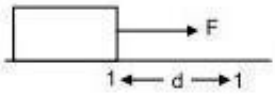
CHAPTER 26
LAWS OF THERMODYNAMICS
QUESTIONS FOR SHORT ANSWER

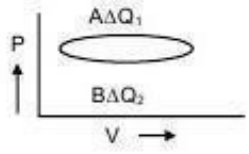
1. No in isothermal process heat is added to a system. The temperature does not increase so the internal energy does not.
2. Yes, the internal energy must increase when temp. increases; as internal energy depends upon temperature $U \propto T$
3. Work done on the gas is 0. as the P.E. of the container si increased and not of gas. Work done by the gas is 0. as the gas is not expanding.
   The temperature of the gas is decreased.
4. $W = F \times d = Fd \cos 0° = Fd$
   Change in PE is zero. Change in KE is non Zero.
   So, there may be some internal energy.



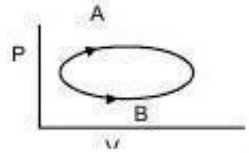
5. The outer surface of the cylinder is rubbed vigorously by a polishing machine.
   The energy given to the cylinder is work. The heat is produced on the cylinder which transferred to the gas.
6. No. work done by rubbing the hands in converted to heat and the hands become warm.
7. When the bottle is shaken the liquid in it is also shaken. Thus work is done on the liquid. But heat is not transferred to the liquid.
8. Final volume = Initial volume. So, the process is isobaric.
   Work done in an isobaric process is necessarily zero.
9. No word can be done by the system without changing its volume.
10. Internal energy = $U = nC_VT$
    Now, since gas is continuously pumped in. So $n_2 = 2n_1$ as the $p_2 = 2p_1$. Hence the internal energy is also doubled.
11. When the tyre bursts, there is adiabatic expansion of the air because the pressure of the air inside is sufficiently higher than atmospheric pressure. In expansion air does some work against surroundings. So the internal energy decreases. This leads to a fall in temperature.
12. 'No', work is done on the system during this process. No, because the object expands during the process i.e. volume increases.
13. No, it is not a reversible process.
14. Total heat input = Total heat out put i.e., the total heat energy given to the system is converted to mechanical work.
15. Yes, the entropy of the body decreases. But in order to cool down a body we need another external sink which draws out the heat the entropy of object in partly transferred to the external sink. Thus once entropy is created. It is kept by universe. And it is never destroyed. This is according to the 2nd law of thermodynamics

OBJECTIVE – I

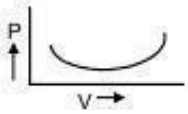
1. (d) $Dq = DU + DW$. This is the statement of law of conservation of energy. The energy provided is utilized to do work as well as increase the molecular K.E. and P.E.
2. (b) Since it is an isothermal process. So temp. will remain constant as a result 'U' or internal energy will also remain constant. So the system has to do positive work.
3. (a) In case of A $\Delta W_1 > \Delta W_2$ (Area under the graph is higher for A than for B).
   $\Delta Q = \Delta u + dw$.
   du for both the processes is same (as it is a state function)
   $\therefore \Delta Q_1 > \Delta Q_2$ as $\Delta W_1 > \Delta W_2$



4. (b) As Internal energy is a state function and not a path function. $\Delta U_1 = \Delta U_2$

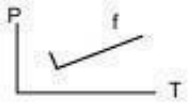


5. (a) In the process the volume of the system increases continuously. Thus, the work done increases continuously.

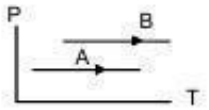


6. (c) for A → In a so thermal system temp remains same although heat is added.
for B → For the work done by the system volume increase as is consumes heat.

7. (c) In this case P and T varry proportionally i.e. P/T = constant. This is possible only when volume does not change. ∴ pdv = 0 ω



8. (c) Given : $\Delta V_A = \Delta V_B$. But $P_A < P_B$
Now, $W_A = P_A \Delta V_B$; $W_B = P_B \Delta V_B$; So, $W_A < W_B$.



9. (b) As the volume of the gas decreases, the temperature increases as well as the pressure. But, on passage of time, the heat develops radiates through the metallic cylinder thus T decreases as well as the pressure.

OBJECTIVE – II

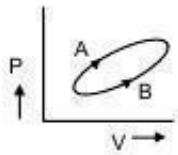
1. (b), (c) Pressure P and Volume V both increases. Thus work done is positive (V increases). Heat must be added to the system to follow this process. So temperature must increases.

2. (a) (b) Initial temp = Final Temp. Initial internal energy = Final internal energy.
i.e. ΔU = 0, So, this is found in case of a cyclic process.



3. (d) ΔU = Heat supplied, ΔW = Work done.
(ΔQ – ΔW) = du, du is same for both the methods since it is a state function.

4. (a) (c) Since it is a cyclic process.
So, $\Delta U_1 = -\Delta U_2$, hence $\Delta U_1 + \Delta U_2 = 0$
ΔQ – ΔW = 0

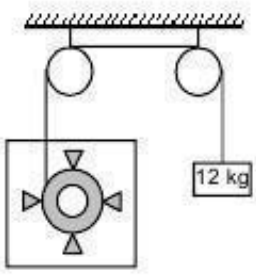


5. (a) (d) Internal energy decreases by the same amount as work done.
du = dw, ∴ dQ = 0. Thus the process is adiabatic. In adiabatic process, dU = – dw. Since 'U' decreases $U_2 - U_2$ is –ve. ∴dw should be +ve $\Rightarrow \frac{nR}{\upsilon - 1}(T_1 - T_2)$ is +ve. $T_1 > T_2$ ∴ Temperature decreases.

EXERCISES

1. $t_1 = 15°c$ $t_2 = 17°c$
$\Delta t = t_2 - t_1 = 17 - 15 = 2°C = 2 + 273 = 275$ K
$m_v = 100$ g = 0.1 kg $m_w = 200$ g = 0.2 kg
$cu_g = 420$ J/kg–k $W_g = 4200$ J/kg–k
(a) The heat transferred to the liquid vessel system is 0. The internal heat is shared in between the vessel and water.
(b) Work done on the system = Heat produced unit
$\Rightarrow dw = 100 \times 10^{-3} \times 420 \times 2 + 200 \times 10^{-3} \times 4200 \times 2 = 84 + 84 \times 20 = 84 \times 21 = 1764$ J.
(c)dQ = 0, dU = – dw = 1764. [since dw = –ve work done on the system]

2. (a) Heat is not given to the liquid. Instead the mechanical work done is converted to heat. So, heat given to liquid is z.
(b) Work done on the liquid is the PE lost by the 12 kg mass = mgh = 12 × 10× 0.70 = 84 J
(c) Rise in temp at Δt We know, 84 = msΔt
$\Rightarrow 84 = 1 \times 4200 \times \Delta t$ (for 'm' = 1kg) $\Rightarrow \Delta t = \frac{84}{4200} = 0.02$ k



3. mass of block = 100 kg
u = 2 m/s, m = 0.2 v = 0
dQ = du + dw
In this case dQ = 0
$\Rightarrow -du = dw \Rightarrow du = -\left(\frac{1}{2}mv^2 - \frac{1}{2}mu^2\right) = \frac{1}{2} \times 100 \times 2 \times 2 = 200$ J

4. Q = 100 J

We know, $\Delta U = \Delta Q - \Delta W$

Here since the container is rigid, $\Delta V = 0$,

Hence the $\Delta W = P\Delta V = 0$,

So, $\Delta U = \Delta Q = 100$ J.

5. $P_1 = 10$ kpa $= 10 \times 10^3$ pa. $P_2 = 50 \times 10^3$ pa. $v_1 = 200$ cc. $v_2 = 50$ cc

(i) Work done on the gas $= \frac{1}{2}(10+50)\times 10^3 \times (50-200)\times 10^{-6} = -4.5$ J

(ii) $dQ = 0 \Rightarrow 0 = du + dw \Rightarrow du = -dw = 4.5$ J

6. initial State 'I' Final State 'f'

Given $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

where $P_1 \rightarrow$ Initial Pressure ; $P_2 \rightarrow$ Final Pressure.

$T_2, T_1 \rightarrow$ Absolute temp. So, $\Delta V = 0$

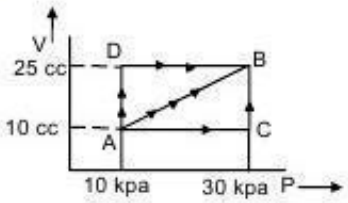
Work done by gas $= P\Delta V = 0$

7. In path ACB,

$W_{AC} + W_{BC} = 0 + pdv = 30 \times 10^3 (25 - 10) \times 10^{-6} = 0.45$ J

In path AB, $W_{AB} = ½ \times (10 + 30) \times 10^3\ 15 \times 10^{-6} = 0.30$ J

In path ADB, $W = W_{AD} + W_{DB} = 10 \times 10^3 (25 - 10) \times 10^{-6} + 0 = 0.15$ J



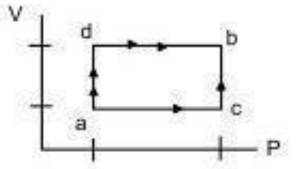
8. $\Delta Q = \Delta U + \Delta W$

In abc, $\Delta Q = 80$ J $\Delta W = 30$ J

So, $\Delta U = (80 - 30)$ J $= 50$ J

Now in adc, $\Delta W = 10$ J

So, $\Delta Q = 10 + 50 = 60$ J $[\therefore \Delta U = 50$ J$]$



9. In path ACB,

dQ = 50 0 50 × 4.2 = 210 J

$dW = W_{AC} + W_{CB} = 50 \times 10^3 \times 200 \times 10^{-6} = 10$ J

$dQ = dU + dW$

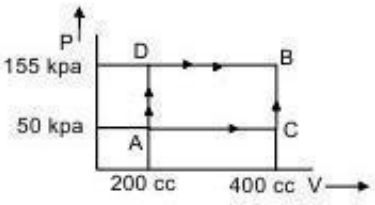
$\Rightarrow dU = dQ - dW = 210 - 10 = 200$ J

In path ADB, dQ = ?

dU = 200 J (Internal energy change between 2 points is always same)

$dW = W_{AD} + W_{DB} = 0 + 155 \times 10^3 \times 200 \times 10^{-6} = 31$ J

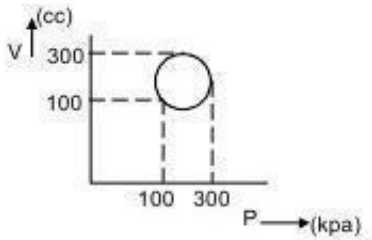
$dQ = dU + dW = 200 + 31 = 231$ J $= 55$ cal



10. Heat absorbed = work done = Area under the graph

In the given case heat absorbed = area of the circle

$= \pi \times 10^4 \times 10^{-6} \times 10^3 = 3.14 \times 10 = 31.4$ J



11. dQ = 2.4 cal = 2.4 J Joules

$dw = W_{AB} + W_{BC} + W_{AC}$

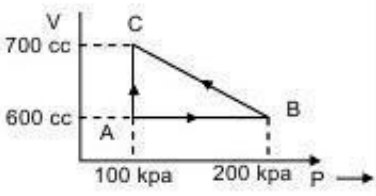
$= 0 + (1/2) \times (100 + 200) \times 10^3\ 200 \times 10^{-6} - 100 \times 10^3 \times 200 \times 10^{-6}$

$= (1/2) \times 300 \times 10^3\ 200 \times 10^{-6} - 20 = 30 - 20 = 10$ joules.

du = 0 (in a cyclic process)

$dQ = dU + dW \Rightarrow 2.4$ J $= 10$

$\Rightarrow J = \frac{10}{2.4} \approx 4.17$ J/Cal.

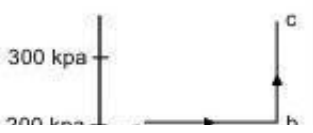


12. Now, $\Delta Q = (2625 \times J)$ J

$\Delta U = 5000$ J

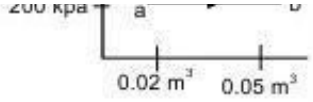
From Graph $\Delta W = 200 \times 10^3 \times 0.03 = 6000$ J.

Now, $\Delta Q = \Delta W + \Delta U$



$\Rightarrow$ 2625 J = 6000 + 5000 J

$J = \frac{11000}{2625} = 4.19$ J/Cal



13. dQ = 70 cal = (70 × 4.2) J

dW = (1/2) × (200 + 500) × 10^3 × 150 × 10^{-6}

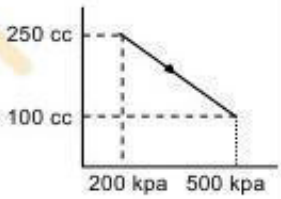
= (1/2) × 500 × 150 × 10^{-3}

= 525 × 10^{-1} = 52.5 J

dU = ? dQ = du + dw

$\Rightarrow$ – 294 = du + 52.5

$\Rightarrow$ du = – 294 – 52.5 = – 346.5 J



14. U = 1.5 pV P = 1 × 10^5 Pa

dV = (200 – 100) cm^3 = 100 cm^3 = 10^{-4} m^3

dU = 1.5 × 10^5 × 10^{-4} = 15

dW = 10^5 × 10^{-4} = 10

dQ = dU + dW = 10 + 15 = 25 J

15. dQ = 10 J

dV = A × 10 cm^3 = 4 × 10 cm^3 = 40 × 10^{-6} cm^3

dw = Pdv = 100 × 10^3 × 40 × 10^{-6} = 4 cm^3

du = ? 10 = du + dw $\Rightarrow$ 10 = du + 4 $\Rightarrow$ du = 6 J.

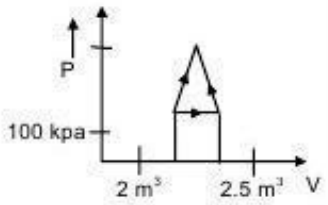
16. (a) P_1 = 100 KPa

V_1 = 2 m^3

ΔV_1 = 0.5 m^3

ΔP_1 = 100 KPa

From the graph, We find that area under AC is greater than area under than AB. So, we see that heat is extracted from the system.



(b) Amount of heat = Area under ABC.

$= \frac{1}{2} \times \frac{5}{10} \times 10^5 = 25000$ J

17. n = 2 mole

dQ = – 1200 J

dU = 0 (During cyclic Process)

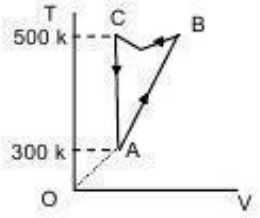
dQ = dU + dwc

$\Rightarrow$ – 1200 = W_{AB} + W_{BC} + W_{CA}

$\Rightarrow$ – 1200 = nRΔT + W_{BC} + 0

$\Rightarrow$ – 1200 = 2 × 8.3 × 200 + W_{BC}

$\Rightarrow$ W_{BC} = – 400 × 8.3 – 1200 = – 4520 J.



18. Given n = 2 moles

dV = 0

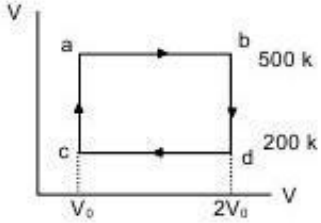
in ad and bc.

Hence dW = dQ dW = dW_{ab} + dW_{cd}

$= nRT_1 Ln \frac{2V_0}{V_0} + nRT_2 Ln \frac{V_0}{2V_0}$

= nR × 2.303 × log 2(500 – 300)

= 2 × 8.314 × 2.303 × 0.301 × 200 = 2305.31 J



19. Given M = 2 kg 2t = 4°c Sw = 4200 J/Kg–k

f_0 = 999.9 kg/m^3 f_4 = 1000 kg/m^3 P = 10^5 Pa.

Net internal energy = dv

dQ = DU + dw $\Rightarrow$ msΔQϕ = dU + P(v_0 – v_4)

$\Rightarrow$ 2 × 4200 × 4 = dU + 10^5(m – m)

$\Rightarrow 33600 = dU + 10^5\left(\frac{m}{V_0} - \frac{m}{v_4}\right) = dU + 10^5(0.0020002 - 0.002) = dU + 10^5\ 0.0000002$

$\Rightarrow$ 33600 = du + 0.02 $\Rightarrow$ du = (33600 – 0.02) J

20. Mass = 10g = 0.01kg.

$P = 10^5 Pa$

$dQ = Q_{H_2O}\,0° - 100° + Q_{H_2O}$ – steam

$= 0.01 \times 4200 \times 100 + 0.01 \times 2.5 \times 10^6 = 4200 + 25000 = 29200$

$dW = P \times \Delta V$

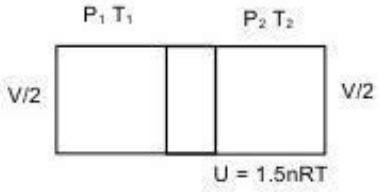
$\Delta = \frac{0.01}{0.6} - \frac{0.01}{1000} = 0.01699$

$dW = P\Delta V = 0.01699 \times 10^5$ 1699J

$dQ = dW + dU$ or $dU = dQ - dW = 29200 - 1699 = 27501 = 2.75 \times 10^4$ J

21. (a) Since the wall can not be moved thus dU = 0 and dQ = 0.

Hence dW = 0.



(b) Let final pressure in LHS = P_1

In RHS = P_2

($\therefore$ no. of mole remains constant)

$\frac{P_1V}{2RT_1} = \frac{P_1V}{2RT}$

$\Rightarrow P_1 = \frac{P_1T}{T_1} = \frac{P_1(P_1+P_2)T_1T_2}{\lambda}$

As, $T = \frac{(P_1+P_2)T_1T_2}{\lambda}$

Simillarly $P_2 = \frac{P_2T_1(P_1+P_2)}{\lambda}$

(c) Let $T_2 > T_1$ and 'T' be the common temp.

Initially $\frac{P_1V}{2} = n_1 rt_1 \Rightarrow n_1 = \frac{P_1V}{2RT_1}$

$n_2 = \frac{P_2V}{2RT_2}$ Hence dQ = 0, dW = 0, Hence dU = 0.

In case (LHS)	RHS
$\Delta u_1 = 1.5n_1 R(T - T_1)$ But $\Delta u_1 - \Delta u_2 = 0$	$\Delta u_2 = 1.5n_2 R(T_2 - T)$

$\Rightarrow 1.5\, n_1 R(T - T_1) = 1.5\, n_2 R(T_2 - T)$

$\Rightarrow n_2 T - n_1 T_1 = n_2 T_2 - n_2 T \Rightarrow T(n_1 + n_2) = n_1 T_1 + n_2 T_2$

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

$= \frac{\frac{P_1V}{2RT_1} \times T_1 + \frac{P_2V}{2RT_2} \times T_2}{\frac{P_1V}{2RT_1} + \frac{P_2V}{2RT_2}} = \frac{P_1 + P_2}{\frac{P_1T_2 + P_2T_1}{T_1T_2}}$

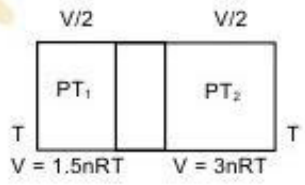
$= \frac{(P_1+P_2)T_1T_2}{P_1T_2 + P_2T_1} = \frac{(P_1+P_2)T_1T_2}{\lambda}$ as $P_1 T_2 + P_2 T_1 = \lambda$

(d) For RHS dQ = dU (As dW = 0) $= 1.5\, n_2 R(T_2 - t)$

$= \frac{1.5P_2V}{2RT_2} R\left[\frac{T_2 - (P_1 - P_2)T_1T_2}{P_1T_2 - P_2T_1}\right] = \frac{1.5P_2V}{2T_2}\left(\frac{P_1t_2^2 - P_1T_1T_2}{\lambda}\right)$

$= \frac{1.5P_2V}{2T_2} \times \frac{T_2P_1(T_2 - T_1)}{\lambda} = \frac{3P_1P_2(T_2 - T_1)V}{4\lambda}$

22. (a) As the conducting wall is fixed the work done by the gas on the left part during the process is Zero.



(b) For left side

Pressure = P

Volume = V

No. of moles = n(1mole)

For right side

Let initial Temperature = T_2

Let initial Temperature = T_1

$\frac{PV}{2} = nRT_1$ $\qquad$ $\frac{PV}{2} = n_2 RT_2$

$\Rightarrow \frac{PV}{2} = (1)RT_1$ $\qquad$ $\Rightarrow T_2 = \frac{PV}{2n_2R} \times 1$

$\Rightarrow T_1 = \frac{PV}{2(\text{moles})R}$ $\qquad$ $\Rightarrow T_2 = \frac{PV}{4(\text{moles})R}$

(c) Let the final Temperature = T

Final Pressure = R

No. of mole = 1 mole + 2 moles = 3 moles

$\therefore PV = nRT \Rightarrow T = \frac{PV}{nR} = \frac{PV}{3(\text{mole})R}$

(d) For RHS dQ = dU [as, dW = 0]

$= 1.5\, n_2\, R(T - T_2) = 1.5 \times 2 \times R \times \left[\frac{PV}{3(\text{mole})R} - \frac{PV}{4(\text{mole})R}\right]$

$= 1.5 \times 2 \times R \times \frac{4PV - 3PV}{4 \times 3(\text{mole}} = \frac{3 \times R \times PV}{3 \times 4 \times R} = \frac{PV}{4}$

(e) As, dQ = –dU

$\Rightarrow dU = -dQ = \frac{-PV}{4}$