar. (स्थायी अवस्था में छड़ के अनुदिश रेखीय रूप से ताप घटता है)

i.e. (अर्थात्) $\frac{dQ}{dt} = -KA\left(\frac{d\theta}{dx}\right)$

51. Rate of cooling (शीतलन की दर) = $-\frac{d\theta}{dt}$ = $k(\theta - \theta_0)$

$$\frac{d\theta}{\theta - \theta_0} = -kdt \Rightarrow \int \frac{d\theta}{\theta - \theta_0} = -\int kdt$$

$\Rightarrow \ell n(\theta - \theta_0) = -k\,t + C \Rightarrow$ correct answer is (2)

52. $Y = \frac{\text{stress}}{\text{strain}} \Rightarrow$ stress = Y strain

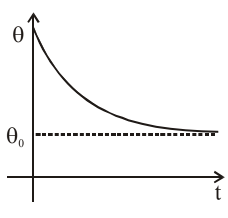
$$\frac{F}{S} = Y(\alpha\Delta T) \quad \Rightarrow \quad F = YS\alpha\Delta T$$

Therefore force by one part on other part
(अत: एक भाग द्वारा दूसरे भाग पर बल)
$= 2F = 2SY\alpha\Delta T$

53. By Newton's Law of cooling $T = T_S + (T_H - T_S)e^{-kt}$
(न्यूटन के शीतलन नियमानुसार)

$T_S \rightarrow$ Temperature of surrounding (परिवेश का ताप)
$T_H \rightarrow$ Temperature of body at t = 0
(t=0 पर वस्तु का ताप)
$K \rightarrow$ constant (नियत)
$T \rightarrow$ Temperature of body at time t
(समय t पर वस्तु का ताप)

So graph is



EXERCISE –V-B

1. Average rotational KE (औसत घूर्णन गतिज ऊर्जा)

$$= 2 \quad \frac{1}{2} \; kT$$

(for diatomic gas) (द्विपरमाण्विक गैस के लिए)

2. Initial conditions $P_1V = n_1RT$, $P_2V = n_2RT$
Final condition $(P_1 - \Delta P)2V = n_1RT$
$(P_2 - 1.5\Delta P)\ 2V = n_2RT$

$$\Rightarrow \frac{n_1RT}{2V} = \Delta P$$

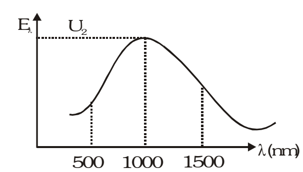
$$\frac{n_2RT}{2V} = 1.5\Delta P \Rightarrow \frac{n_1}{n_2} = \frac{1}{1.5} = \frac{2}{3} \Rightarrow \frac{m_A}{m_B} = \frac{2}{3}$$

3. For A : $Q = nC_P\Delta T = (nC_P)\ (30)$
For B : $Q = nC_V\Delta T = nC_V\Delta T = nC_P(30)$

$$\Rightarrow \Delta T = (30)\left(\frac{C_P}{C_V}\right) = 30 \quad \frac{7}{5} = 42\text{ K}$$

4. At 2880 K :

$$\lambda_m = \frac{b}{T} = \frac{2.88 \times 10^6\,\text{nm} - \text{K}}{2880\text{K}} = 1000\text{ nm}$$



Therefore $U_2 > U_1$ & $U_2 > U_3$

5. $\because v_{sound} = \sqrt{\frac{\gamma RT}{M_W}}$

$$\therefore \frac{v_{N_2}}{v_{He}} = \sqrt{\frac{\gamma_{N_2}}{M_{N_2}} \times \frac{M_{He}}{\gamma_{He}}} = \sqrt{\frac{7}{5} \times \frac{1}{28} \times \frac{4}{1} \times \frac{3}{5}} = \frac{\sqrt{3}}{5}$$

6. $$C_{V_{mix}} = \frac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2} = \frac{(2)\left(\frac{5}{2}R\right) + 4\left(\frac{3}{2}R\right)}{2+4} = \frac{11R}{6}$$

$U = (n_1 + n_2)\ C_{V\,mix}\ T = (6)\left(\frac{11R}{6}\right)T = 11RT$

7. $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$ but V = AL

$$\text{So } \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{5/3-1} = \left(\frac{L_2}{L_1}\right)^{2/3}$$

8. $\lambda_1 T_1 = \lambda_2 T_2 = \lambda_3 T_3 = b$ so $T_1 > T_3 > T_2$

9. The temperature of ice will first increase from –10 C to 0 C. (बर्फ का ताप पहले –10 C से 0 C तक बढ़ेगा)

Heat supplied in this process will be: $Q_1 = mS_i(10)$ (इस प्रक्रम में दी गई ऊष्मा)

m=mass of ice (बर्फ क द्रव्यमान)

S_i = specific heat of ice (बर्फ की विशिष्ट ऊष्मा)

Then, ice starts melting (तब बर्फ पिघलता है)

Temperature during melting will remain constant (0 C) (पिघलने के दौरान ताप नियत (0 C) होगा)

Heat supplied in the process will be $Q_2 = mL$ (इस प्रक्रम में दी गई ऊष्मा)

L = latent heat of melting (पिघलने की गुप्त ऊष्मा)

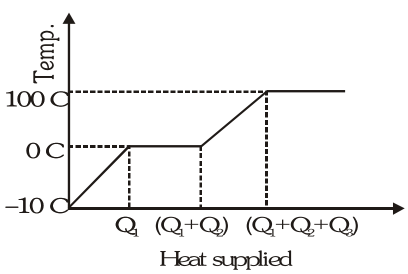
Now the temperature of water will increase from 0 C to 100 C. (अब पानी का ताप 0 C से 100 C तक बढ़ेगा)

Heat supplied will be (दी गई ऊष्मा) $Q_3 = mS_w(100)$

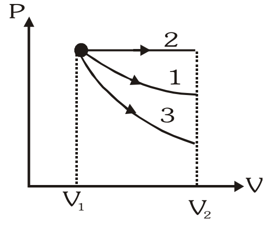
where S_w = Specific heat of water

(जहां S_w = पानी की विशिष्ट ऊष्मा)

Finally water at 100 C will be converted into steam at 100 C and during this process temperature again remains constant. Temperature versus heat supplied graph will be as follows



(अन्त में 100 C पर पानी 100 C पर भाप में परिवर्तित होगा तथा इस प्रक्रम के दौरान ताप पुन: नियत होगा। ताप व दी गई ऊष्मा के मध्य वक्र होगा)

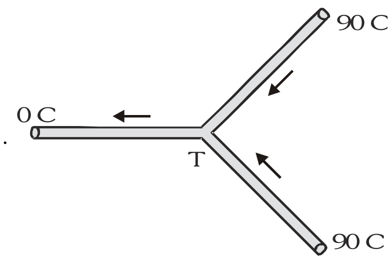
10. 

$W_2 > W_1 > W_3$

11. As P = constant

so $P\Delta V = nR\Delta T \Rightarrow \delta = \dfrac{\Delta V}{V\Delta T} = \dfrac{nR}{PV} = \dfrac{1}{T}$

12. $v_{sound} = \sqrt{\dfrac{\gamma RT}{M_W}}$ so $\dfrac{v_1}{v_2} = \sqrt{\dfrac{m_2}{m_1}}$

13. 

$$\frac{kA(90-T)}{\ell} + \frac{kA(90-T)}{\ell} = \frac{kA(T-0)}{\ell}$$

$\Rightarrow$ 90 – T + 90 – T = T

$\Rightarrow$ 3T = 180 $\Rightarrow$ T = 60 C

14. If dW = 0, dQ < 0 then dU < 0

$\Rightarrow$The temperature will decrease (ताप घटेगा)

15. As $\gamma_{mono} > \gamma_{dia}$ so 2 $\rightarrow$ monoatomic & 1 $\rightarrow$ diatomic

16. For complete cycle (सपूर्ण चक्र के लिए)

$\Delta U = 0$ so W = Q = 5

$\Rightarrow W_{AB} + W_{BC} + W_{CA} = 5$ But $W_{BC} = 0$ &

$W_{AB} = 10\,(2-1) = 10 \Rightarrow W_{CA} = 5 - 10 = -5J$

17. At constant temperature PV = constant (नियत ताप पर PV=नियत)

So $PdV + VdP = 0 \Rightarrow \dfrac{dV}{dP} = -\dfrac{V}{P} \Rightarrow \beta = -\dfrac{dV/dP}{V} = \dfrac{1}{P}$

18. Black body radiates maximum number of wavelength and maximum energy if all other conditions (e.g., temperature surface area etc.) are same. So, when the temperature of black body becomes equal to the temperature of the furnace, the black body will ,radiate ,maximum energy and it will be brighted of all. Initially it will absorb all the radiant energy incident on it, so it is the darkest one.

(कृष्णिका अधिकतम संख्या में तरंगदैर्ध्य तथा अधिकतम ऊर्जा का उत्सर्जन करती है, यदि अन्य सभी स्थितियां (उदाहरण ताप, पृष्ठीय क्षेत्रफल इत्यादि) समान रहती है। अत: जब कृष्णिका का ताप भट्टी के ताप के बराबर हो जाता है तो कृष्णिका अधिकतम ऊर्जा उत्सर्जित करेगी तथा यह सभी चमक उत्सर्जित करेगी। प्रारम्भ में यह इस पर आपतित होने वाली विकिरण ऊर्जा अवशोषित करेगी। अत: यह सबसे गहरी काली वस्तु होगी)

19. Ans. (C)

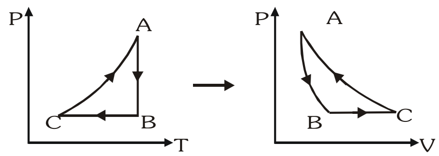
For same temperature difference less time is taken for x, this means $e_x > e_y$. (समान तापान्तर के लिए x के लिये कम समय लगता है, इसका अर्थ है कि $e_x > e_y$)

According to Kirchoff's law (किरचॉफ नियमानुसार) $a_x > a_y$

20. $\Delta\ell_1 = \Delta\ell_2 \Rightarrow \ell_1\alpha_a\Delta T = \ell_2\alpha_S\Delta T$

$$\Rightarrow \frac{\ell_1}{\ell_2} = \frac{\alpha_s}{\alpha_a} \Rightarrow \frac{\ell_1}{\ell_1+\ell_2} = \frac{\alpha_s}{\alpha_a+\alpha_s}$$

21.



22.

2kg ice (-20 C)	5kg water (20 C)
↓ 20 kcal	↓ 100 kcal
2kg ice (0 C)	5kg water (0 C)
↓ 160 kcal	
2 kg water (0 C)	

$\Rightarrow$ Final temperature (अन्तिम ताप) 0 C

Amount of ice melted (पिघली हुई बर्फ की मात्रा)

$= \dfrac{100-20}{80} = 1$ kg

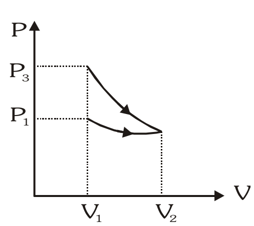
$\Rightarrow$ Final mass of water (जल का अन्तिम द्रव्यमान)

$= 5 + 1 = 6$ kg

23. Temperature of liquid oxygen will first increase in the same phase. Then, phase change (liquid to gas) will take place. During which temperature will remain constant. After that temperature of oxygen in gaseous state will further increase.

(द्रवित ऑक्सीजन का ताप पहले समान अवस्था में बंढता है। अवस्था परिवर्तन के दौरान (द्रव से गैस) ताप नियत रहता है ओर बाद में गैसीय अवस्था में ऑक्सीजन का ताप अधिक बढ़ता है)

24.



$\Rightarrow W < 0$ & $P_3 > P_1$

25. $q_1L = \dfrac{k(2A)(T_1-T_2)}{\ell}$

$q_2L = \dfrac{kA(T_1-T_2)}{2\ell} \Rightarrow \dfrac{q_2}{q_1} = \dfrac{1}{4}$

26. Power radiated (उत्सर्जित शक्ति)

$Q = e\sigma AT^4$ and $\lambda_m T = b$

So $(300)\ T_1 = (400)\ T_2 = (500)\ T_3$

$\Rightarrow 3T_1 = 4T_2 = 5T_3$

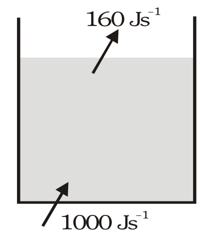
and $A_1 : A_2 : A_3 = 4 : 16 : 36 = 1 : 4 : 9$

$Q_A : Q_B : Q_C = \dfrac{1}{81} : \dfrac{4}{256} : \dfrac{9}{625} \Rightarrow Q_B$ is maximum.

27. Net heat absorbed by water

(पानी द्वारा अवशोषित कुल ऊष्मा)

$= 1000 - 160 = 840$ J/s



$$\frac{Q}{t} = \frac{ms\Delta T}{t}$$

$$840 = \frac{2\times 4200\times(77-27)}{t}$$

$\Rightarrow t = 500$ s $= 8$ min 20 s

28. Heat transfer in warming of glass of bulb due to filament is through radiation.

(तन्तु द्वारा बल्ब गर्म होने में ऊष्मा का स्थानान्तरण विकिरणों के माध्यम से होता है)

29. The temperature of sun is a higher than that of welding arc which in turn greater than tungsten filament.

(सूर्य का ताप वेल्डिंग ऑर्क की तुलना में अधिक होता है जो टंगस्टन तन्तु की तुलना में अधिक चक्कर लगाता है)

30. 1 calorie is the heat required to raise the temp. of 1g of water from 14.5 to 15.5 C at 760 mm of Hg.

(760 mm पारे के स्तम्भ पर 14.5 से 15.5 C तक 1g पानी का ताप 1 C बढ़ाने के लिये आवश्यक है)

32. $\gamma_V = \dfrac{\Delta V}{V\Delta T}$

$PT^2 =$ constant & $PV = nRT$

$$\Rightarrow V \propto T^3 \Rightarrow \frac{\Delta V}{V} = 3\frac{\Delta T}{T} \Rightarrow \frac{\Delta V}{V\Delta T} = \frac{3}{T} = \gamma_V$$

33. $P = \dfrac{\rho}{M}RT \Rightarrow \dfrac{P_1}{P_2} = \dfrac{\rho_1 M_2}{\rho_2 M_1} = \dfrac{4}{3}$

$$\Rightarrow \frac{\rho_1}{\rho_2} = \frac{4}{3}\times\frac{2}{3} = \frac{8}{9}$$

34. For two rectangular blocks

(दो आयताकार ब्लॉकों के लिये)

$R_1 = \frac{\ell}{kA} = 2R$; $R_2 = \frac{\ell}{2kA} = R$

In configuration 1 (विन्यास 1 में)

Equivalent thermal resistance = 3R

(तुल्य ऊष्मीय प्रतिरोध =3R)

In configuration 2 (विन्यास 2 में);

Equivalent thermal resistance = $\frac{2}{3}R$

(तुल्य ऊष्मीय प्रतिरोध = $\frac{2}{3}R$)

Rate of heat flow (ऊष्मा प्रवाह की दर)

$\Delta Q_1 = \frac{\Delta T}{3R}t_1$ and $\Delta Q_2 = \frac{\Delta T}{\frac{2R}{3}}t_2$

$\Rightarrow \frac{\Delta T}{3R}t_1 = \frac{3\Delta T}{2R}t_2 \Rightarrow t_2 = \frac{2}{9}t_1 = 2\,\text{sec}.$

35. Process FG is isothermal (प्रक्रम FG समतापीय है)

so work done (अतः किया गया कार्य)= nRT ln $\left(\frac{P_i}{P_f}\right)$

$= 32\ P_0V_0 \ln\left(\frac{32P_0}{P_0}\right) = 160\ P_0V_0 \ln 2.$

Process GE is isobaric (प्रक्रम GE समदाबीय है)

So work done (अतः किया गया कार्य)

$= P|\Delta V| = P_0|(V_G - V_E)|$

$= P_0|(32V_0 - V_0)|$

$= 31\ P_0V_0$

Process FH is adiabatic (प्रक्रम FH रूद्धोष्म है)

so $(32P_0)V_0^{5/3} = (P_0)V_H^{5/3} \Rightarrow V_H = 8V_0$

Since process FH is adiabatic so

(चूंकि प्रक्रम FH रूद्धोष्म है अतः)

$$\left|\frac{(P_HV_H - P_FV_F)}{(8-1)}\right| = \frac{|(P_08V_0) - 32P_0V_0)|}{\left(\frac{5}{3}-1\right)} = 36P_0V_0$$

Process G→H is isobaric so work done

(प्रक्रम G→H समदाबीय है अतः किया गया कार्य)

$= P_0|(32V_0 - 8V_0)| = 24\ P_0V_0$

MCQ's

1. $v_P = \sqrt{\frac{2kT}{m}}$; $\bar{v} = \sqrt{\frac{8kT}{\pi m}}$,$v_{rms} = \sqrt{\frac{3kT}{m}} \Rightarrow v_P < \bar{v} < v_{rms}$

Average KE of a molecule (अणु की औसत गतिज ऊर्जा)

$= \frac{3}{2}\ kT = \frac{3}{4}mv_P^2$

2. There is a decrease in volume during melting of an ice slab. Therefore negative work is done by the ice–water system on to the surrounding $\Rightarrow$ W =–ve

(बर्फ की एक शीला के पिघलने के दौरान आयतन में कमी होती है। अतः बर्फ–जल निकाय द्वारा किया गया कार्य ऋणात्मक होगा)

Heat is absorbed during melting

(पिघलने के दौरान अवशोषित ऊष्मा)

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

3. Radius of curvature (वक्रता त्रिज्या) $R = \frac{d}{(\alpha_1 - \alpha_2)\Delta T}$

4. $C_p - C_v = R$ Always constant (हमेशा नियत)

$\frac{C_p}{C_v} = \gamma$ decreases with atomicity

(परमाणुकता के साथ घटता है)

$(C_p + C_v)$ and $C_p.C_v$ depends on degree of freedom therefore it will be more for diatomic gas

[$(C_p + C_v)$ व $C_p.C_v$ स्वतंत्रता की कोटि पर निर्भर करते हैं अतः द्विपरमाण्विक गैस के लिए इनका मान अधिक होगा।]

5. (i) For isothermal process curve should be hyperbola. (समतापीय प्रक्रम के लिये वक्र अतिपरवलयिक होगा)

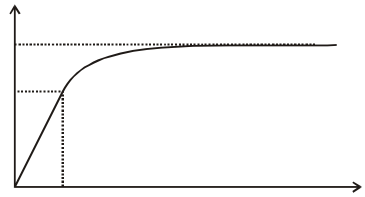
(ii) Work done & change in internal energy are both negative. (किया गया कार्य व आन्तरिक ऊर्जा में परिवर्तन दोनों ऋणात्मक होंगे)

(iii) For higher pressure volume is increasing and lower pressure volume is decreasing. (उच्च दाब के लिये आयतन बढ़ेगा व निम्न दाब के लिये आयतन घटेगा)

6. (A) From 0 to 100 k the major part of graph lies in linear region and very small part in non-linear region, therefore to a reasonable approximation between 0 K – 100 K, graph of C vs T is linear.

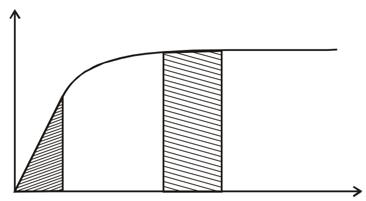
(0 से 100K पर वक्र का बड़ा भाग रेखीय क्षेत्र में तथा बहुत छोटा भाग अरेखीय क्षेत्र में है। अतः 0 K – 100 K के

मध्य तर्कसंगत सन्निकट है C व T के मध्य वक्ररेखीय है)



(B) by comparing area under curve

(वक्र के अन्तर्गत क्षेत्रफल से तुलना करने पर)



(C) from 400 K to 500 K, Graph of C vs T become asymptotic hence rate of heat absorption become constant (400 K से 500 K तक C व T का वक्र अस्पर्शी होगा। अतः ऊष्मा अवशोषण की दर नियत होगी)

(D) The rate of heat absorption increases as C is increasing.

(C के बढ़ने पर ऊष्मा अवशोषण की दर भी बढ़ती है)

Match the column

1. Process J $\rightarrow$ K (isochoric) : $W = 0, \Delta U < 0 \Rightarrow Q < 0$

   Process K $\rightarrow$ L (isobaric) : $W > 0, \Delta U > 0 \Rightarrow Q > 0$

   Process L $\rightarrow$ M (isochoric) : $W = 0, \Delta U > 0 \Rightarrow Q > 0$

   Process M $\rightarrow$ J , $W < 0$, $\Delta U < 0 \Rightarrow Q < 0$

2. **(A) Bimetallic strip** : Works on the thermal expansion of solids (different solids expands by different length for the same rise of temperature). The energy is converted to kinetic energy.

   (द्विधात्विक पट्टी : ठोंसों के ऊष्मीय प्रसार पर कार्य करती है (ताप को समान बढ़ाने के लिये भिन्न लम्बाई द्वारा भिन्न ठोस विस्तारित होते हैं) ऊर्जा, गतिज ऊर्जा में परिवर्तित होते हें।

   (B) Steam engine (भाप इंजन)

   Energy is converted (heat–mechanical)

   (C) Incandescent lamp (अदिप्त लैम्प)

   Heat $\rightarrow$ Light ; radiation from hot body.

   (D) Electric fuse (विद्युत फ्यूज)

   Works on melting of fuse wire on heating.

   Heat $\rightarrow$ P.E. of molecules.

3. For (A)

   $Q = 0,\ W = PdV = 0$ so $\Delta U = 0 \Rightarrow T = \text{constant}$

   For (B) :

   $P \propto V^{-2}$ & $PV = \mu RT \Rightarrow V \propto \dfrac{1}{T}$

   Since volume increases so temperature decreases.

   (चूंकि आयतन बढ़ता है, अतः ताप घटेगा)

   For polytropic process PV^2 = constant

   बहुदैशिक प्रक्रम के लिये PV^2 =नियत)

   $$C = C_v + \frac{R}{1-x} = C_v + \frac{R}{1-2} = \frac{3}{2}R - R = \frac{R}{2}$$

   $$Q = \mu C\Delta T = \mu\left(\frac{R}{2}\right)\Delta T = \text{Negative}$$

   For (C) :

   $$C = C_v + \frac{R}{1-\frac{4}{3}} = -\frac{3}{2}R \Rightarrow Q = \mu C\Delta T$$

   $$= -\mu\left(\frac{3}{2}R\right)\Delta T \equiv \text{Positive}$$

   For (D) :

   $P\uparrow, V\uparrow, T\uparrow$

   Work = Area under PV curve $\rightarrow$ positive

   $\Delta U \rightarrow$ positive

   $Q \rightarrow$ positive (given to system)

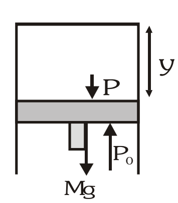
Comprehension #1

1. When the piston is pulled out slowly, the pressure drop produced inside the cylinder is almost instantaneously neutralised by the air entering from outside into the cylinder. Therefore the pressure inside is P_0.

   (जब पिस्टन को धीरे से बाहर खींचा जाता है तो बेलन के अन्दर उत्पन्न दाब पतन लगभग तात्क्षणिक रूप से बेलन के अन्दर बाहर से आने वाली हवा द्वारा उदासीन कर दिया जाता है। अतः बेलन के अन्दर दाब P_0 है)

2. $Mg = (P_0 - P)\,\pi R^2 \Rightarrow P = P_0 - \dfrac{Mg}{\pi R^2}$

   Since the cylinder is thermally conducting, the temperature remains the same.



(चूंकि बेलन ऊष्मीय चालक है, अत: ताप समान होगा)

$$P_0\ (2L\ \ \pi R^2) = P\ (y\ \ \pi R^2)\ \Rightarrow y = \left(\frac{P_0 \times \pi R^2}{P_0 \pi R^2 - Mg}\right)(2L)$$

3. Equating pressures (तुल्य दाब)

$$P_0 + \rho g(L_0 - H) = P = \frac{P_0 L_0}{(L_0 - H)}$$

Comprehension #2

1. Force due to the pressure of liquid = The buoyancy force.
(द्रव के दाब के कारण बल = उत्प्लावन बल)

2. $T^{\gamma}P^{1-\gamma}$=constant $\Rightarrow T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$

$$= T_0\left(\frac{P_0 + \rho_\ell g(H-y)}{P_0 + \rho_\ell gH}\right)^{1-\frac{3}{5}} = T_0\left(\frac{P_0 + \rho_\ell g(H-y)}{P_0 + \rho_\ell gH}\right)^{\frac{2}{5}}$$

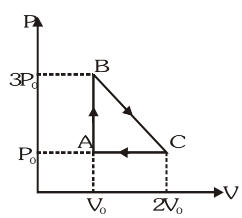
3. Buoyancy force (उत्प्लावन बल)$= V\rho_\ell g = \left(\frac{nRT_2}{P_2}\right)\rho_\ell g$

$$= \frac{nR\rho_\ell g T_0}{P_0 + \rho_\ell g(H-y)}\left[\frac{P_0 + \rho_\ell g(H-y)}{P_0 + \rho_\ell gH}\right]^{\frac{2}{5}}$$

$$= \frac{\rho_\ell nRgT_0}{(P_0 + \rho_\ell gH)^{\frac{2}{5}}(P_0 + \rho_\ell g(H-y))^{\frac{3}{5}}}$$

Subjective Questions

1. (a) ABCA is a clockwise cyclic process.
(ABCA एक दक्षिणावर्त चक्रीय प्रक्रम है)



$\therefore$ Work done by the gas (गैस द्वारा किया गया कार्य)

W=+Area of triangle ABC (त्रिभुज ABC का क्षेत्रफल)

$$W = \frac{1}{2}\ (\text{base})\ (\text{height}) = \frac{1}{2}(2V_0 - V_0)\ (3P_0 - P_0) = P_0V_0$$

(b) No. of moles n=1 and gas is monoatomic, therefore
(मोलों की संख्या n=1 तथा गैस एकलपरमाण्विय होगी)

$$C_V = \frac{3}{2}R \text{ and } C_P = \frac{5}{2}R \Rightarrow \frac{C_V}{R} = \frac{3}{2} \text{ and } \frac{C_P}{R} = \frac{5}{2}$$

(i) **Heat rejected in path CA**
(पथ CA में निष्कासित ऊष्मा)

(Process is isobaric) (प्रक्रम समदाबीय है)

$$\therefore Q_{CA} = C_P\Delta T = C_P(T_f - T_i) = C_P\left(\frac{P_fV_f}{R} - \frac{P_iV_i}{R}\right)$$

$$= \frac{C_P}{R}(P_fV_f - P_iV_i)$$

Substituting the values (मान रखने पर)

$$Q_{CA} = \frac{5}{2}(P_0V_0 - 2P_0V_0) = -\frac{5}{2}P_0V_0$$

Therefore, heat rejected in the process CA is $\frac{5}{2}P_0V_0$.

(अत: पथ CA में निष्कासित ऊष्मा $\frac{5}{2}P_0V_0$ है)

(ii) **Heat absorbed in path AB:**
(पथ AB में अवशोषित ऊष्मा)

(process is isochoric) (समआयतनिक प्रक्रम है)

$$\therefore Q_{AB} = C_V\Delta T = C_V(T_f - T_i)$$

$$= C_V\left(\frac{P_fV_f}{R} - \frac{P_iV_i}{R}\right) = \frac{C_V}{R}(P_fV_f - P_iV_i)$$

$$= \frac{3}{2}(P_fV_f - P_iV_i) = \frac{3}{2}(3P_0V_0 - P_0V_0) = 3P_0V_0$$

$\therefore$ Heat absorbed in the process AB is $3P_0V_0$.
(प्रक्रम AB में अवशोषित ऊष्मा $3P_0V_0$ होगी)

(c) Let Q_{BC} be the heat absorbed in the process BC
(माना पथ BC में अवशोषित ऊष्मा Q_{BC} है)

Total heat absorbed (अवशोषित कुल ऊष्मा)

$$Q = Q_{CA} + Q_{AB} + Q_{BC}$$

$$Q = \left(-\frac{5}{2}P_0V_0\right) + (3P_0V_0) + Q_{BC}$$

$$Q = Q_{BC} + \frac{P_0V_0}{2}$$

Change in internal energy $\Delta U = 0$
(आन्तरिक ऊर्जा में परिवर्तन)

$$\therefore Q = W \quad \therefore Q_{BC} + \frac{P_0V_0}{2} = P_0V_0 \quad \therefore Q_{BC} = \frac{P_0V_0}{2}$$

$\therefore$ Heat absorbed in the process BC is $\frac{P_0V_0}{2}$

(प्रक्रम BC में अवशोषित ऊष्मा)

(d) Maximum temperature of the gas will some where between B and C. Line BC is a straight line. Therefore, P–V equation for the process BC can be written as (गैस का अधिकतम तापमान B व C के मध्य कहीं भी हो सकता है। रेखा BC सरल रेखा है। अत: प्रक्रम BC के लिये PV समीकरण)

$$P = -mV + c; \ (y = mx + c)$$

Here, $m = \dfrac{2P_0}{V_0}$ and $c=5P_0$ $\therefore P = -\left(\dfrac{2P_0}{V_0}\right)V + 5P_0$

Multiplying the equation by V

$PV = -\left(\dfrac{2P_0}{V_0}\right)V^2 + 5P_0V$ (PV = RT for n=1)

$$RT = -\left(\frac{2P_0}{V_0}\right)V^2 + 5P_0V$$

$$\Rightarrow T = \frac{1}{R}\left[5P_0V - \frac{2P_0}{V_0}V^2\right] \quad ...(i)$$

For T to be maximum (T के अधिकतम मान के लिए)

$$\frac{dT}{dV} = 0 \ \Rightarrow 5P_0 - \frac{4P_0}{V_0}, \ V=0 \Rightarrow V = \frac{5V_0}{4}$$

i.e., at $V=\dfrac{5V_0}{4}$ (on line BC), temperature of the gas is maximum

(अर्थात् $V=\dfrac{5V_0}{4}$ पर (रेखा BC पर) गैस का ताप अधिकतम होगा।

From Equation (i) this maximum temperature will be (समीकरण (i) से यह ताप अधिकतम होगा)

$$T_{max} = \frac{1}{R}\left[5P_0\left(\frac{5V_0}{4}\right) - \frac{2P_0}{V_0}\left(\frac{5V_0}{4}\right)^2\right] = \frac{25}{8}\frac{P_0V_0}{R}$$

2. In the first part of the question ($t \le t_1$)
[प्रश्न के प्रथम भाग में ($t \le t_1$)]

At t=0, $T_X=T_0=400K$ and at $t=t_1$ $T_X=T_1=350K$

Temperature of atmosphere, T_A = 300K (constant)

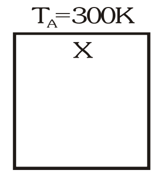
This cools down according to Newton's law of cooling.

[वातावरण का ताप T_A = 300K (नियत)]

(इसे न्यूटन के शीतलन नियम के अनुसार ठंडा किया जाता है)

Therefore, rate of cooling $\propto$ temperature difference.

(शीतलन की दर $\propto$ तापान्तर)

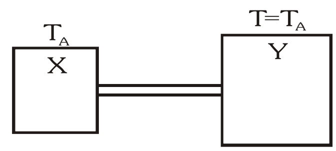


$$\therefore \left(-\frac{dT}{dt}\right) = k(T - T_A) \Rightarrow \frac{dT}{T - T_A} = -k.dt$$

$$\Rightarrow \int_{T_0}^{T_1}\frac{dT}{T - T_A} = -k\int_0^{t_1}dt \ \Rightarrow \ell n\left(\frac{T_1 - T_A}{T_0 - T_A}\right) = -kt_1$$

$$\Rightarrow kt_1 = -\ell n\left(\frac{350-300}{400-300}\right) \Rightarrow kt_1 = \ell n(2)$$

In the IInd part, body X cools by radiation (according to Newton's law) as well as by conduction ($t > t_1$).
(भाग II में वस्तु X विकिरण (न्यूटन के नियम के अनुसार) के साथ-साथ चालन ($t > t_1$) के द्वारा भी ठण्डी होती है)



Therefore, rate of cooling (अत: शीतलन की दर)

= (cooling by radiation) + (cooling by conduction)

= (विकिरण द्वारा शीतलन + चालन द्वारा शीतलन)

In conduction (चालन में) $\dfrac{dQ}{dt} = \dfrac{KA(T - T_A)}{L} = C\left(-\dfrac{dT}{dt}\right)$

$$\therefore \left(-\frac{dT}{dt}\right) = \frac{KA}{LC}(T - T_A)$$

where C = heat capacity of body X
(जहां C= वस्तु X की ऊष्माधारिता)

$$\therefore \left(-\frac{dT}{dt}\right) = k(T - T_A) + \frac{KA}{CL}(T - T_A) \quad ...(ii)$$

$$\left(-\frac{dT}{dt}\right) = \left(k + \frac{KA}{CL}\right)(T - T_A) \quad ...(iii)$$

Let at t = $3t_1$, temperature of X becomes T_2

Therefore, from Equation (iii)

(माना $t=3t_1$ पर X का ताप T_2 हो जाता है तो समीकरण (iii) से)

$$\int_{T_1}^{T_2}\frac{dT}{T - T_A} = -\left(k + \frac{KA}{LC}\right)\int_{t_1}^{3t_1}dt$$

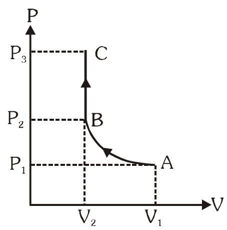
$$\Rightarrow \ell n\left(\frac{T_2 - T_A}{T_1 - T_A}\right) = -\left(k + \frac{KA}{LC}\right)(2t_1) = -\left(2kt_1 + \frac{2KA}{LC}t_1\right)$$

$$\Rightarrow \ell n\left(\frac{T_2 - 300}{350 - 300}\right) = -2\ell n(2) - \frac{2KAt_1}{LC}$$

$\Rightarrow kt_1 = \ell n2$ from Equation (i) (समीकरण (i) से)

This equations gives $T_2 = \left(300 + 12.5e^{\frac{-2KAt_1}{CL}}\right)$ kelvin

3. The P–V diagram for the complete process will be as follows (पूर्ण प्रक्रम के लिये P-V आरेख निम्न होगा)



Process A $\rightarrow$ B is adiabatic compression and Process B $\rightarrow$ C is isochoric.

(प्रक्रम A$\rightarrow$B रूद्धोष्म सम्पीड़न व प्रक्रम B $\rightarrow$ C समआयतनिक है)

(b) (i) Total work done by the gas process A–B : (गैस द्वारा प्रक्रम A–B में किया गया कुल कार्य)

$$W_{AB} = \frac{P_AV_A - P_BV_B}{\gamma - 1} = \frac{P_iV_i - P_fV_f}{\gamma - 1} = \frac{P_1V_1 - P_2V_2}{\frac{5}{3} - 1}$$

$$= \frac{P_1V_1 - P_1\left(\frac{V_1}{V_2}\right)^{\gamma} V_2}{2/3} \quad \left[\begin{array}{l} P_1V_1^{\gamma} = P_2V_2^{\gamma} \\ \therefore P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} \end{array}\right]$$

$$= \frac{3}{2}P_1V_1\left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right] = -\frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{5/3-1} - 1\right]$$

$$= -\frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right]$$

Process B–C : $W_{BC} = 0$ (V= constant)

$$\therefore W_{Total} = W_{AB} + W_{BC} = -\frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right]$$

(ii) Total change in internal energy (आन्तरिक ऊर्जा में कुल परिवर्तन)

Process A–B (प्रक्रम A-B):

$Q_{AB} = 0$ (Process is adiabatic) (प्रक्रम रूद्धोष्म है)

$$\therefore \Delta U_{AB} = -W_{AB} = \frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right]$$

Process B–C (प्रक्रम B-C):

$W_{BC} = 0$

$\therefore \Delta U_{BC} = Q_{BC} = Q$ (Given)

$$\therefore \Delta U_{Total} = \Delta U_{AB} + \Delta U_{BC} = \frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right] + Q$$

(iii) Final temperature of the gas (गैस का अन्तिम ताप)

$$\Delta U_{Total} = nC_V\Delta T = 2\left(\frac{R}{\gamma - 1}\right)(T_C - T_A)$$

$$\therefore \frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right] + Q = \frac{2R}{5/3 - 1}\left(T_C - \frac{P_AV_A}{2R}\right)$$

$$\Rightarrow \frac{3}{2}P_1V_1\left[\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right] + Q = 3R\left(T_C - \frac{P_1V_1}{2R}\right)$$

$$\therefore T_C = \frac{Q}{3R} + \frac{P_1V_1}{2R}\left(\frac{V_1}{V_2}\right)^{2/3} = T_{final}$$

4. (i) Number of moles (मोलों की संख्या)

$n=2,\ T_1 = 300K$

During the process A $\rightarrow$ B (प्रक्रम A $\rightarrow$ B के दौरान)

PT = constant or P^2V =constant=K(say)

$$\therefore P = \frac{\sqrt{K}}{\sqrt{V}}$$

$$\therefore W_{A\rightarrow B} = \int_{V_A}^{V_B} P.dV = \int_{V_A}^{V_B} \frac{\sqrt{K}}{\sqrt{V}}dV$$

$$= 2\sqrt{K}[\sqrt{V_B} - \sqrt{V_A}] \quad = 2[\sqrt{KV_B} - \sqrt{KV_A}]$$

$$= 2\left[\sqrt{(P_B^2V_B)V_B} - \sqrt{(P_A^2V_A)V_A}\right] \quad (K = P^2V)$$

$= 2[P_BV_B - P_AV_A] = 2[nRT_B - nRT_A]$

$= 2nR[T_1 - 2T_1] = (2)(2)(R)\ [300–600]$

$= –1200R$

$\therefore$ Work done on the gas in the process AB is 1200R. (प्रक्रम AB में गैस पर किया गया कार्य)

(ii) Heat absorbed/released in different processes. (भिन्न प्रक्रमों में अवशोषित/मुक्त ऊष्मा)

Since, the gas is monoatomic. (चूंकि गैस एकल परमाण्विक है)

Therefore, $C_V = \frac{3}{2}R$ and $C_P = \frac{5}{2}R$ and $\gamma = \frac{5}{3}$

Process A–B :

$\Delta U = nC_V\Delta T = (2)\left(\frac{3}{2}R\right)(T_B - T_A) = (2)\left(\frac{3}{2}R\right)$

$(300-600) = -900R$

$\therefore Q_{A\to B} = W_{A\to B} + \Delta U = (-1200R) - (900\ R)$

$Q_{A\to B} = -2100R$(Released)

Process B–C :

Process is isobaric (प्रक्रम समदाबीय है)

$\therefore\ Q_{B\to C} = nC_P\Delta T$

$= (2)\left(\frac{5}{2}R\right)(T_C - T_B) = 2\left(\frac{5}{2}R\right)(2T_1 - T_1)$

$= (5R)\ (600-300)$

$Q_{B\to C} = 1500\ R$(absorbed) (अवशोषित)

Process C–A :

Process is isothermal (प्रक्रम समतापीय है)

$\therefore\ \Delta U = 0$ and $Q_{C\to A} = W_{C\to A} = nRT_C\ell n\left(\frac{P_C}{P_A}\right)$

$= nR(2T_1)\ell n\left(\frac{2P_1}{P_1}\right) = (2)(R)(600)\ell n(2)$

$Q_{C\to A} = 831.6\ R$ (absorbed) (अवशोषित)

5. Let m be the mass of the container. Initial temperature of container, $T_i = (227 + 273) = 500$ K and final temperature of container,

$$T_f = (27 + 273) = 300\ K$$

Now, heat gained by the ice cube = heat lost by the container i.e., (mass of ice) (latent heat of fusion of ice) + (mass of ice) (specific heat of water)

(माना m पात्र का द्रव्यमान है, पात्र का प्रारम्भिक ताप

$T_i = (227 + 273) = 500$ K

व अन्तिम ताप $T_f = (27 + 273) = 300$ K है।

अब बर्फ के घन द्वारा ऊष्मा वृद्धि = पात्र के द्वारा ऊष्मा हानि अर्थात् (बर्फ का द्रव्यमान) (बर्फ के गलन की गुप्त ऊष्मा) + (बर्फ का द्रव्यमान) (पानी की विशिष्ट ऊष्मा)

$$(300\ K - 273\ K) = -m\int_{T_i}^{T_f} S.dT$$

Substituting the values, we have (मान रखने पर)

$(0.1)\ (8\quad 10^4) + (0.1)\ (10^3)\ (27)$

$$= -m\int_{500}^{300}(A + BT)dT \text{ of } 10700 = -m\left[AT + \frac{BT^2}{2}\right]_{500}^{300}$$

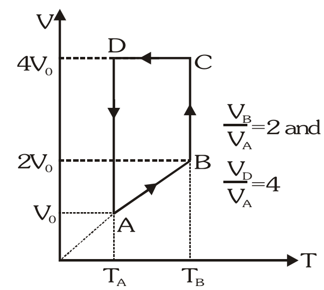
After substituting the values of A and B and the proper limits

(A व B के मान रखने के बाद)

we get m=0.495 kg.

6. Given :

No. of moles, n=2



$C_V = \frac{3}{2}R\ \&\ C_P = \frac{5}{2}R$

(Monoatomic)

$T_A = 27\ C = 300\ K$

Let $V_A = V_0$

then $V_B = 2V_0$

and $V_D = V_C = 4V_0$

(i) Process A → B :

$V \propto T \Rightarrow \frac{T_B}{T_A} = \frac{V_B}{V_A}$

$\therefore T_B = T_A\left(\frac{V_B}{V_A}\right) = (300)\ (2) = 600K$

$\therefore T_B = 600\ K$

(ii) Process A→ B :

$V \propto T \Rightarrow P = \text{constant}$

$\therefore Q_{AB} = nC_PdT = nC_P(T_B - T_A)$

$= (2)\left(\frac{5}{2}R\right)(600 - 300)$

$\therefore Q_{AB} = 1500R$ (absorbed)

Process B → C :

T = constant $\quad\therefore$ dU =0

$\therefore Q_{BC} = W_{BC} = nRT_B\ell n\left(\frac{V_C}{V_B}\right) = (2)\ (R)\ (600)\ \ell n\left(\frac{4V_0}{2V_0}\right)$

$= (1200\ R)\ell n(2) = (1200\ R)\ (0.693)$

$\Rightarrow Q_{BC} \approx 831.6\ R$ (absorbed)

Process C → D

V = constant

$\therefore\ Q_{CD} = nC_VdT = nC_V\ (T_D - T_C)$

$= n\left(\frac{3}{2}R\right)(T_A - T_B)\ (T_D = T_A \text{ and } T_C = T_B)$

$= (2)\left(\frac{3}{2}R\right)(300 - 600)$

$\Rightarrow Q_{CD} = -900\ R$ (released)

Process D → A :

T = constant $\Rightarrow$ dU = 0

$\therefore Q_{DA} = W_{DA} = nRT_D \ \ell n\left(\frac{V_A}{V_D}\right)$

$= (2)\ (R)\ (300)\ \ell n\left(\frac{V_0}{4V_0}\right) = 600R\ \ell n\left(\frac{1}{4}\right)$

$Q_{DA} \approx -831.6$ R (Released)

(iii) In the complete cycle: dU =0

Therefore, from conservation of energy

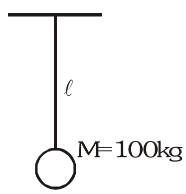
(पूर्ण चक्र में dU=0 अतः ऊर्जा संरक्षण से)

$W_{net} = Q_{AB} + Q_{BC} + Q_{CD} + Q_{DA}$

$W_{net} = 1500R + 831.6R - 900\ R - 831.6\ R$

$\Rightarrow W_{net} = W_{total} = 600\ R$

7. Given (दिया है)



Length of the wire (तार की लम्बाई) ℓ=5m

Radius of the wire (तार की त्रिज्या) r=2 10^{-3}m

Density of wire (तार का घनत्व) ρ = 7860 kg/m^3

Young's, modulus (यंग प्रत्यास्थता गुणांक)

Y= 2.1 10^{11} N/m^2 and specific heat (विशिष्ट ऊष्मा)

S = 420 J/kg–K

Mass of wire, m = (density) (volume)

[तार का द्रव्यमान m= (घनत्व)(आयतन)]

$= (\rho)\ (\pi r^2\ell) = (7860)(\pi)(2\ \ 10^{-3})^2(5)$ kg=0.494 kg

Elastic potential energy stored in the wire,

(तार में संचित प्रत्यास्थ स्थितिज ऊर्जा)

$U = \frac{1}{2}$ (stress) (strain) (volume)

$U = \frac{1}{2}$ (प्रतिबल) (विकृति) (आयतन)

$$\Rightarrow U = \frac{1}{2}\left(\frac{Mg}{\pi r^2}\right)\left(\frac{\Delta\ell}{\ell}\right)(\pi r^2\ell) = \frac{1}{2}(Mg).\Delta\ell$$

$$\because \left(\Delta\ell = \frac{F\ell}{AY}\right)$$

$$= \frac{1}{2}(Mg)\frac{(Mg\ell)}{(\pi r^2)Y} = \frac{1}{2}\frac{M^2g^2\ell}{\pi r^2 Y}$$

Substituting the values, we have (मान रखने पर)

$$U = \frac{1}{2}\frac{(100)^2(10)^2(5)}{(3.14)(2\times10^{-3})^2(2.1\times10^{11})}J = 0.9478\ J$$

When the bob gets snapped, this energy is utilised in raising the temperature of the wire.

(जब गोलक टूट जाता है तो इसकी ऊर्जा तार के ताप को बढ़ाने में काम में ली जाती है)

So, U = ms$\Delta\theta$

$$\therefore \Delta\theta = \frac{U}{ms} = \frac{0.9478}{0.494(420)}{}^\circ C \text{ or } K$$

$\Rightarrow \Delta\theta = 4.568\ \ \ 10^{-3}$ C

8. Volume of the box (बॉक्स का आयतन)= 1m^3

Pressure of the gas (गैस का दाब)= 100N/m^2

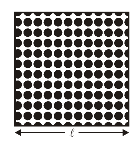
Let T be the temperature of the gas.

(माना T गैस का ताप है)

Then (तो)

(i) Time between two consecutive collisions with one wall (एक दीवार की दो क्रमागत टक्करों के मध्य समय)

$= \frac{1}{500}$ s.



This time should be equal to $\frac{2\ell}{v_{rms}}$

(यह समय $\frac{2\ell}{v_{rms}}$ के बराबर होगा)

where ℓ is the side of the cube.

(जहां ℓ घन की भुजा है)

$\Rightarrow \frac{2\ell}{v_{rms}} = \frac{1}{500} \Rightarrow v_{rms}$=1000m/s (as ℓ=1m)

$\Rightarrow \sqrt{\frac{3RT}{M}}$ =1000

$$\therefore T = \frac{(1000)^2 M}{3R} = \frac{(10)^6(4\times10^{-3})}{3(25/3)} = 160K$$

(ii) Average kinetic energy per atom $= \frac{3}{2}kT$

(प्रति अणु औसत गतिज ऊर्जा $= \frac{3}{2}kT$)

$= \frac{3}{2}(1.38\ \ \ 10^{-23})(160)$ J = 3.312 10^{-21}J

(iii) From $PV = nRT = \frac{m}{M}RT$

We get mass of helium gas in the box,

(बॉक्स में हीलियम गैस का द्रव्यमान) $m = \frac{PVM}{RT}$

Substituting the values we get (मान रखने पर)

$$m = \frac{(100)(1)(4)}{(25/3)(160)} = 0.3g$$

9. Decrease in kinetic energy = increase in internal energy of the gas

(गतिज ऊर्जा में कमी = गैस की आन्तरिक ऊर्जा में वृद्धि)

$$\therefore \frac{1}{2}mv_0^2 = nC_V\Delta T = \left(\frac{m}{M}\right)\left(\frac{3}{2}R\right)\Delta T \therefore \Delta T = \frac{Mv_0^2}{3R}$$

10. (i) Rate of heat loss per unit area due to radiation (विकिरण के कारण प्रति ईकाई क्षेत्रफल की ऊष्मा हानि की दर)

$$I = e\sigma(T^4 - T_0^4)$$

Here. $T = 127 + 273 = 400$ K

and $T_0 = 27 + 273 = 300$ K

$$\therefore I = 0.6 \quad \frac{17}{3} \quad 10^{-8}[(400)^4 - (300)^4] = 595 \text{ W/m}^2$$

(ii) Let θ be the temperature of the oil.

Then, rate of heat flow through conduction =rate of heat loss due to radiation

(माना तेल का ताप θ है तो संवहन के कारण ऊष्मा प्रवाह की दर =विकिरण के कारण ऊष्मा हानि की दर)

$$\therefore \frac{\text{temperature difference}}{\text{thermal resistance}} = (595)\ A \Rightarrow \frac{(\theta-127)}{\left(\frac{\ell}{KA}\right)} = (595)A$$

Here, A = area of disc; K = thermal conductivity and ℓ = thickness (or length) of disc (यहां A = चकती का क्षेत्रफल; K = ऊष्मीय चालकता व ℓ = चकती की मोटाई (या लम्बाई))

$$\therefore (\theta-127)\frac{K}{\ell} = 595$$

$$\therefore \theta = 595\left(\frac{\ell}{K}\right) + 127 = \frac{595\times10^{-2}}{0.167} + 127 = 162.6 \text{ C}$$

11. At constant pressure (नियत दाब पर)

$$V \propto T \Rightarrow \frac{V_2}{V_1} = \frac{T_2}{T_1} \Rightarrow \frac{Ah_2}{Ah_1} = \frac{T_2}{T_1}$$

$$\therefore h_2 = h_1\left(\frac{T_2}{T_1}\right) = (1.0)\left(\frac{400}{300}\right)m = \frac{4}{3}m$$

As there is no heat loss, process is adiabatic.

(चूंकि यहां कोई ऊष्मा हानि नहीं होती है। अतः प्रक्रम रूद्धोष्म है।)

For adiabatic process (रूद्धोष्म प्रक्रम के लिये)

$$T_fV_f^{\gamma-1} = T_iV_i^{\gamma-1}$$

$$\therefore T_f = T_i\left(\frac{V_i}{V_f}\right)^{\gamma-1} = (400)\left(\frac{h_i}{h_f}\right)^{1.4-1} = 400\left(\frac{4}{3}\right)^{0.4}$$

12. When the temperature is increased, volume of the cube will increase while density of liquid will decrease. The depth upto which the cube is submerged in the liquid remains the same, hence the upthrust will not change.

(जब ताप बढ़ाते हैं तो घन का आयतन बढ़ेगा जबकि द्रव का घनत्व घटेगा। घन का आधार भाग द्रव में डूब जाता है अतः उत्प्लावकता में कोई परिवर्तन नहीं होता है)

$F = F'$

$\therefore \quad V_i\rho_Lg = V_i'\rho'_Lg$

(V_i = volume immersed (डुबा आयतन))

$$\therefore (Ah_i)(\rho_L)(g) = A(1 + 2\alpha_s\ \Delta T)\ (h_i)\left(\frac{\rho_L}{1+\gamma_\ell\Delta T}\right)g$$

Solving this equation, we get (समीकरण को हल करने पर)

$\gamma_l = 2\alpha_s$

13. Rate of heat conduction through rod= rate of the heat lost from right end of the rod. (छड़ से होकर ऊष्मा चालन की दर = छड़ के दांये सिरे से ऊष्मा हानि की दर)

$$\therefore \frac{KA(T_1-T_2)}{L} = eA\sigma(T_2^4 - T_s^4) \quad ...(i)$$

Given that $T_2 = T_s + \Delta T$

$$\therefore T_2^4 = (T_s+\Delta T)^4 = T_s^4\left(1+\frac{\Delta T}{T_s}\right)^4$$

Using binomial expansion, we have (द्विपद प्रसार से)

$$T_2^4 = T_s^4\left(1+4\frac{\Delta T}{T_s}\right) \text{ (as } \Delta T << T_s)$$

$\therefore T_2^4 - T_s^4 = 4(\Delta T)(T_s^3)$

Substituting in Eq.(i), we have (समीकरण (i) में रखने पर)

$$\frac{K(T_1 - T_s - \Delta T)}{L} = 4e\sigma T_s^{3}.\Delta T$$

$$\Rightarrow \frac{K(T_1 - T_s)}{L} = \left(4e\sigma T_s^3 + \frac{K}{L}\right)\Delta T$$

$$\therefore \ \Delta T = \frac{K(T_1 - T_s)}{(4e\sigma L T_s^3 + K)}$$

Comparing with the given relation, proportionality constant (दिये गये सम्बन्ध से तुलना करने पर समानुपाती नियतांक)

$$= \frac{K}{4e\sigma L T_s^3 + K}$$

14. (a) From $\Delta Q = ms\Delta T$

$$\Delta T = \frac{\Delta Q}{ms} = \frac{20000}{1 \times 400} = 50°C$$

(b) $\Delta V = V\gamma\Delta T = \left(\frac{1}{9000}\right)(8 \quad 10^{-5})\ (50)$

$= 5 \quad 10^{-7}\ m^3$

$\therefore\ W = P.\Delta V = (10^5)\ (5 \quad 10^{-7}) = 0.05\ J$

(c) $\Delta U = \Delta Q - W = (20000 - 0.05)\ J$

$= 19999.95\ J$

15. 0.05 kg steam at

$373\ K \xrightarrow{Q_1} 0.05$ kg water at 373 K

0.05 kg water at

$373\ K \xrightarrow{Q_2} 0.05$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

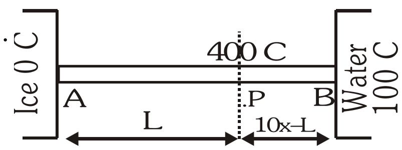
$Q_3 = (450)\ (0.5)\ (20) = 4500$ cal = 4.5 kcal

$Q_4 = (450)\ (80) = 36000$ cal = 36 kcal

Now since $Q_1 + Q_2 > Q_3$ but $Q_1 + Q_2 < Q_3 + Q_4$ ice will come to 273K from 253 K, but whole ice will not melt. Therefore, temperature of the mixture is 273K.

(अब चूंकि $Q_1 + Q_2 > Q_3$ लेकिन $Q_1 + Q_2 < Q_3 + Q_4$ बर्फ का ताप 273K से 253 K हो जाता है लेकिन सम्पूर्ण बर्फ नहीं पिघलती है। अत: मिश्रण का ताप 273K होगा)

16.



$$\frac{k(400-0)A}{L} = m\ (80) \ ...(i)$$

$$\frac{kA(400-100)}{(10x-L)} = m\ (540) \ ...(ii)$$

Divide (i) by (ii) $1080\ x = 120\ L$

$\because L = \lambda x \quad \therefore \lambda = 9$