10. *A sample of 100 g water is slowly heated from 27°C to 87°C. Calculate the change in the entropy of the water. Specific heat capacity of water = 4200 J/kg-K.*

Solution : The heat supplied to increase the temperature of the sample from T to $T + \Delta T$ is

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

where $m = 100 \, g = 0.1 \, kg$ and $C = 4200 \, J/kg\text{-}K$.

The change in entropy during this process is

$$\Delta S = \frac{\Delta Q}{T} = ms \, \frac{\Delta T}{T} .$$

The total change in entropy as the temperature rises from T_1 to T_2 is,

$$S_2 - S_1 = \int_{T_1}^{T_2} ms \, \frac{dT}{T}$$

$$= ms \, \ln \frac{T_2}{T_1} .$$

Putting $T_1 = 27°C = 300 \, K$ and $T_2 = 87°C = 360 \, K$,

$$S_2 - S_1 = (0.1 \, kg) \, (4200 \, J/kg\text{-}K) \, \ln \frac{360}{300}$$

$$= 76.6 \, J/K.$$

11. *A heat engine operates between a cold reservoir at temperature* $T_2 = 300 \, K$ *and a hot reservoir at temperature* T_1*. It takes 200 J of heat from the hot reservoir and delivers 120 J of heat to the cold reservoir in a cycle. What could be the minimum temperature of the hot reservoir?*

Solution : The work done by the engine in a cycle is

$$W = 200 \, J - 120 \, J = 80 \, J.$$

The efficiency of the engine is

$$\eta = \frac{W}{Q} = \frac{80 \, J}{200 \, J} = 0.40.$$

From Carnot's theorem, no engine can have an efficiency greater than that of a Carnot engine.

Thus, $0.40 \leq 1 - \dfrac{T_2}{T_1} = 1 - \dfrac{300 \, K}{T_1}$

or, $\dfrac{300 \, K}{T_1} \leq 1 - 0.40 = 0.60$

or, $T_1 \geq \dfrac{300 \, K}{0.60}$

or, $T_1 \geq 500 \, K.$

The minimum temperature of the hot reservoir may be 500 K.

□

QUESTIONS FOR SHORT ANSWER

1. Should the internal energy of a system necessarily increase if heat is added to it?

2. Should the internal energy of a system necessarily increase if its temperature is increased?

3. A cylinder containing a gas is lifted from the first floor to the second floor. What is the amount of work done on the gas? What is the amount of work done by the gas? Is the internal energy of the gas increased? Is the temperature of the gas increased?

4. A force F is applied on a block of mass M. The block is displaced through a distance d in the direction of the force. What is the work done by the force on the block? Does the internal energy change because of this work?

5. The outer surface of a cylinder containing a gas is rubbed vigorously by a polishing machine. The cylinder and its gas become warm. Is the energy transferred to the gas heat or work?

6. When we rub our hands they become warm. Have we supplied heat to the hands?

7. A closed bottle contains some liquid. The bottle is shaken vigorously for 5 minutes. It is found that the temperature of the liquid is increased. Is heat transferred to the liquid? Is work done on the liquid? Neglect expansion on heating.

8. The final volume of a system is equal to the initial volume in a certain process. Is the work done by the system necessarily zero? Is it necessarily nonzero?

9. Can work be done by a system without changing its volume?

10. An ideal gas is pumped into a rigid container having diathermic walls so that the temperature remains constant. In a certain time interval, the pressure in the container is doubled. Is the internal energy of the contents of the container also doubled in the interval?

11. When a tyre bursts, the air coming out is cooler than the surrounding air. Explain.

12. When we heat an object, it expands. Is work done by the object in this process? Is heat given to the object equal to the increase in its internal energy?

13. When we stir a liquid vigorously, it becomes warm. Is it a reversible process?

14. What should be the condition for the efficiency of a Carnot engine to be equal to 1?

15. When an object cools down, heat is withdrawn from it. Does the entropy of the object decrease in this process? If yes, is it a violation of the second law of thermodynamics stated in terms of increase in entropy?

OBJECTIVE I

1. The first law of thermodynamics is a statement of
   (a) conservation of heat
   (b) conservation of work
   (c) conservation of momentum
   (d) conservation of energy.

2. If heat is supplied to an ideal gas in an isothermal process,
   (a) the internal energy of the gas will increase
   (b) the gas will do positive work
   (c) the gas will do negative work
   (d) the said process is not possible.

3. Figure (26-Q1) shows two processes A and B on a system. Let ΔQ_1 and ΔQ_2 be the heat given to the system in processes A and B respectively. Then
   (a) $\Delta Q_1 > \Delta Q_2$ (b) $\Delta Q_1 = \Delta Q_2$ (c) $\Delta Q_1 < \Delta Q_2$ (d) $\Delta Q_1 \leq \Delta Q_2$.
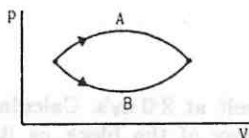
Figure 26-Q1

4. Refer to figure (26-Q1). Let ΔU_1 and ΔU_2 be the changes in internal energy of the system in the processes A and B. Then
   (a) $\Delta U_1 > \Delta U_2$ (b) $\Delta U_1 = \Delta U_2$
   (c) $\Delta U_1 < \Delta U_2$ (d) $\Delta U_1 \neq \Delta U_2$.

5. Consider the process on a system shown in figure (26-Q2). During the process, the work done by the system
   (a) continuously increases
   (b) continuously decreases
   (c) first increases then decreases
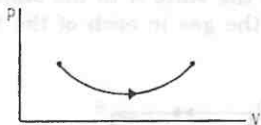   (d) first decreases then increases.

Figure 26-Q2

6. Consider the following two statements.
   (A) If heat is added to a system, its temperature must increase.

(B) If positive work is done by a system in a thermodynamic process, its volume must increase.
   (a) Both A and B are correct.
   (b) A is correct but B is wrong.
   (c) B is correct but A is wrong.
   (d) Both A and B are wrong.

7. An ideal gas goes from the state i to the state f as shown in figure (26-Q3). The work done by the gas during the process
   (a) is positive   (b) is negative   (c) is zero
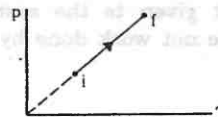   (d) cannot be obtained from this information.

Figure 26-Q3

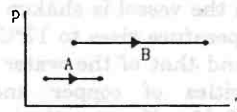8. Consider two processes on a system as shown in figure (26-Q4).

Figure 26-Q4

The volumes in the initial states are the same in the two processes and the volumes in the final states are also the same. Let ΔW_1 and ΔW_2 be the work done by the system in the processes A and B respectively.
   (a) $\Delta W_1 > \Delta W_2$.   (b) $\Delta W_1 = \Delta W_2$.   (c) $\Delta W_1 < \Delta W_2$.
   (d) Nothing can be said about the relation between ΔW_1 and ΔW_2.

9. A gas is contained in a metallic cylinder fitted with a piston. The piston is suddenly moved in to compress the gas and is maintained at this position. As time passes the pressure of the gas in the cylinder
   (a) increases   (b) decreases
   (c) remains constant
   (d) increases or decreases depending on the nature of the gas.

OBJECTIVE II

1. The pressure p and volume V of an ideal gas both increase in a process.
   (a) Such a process is not possible.
   (b) The work done by the system is positive.
   (c) The temperature of the system must increase.

   (d) Heat supplied to the gas is equal to the change in internal energy.

2. In a process on a system, the initial pressure and volume are equal to the final pressure and volume.
   (a) The initial temperature must be equal to the final temperature.

(b) The initial internal energy must be equal to the final internal energy.

(c) The net heat given to the system in the process must be zero.

(d) The net work done by the system in the process must be zero.

3. A system can be taken from the initial state p_1, V_1 to the final state p_2, V_2 by two different methods. Let ΔQ and ΔW represent the heat given to the system and the work done by the system. Which of the following must be the same in both the methods ?
(a) ΔQ (b) ΔW (c) $\Delta Q + \Delta W$ (d) $\Delta Q - \Delta W$.

4. Refer to figure (26-Q5). Let ΔU_1 and ΔU_2 be the change in internal energy in processes A and B respectively, ΔQ be the net heat given to the system in process $A + B$ and ΔW be the net work done by the system in the process $A + B$.
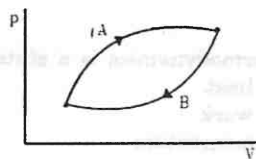
Figure 26-Q5

(a) $\Delta U_1 + \Delta U_2 = 0$.   (b) $\Delta U_1 - \Delta U_2 = 0$.
(c) $\Delta Q - \Delta W = 0$.   (d) $\Delta Q + \Delta W = 0$.

5. The internal energy of an ideal gas decreases by the same amount as the work done by the system.
(a) The process must be adiabatic.
(b) The process must be isothermal.
(c) The process must be isobaric.
(d) The temperature must decrease.

EXERCISES

1. A thermally insulated, closed copper vessel contains water at 15°C. When the vessel is shaken vigorously for 15 minutes, the temperature rises to 17°C. The mass of the vessel is 100 g and that of the water is 200 g. The specific heat capacities of copper and water are 420 J/kg-K and 4200 J/kg-K respectively. Neglect any thermal expansion. (a) How much heat is transferred to the liquid–vessel system ? (b) How much work has been done on this system ? (c) How much is the increase in internal energy of the system ?

2. Figure (26-E1) shows a paddle wheel coupled to a mass of 12 kg through fixed frictionless pulleys. The paddle is immersed in a liquid of heat capacity 4200 J/K kept in an adiabatic container. Consider a time interval in which the 12 kg block falls slowly through 70 cm. (a) How much heat is given to the liquid ? (b) How much work is done on the liquid ? (c) Calculate the rise in the temperature of the liquid neglecting the heat capacity of the container and the paddle.
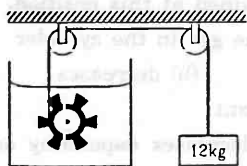

Figure 26-E1

3. A 100 kg block is started with a speed of 2·0 m/s on a long, rough belt kept fixed in a horizontal position. The coefficient of kinetic friction between the block and the belt is 0·20. (a) Calculate the change in the internal energy of the block–belt system as the block comes to a stop on the belt. (b) Consider the situation from a frame of reference moving at 2·0 m/s along the initial velocity of the block. As seen from this frame, the block is gently put on a moving belt and in due time the block starts

moving with the belt at 2·0 m/s. Calculate the increase in the kinetic energy of the block as it stops slipping past the belt. (c) Find the work done in this frame by the external force holding the belt.

4. Calculate the change in internal energy of a gas kept in a rigid container when 100 J of heat is supplied to it.

5. The pressure of a gas changes linearly with volume from 10 kPa, 200 cc to 50 kPa, 50 cc. (a) Calculate the work done by the gas. (b) If no heat is supplied or extracted from the gas, what is the change in the internal energy of the gas ?

6. An ideal gas is taken from an initial state i to a final state f in such a way that the ratio of the pressure to the absolute temperature remains constant. What will be the work done by the gas ?

7. Figure (26-E2) shows three paths through which a gas can be taken from the state A to the state B. Calculate the work done by the gas in each of the three paths.
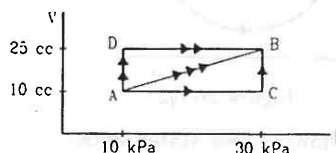

Figure 26-E2

8. When a system is taken through the process abc shown in figure (26-E3), 80 J of heat is absorbed by the system and 30 J of work is done by it. If the system does 10 J
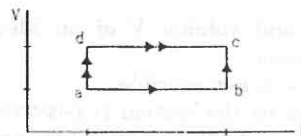

Figure 26-E3

of work during the process *adc*, how much heat flows into it during the process ?

9. 50 cal of heat should be supplied to take a system from the state *A* to the state *B* through the path *ACB* as shown in figure (26-E4). Find the quantity of heat to be supplied to take it from *A* to *B* via *ADB*.
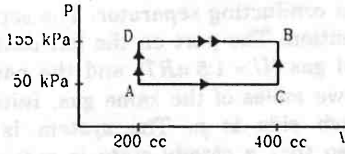

Figure 26-E4

10. Calculate the heat absorbed by a system in going through the cyclic process shown in figure (26-E5).
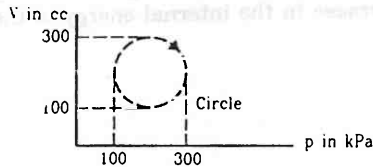

Figure 26-E5

11. A gas is taken through a cyclic process *ABCA* as shown in figure (26-E6). If 2·4 cal of heat is given in the process, what is the value of *J* ?
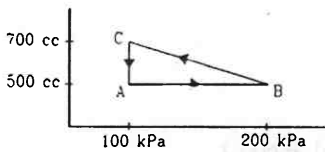
Figure 26-E6

12. A substance is taken through the process *abc* as shown in figure (26-E7). If the internal energy of the substance increases by 5000 J and a heat of 2625 cal is given to the system, calculate the value of *J*.
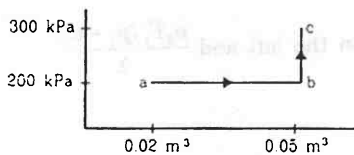
Figure 26-E7

13. A gas is taken along the path *AB* as shown in figure (26-E8). If 70 cal of heat is extracted from the gas in the
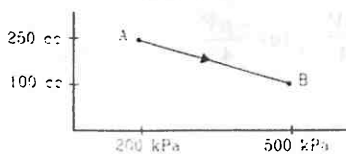

Figure 26-E8

process, calculate the change in the internal energy of the system.

14. The internal energy of a gas is given by $U = 1.5 \, pV$. It expands from $100 \, cm^3$ to $200 \, cm^3$ against a constant pressure of 1.0×10^5 Pa. Calculate the heat absorbed by the gas in the process.

15. A gas is enclosed in a cylindrical vessel fitted with a frictionless piston. The gas is slowly heated for some time. During the process, 10 J of heat is supplied and the piston is found to move out 10 cm. Find the increase in the internal energy of the gas. The area of cross-section of the cylinder = $4 \, cm^2$ and the atmospheric pressure = 100 kPa.

16. A gas is initially at a pressure of 100 kPa and its volume is $2.0 \, m^3$. Its pressure is kept constant and the volume is changed from $2.0 \, m^3$ to $2.5 \, m^3$. Its volume is now kept constant and the pressure is increased from 100 kPa to 200 kPa. The gas is brought back to its initial state, the pressure varying linearly with its volume. (a) Whether the heat is supplied to or extracted from the gas in the complete cycle ? (b) How much heat was supplied or extracted ?

17. Consider the cyclic process *ABCA*, shown in figure (26-E9), performed on a sample of 2·0 mole of an ideal gas. A total of 1200 J of heat is withdrawn from the sample in the process. Find the work done by the gas during the part *BC*.
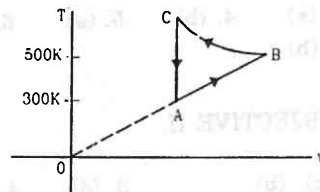

Figure 26-E9

18. Figure (26-E10) shows the variation in the internal energy *U* with the volume *V* of 2·0 mole of an ideal gas in a cyclic process *abcda*. The temperatures of the gas at *b* and *c* are 500 K and 300 K respectively. Calculate the heat absorbed by the gas during the process.
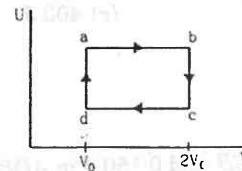

Figure 26-E10

19. Find the change in the internal energy of 2 kg of water as it is heated from 0°C to 4°C. The specific heat capacity of water is 4200 J/kg–K and its densities at 0°C and 4°C are 999·9 kg/m^3 and 1000 kg/m^3 respectively. Atmospheric pressure = 10^5 Pa.

20. Calculate the increase in the internal energy of 10 g of water when it is heated from 0°C to 100°C and converted

into steam at 100 kPa. The density of steam = 0·6 kg/m^3. Specific heat capacity of water = 4200 J/kg–°C and the latent heat of vaporization of water = $2·25 \times 10^6$ J/kg.

21. Figure (26-E11) shows a cylindrical tube of volume V with adiabatic walls containing an ideal gas. The internal energy of this ideal gas is given by $1·5 \, nRT$. The tube is divided into two equal parts by a fixed diathermic wall. Initially, the pressure and the temperature are p_1, T_1 on the left and p_2, T_2 on the right. The system is left for sufficient time so that the temperature becomes equal on the two sides. (a) How
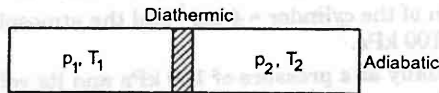
Figure 26-E11

much work has been done by the gas on the left part ? (b) Find the final pressures on the two sides. (c) Find the final equilibrium temperature. (d) How much heat has flown from the gas on the right to the gas on the left ?

22. An adiabatic vessel of total volume V is divided into two equal parts by a conducting separator. The separator is fixed in this position. The part on the left contains one mole of an ideal gas ($U = 1·5 \, nRT$) and the part on the right contains two moles of the same gas. Initially, the pressure on each side is p. The system is left for sufficient time so that a steady state is reached. Find (a) the work done by the gas in the left part during the process, (b) the temperature on the two sides in the beginning, (c) the final common temperature reached by the gases, (d) the heat given to the gas in the right part and (e) the increase in the internal energy of the gas in the left part.

ANSWERS

OBJECTIVE I

1. (d)   2. (b)   3. (a)   4. (b)   5. (a)   6. (c)
7. (c)   8. (c)   9. (b)

OBJECTIVE II

1. (b), (c)   2. (a), (b)   3. (d)   4. (a), (c)
5. (a), (d)

EXERCISES

1. (a) zero   (b) 1764 J   (c) 1764 J
2. (a) zero   (b) 84 J   (c) 0·02°C
3. (a) 200 J   (b) 200 J   (c) 400 J
4. 100 J
5. (a) – 4·5 J   (b) 4·5 J
6. zero
7. 0·30 J in AB, 0·450 J in ACB and 0·150 J in ADB
8. 60 J
9. 55 cal
10. 31·4 J

11. 4·17 J/cal
12. 4·19 J/cal
13. – 241 J
14. 25 J
15. 6 J
16. (a) extracted   (b) 25000 J
17. – 4520 J
18. 2300 J
19. (33600 – 0·02) J
20. $2·5 \times 10^4$ J
21. (a) zero

(b) $\dfrac{p_1 T_2 (p_1 + p_2)}{\lambda}$ on the left and $\dfrac{p_2 T_1 (p_i + p_2)}{\lambda}$ on the right

(c) $\dfrac{T_1 T_2 (p_1 + p_2)}{\lambda}$

(d) $\dfrac{3 p_1 p_2 (T_2 - T_1) V}{4 \lambda}$ where $\lambda = p_1 T_2 + p_2 T_1$

22. (a) zero   (b) $\dfrac{pV}{(2 \text{ mol}) R}$, $\dfrac{pV}{(4 \text{ mol}) R}$

(c) $\dfrac{pV}{(3 \text{ mol}) R}$ (d) $\dfrac{pV}{4}$ (e) $\dfrac{-pV}{4}$

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
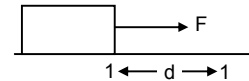
OBJECTIVE – I

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. $\Delta U_1 = \Delta U_2$
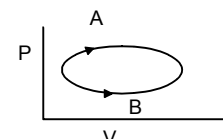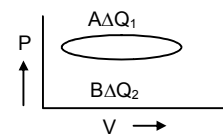
5. (a) In the process the volume of the system increases continuously. Thus, the work done increases continuously.
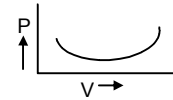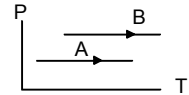
6. (c) for A → In a so thermal system temp remains same although heat is added.
    for B → For the work done by the system volume increase as is consumes heat.

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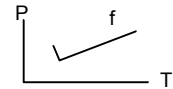
8. (c) Given : $\Delta V_A = \Delta V_B$. But $P_A < P_B$
    Now, $W_A = P_A \Delta V_B$; $W_B = P_B \Delta V_B$; So, $W_A < W_B$.

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. $\Delta U = 0$, So, this is found in case of a cyclic process.

3. (d) ΔU = Heat supplied, ΔW = Work done.
    $(\Delta Q - \Delta W) = du$, 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 $\Delta U_1 + \Delta U_2 = 0$
    $\Delta Q - \Delta W = 0$
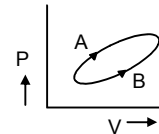
5. (a) (d) Internal energy decreases by the same amount as work done.
    du = dw, ∴ dQ = 0. Thus the process is adiabatic. In adiabatic process, dU = – dw. Since 'U' decreases
    $U_2 - U_2$ is –ve. ∴ dw should be +ve $\Rightarrow \frac{nR}{\upsilon - 1}(T_1 - T_2)$ is +ve. $T_1 > T_2$ ∴ Temperature 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 $= mgh = 12 \times 10 \times 0.70 = 84$ J
    (c) Rise in temp at Δt We know, $84 = ms\Delta t$
    $\Rightarrow 84 = 1 \times 4200 \times \Delta t$ (for 'm' = 1kg) $\Rightarrow \Delta t = \dfrac{84}{4200} = 0.02$ k
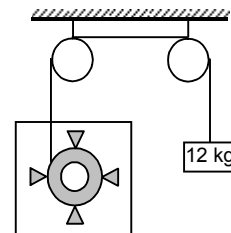
3. mass of block = 100 kg
   u = 2 m/s, m = 0.2 v = 0
   dQ = du + dw
   In this case dQ = 0

   $\Rightarrow -du = dw \Rightarrow du = -\left(\frac{1}{2}mv^2 - \frac{1}{2}mu^2\right) = \frac{1}{2}\times 100 \times 2 \times 2 = 200$ 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 $P_1 \to$ Initial Pressure ; $P_2 \to$ Final Pressure.
   $T_2, T_1 \to$ 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, $W_{AB} = \frac{1}{2} \times (10+30)\times 10^3\ 15\times 10^{-6} = 0.30$ J
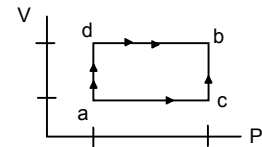   In path ADB, W = $W_{AD} + W_{DB} = 10\times 10^3 (25-10)\times 10^{-6} + 0 = 0.15$ J
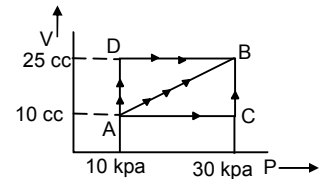
8. $\Delta Q = \Delta U + \Delta W$
   In abc, $\Delta Q = 80$ J $\Delta W = 30$ J
   So, $\Delta U = (80-30)$ J = 50 J
   Now in adc, $\Delta W = 10$ J
   So, $\Delta Q = 10 + 50 = 60$ J $[\because \Delta U = 50$ J$]$

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
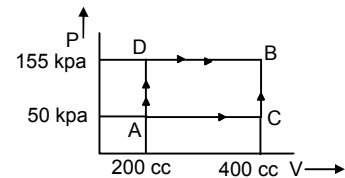 $\Rightarrow$ dU = dQ – dW = 210 – 10 = 200 J
   In path ADB, dQ = ?
   dU = 200 J (Internal energy change between 2 points is always same)
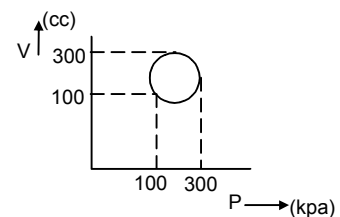   dW = $W_{AD} + W_{DB} = 0 + 155 \times 10^3 \times 200 \times 10^{-6} = 31$ J
   dQ = dU + dW = 200 + 31 = 231 J = 55 cal

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

26.3

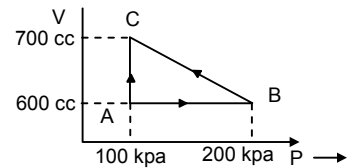11. dQ = 2.4 cal = 2.4 J Joules

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

    = 0 + (1/2) × (100 + 200) × 10^3 200 × 10^{-6} − 100 × 10^3 × 200 × 10^{-6}

    = (1/2) × 300 × 10^3 200 × 10^{-6} − 20 = 30 − 20 = 10 joules.

    du = 0 (in a cyclic process)

    dQ = dU +dW ⇒ 2.4 J = 10

    ⇒ J = $\dfrac{10}{2.4}$ ≈ 4.17 J/Cal.

12. Now, ΔQ = (2625 × J) J

    ΔU = 5000 J

    From Graph ΔW = 200 × 10^3 × 0.03 = 6000 J.

    Now, ΔQ = ΔW + ΔU

    ⇒ 2625 J = 6000 + 5000 J

    J = $\dfrac{11000}{2625}$ = 4.19 J/Cal
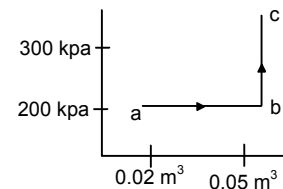
13. dQ = 70 cal = (70 × 4.2) J

    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

    ⇒ − 294 = du + 52.5

    ⇒ du = − 294 − 52.5 = − 346.5 J
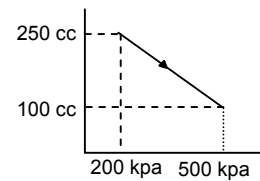
14. U = 1.5 pV   P = 1 × 10^5 Pa

    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 ⇒ 10 = du + 4 ⇒ 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.

    = $\dfrac{1}{2} × \dfrac{5}{10} × 10^5$ = 25000 J
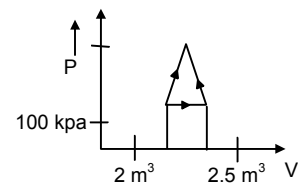
17. n = 2 mole

    dQ = − 1200 J

    dU = 0 (During cyclic Process)

    dQ = dU + dwc

    ⇒ − 1200 = $W_{AB} + W_{BC} + W_{CA}$

    ⇒ − 1200 = nRΔT + W_{BC} + 0

    ⇒ − 1200 = 2 × 8.3 × 200 + W_{BC}

    ⇒ W_{BC} = − 400 × 8.3 − 1200 = − 4520 J.
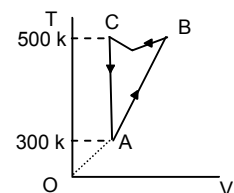
18. Given n = 2 moles

    dV = 0

    in ad and bc.

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

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

    = 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 $\Rightarrow$ msΔQ_ϕ = dU + P(v_0 – v_4)

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

    $\Rightarrow$ 33600 = dU + $10^5 \left(\dfrac{m}{V_0} - \dfrac{m}{v_4} \right)$ = 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 = 10^5Pa

    dQ = $Q_{H_2 O}$ 0° – 100° + $Q_{H_2 O}$ – steam

    = 0.01 × 4200 × 100 + 0.01 × 2.5 × 10^6 = 4200 + 25000 = 29200

    dW = P × ΔV

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

    dW = PΔV = 0.01699 × 10^5 1699J

    dQ = dW + dU or dU = dQ – dW = 29200 – 1699 = 27501 = 2.75 × 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

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

    $\dfrac{P_1 V}{2RT_1} = \dfrac{P_1 V}{2RT}$

    $\Rightarrow P_1 = \dfrac{P_1 T}{T_1} = \dfrac{P_1 (P_1 + P_2) T_1 T_2}{\lambda}$

    As, T = $\dfrac{(P_1 + P_2) T_1 T_2}{\lambda}$

    Simillarly $P_2 = \dfrac{P_2 T_1 (P_1 + P_2)}{\lambda}$

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

    Initially $\dfrac{P_1 V}{2}$ = n_1 rt$_1$ $\Rightarrow n_1 = \dfrac{P_1 V}{2RT_1}$

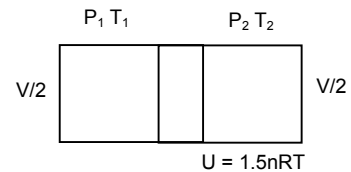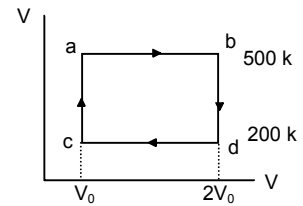 $n_2 = \dfrac{P_2 V}{2RT_2}$ Hence dQ = 0, dW = 0, Hence dU = 0.

    In case (LHS)   RHS

    Δu_1 = 1.5n_1 R(T - T_1) But Δu_1 -Δu_2 = 0 Δu_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

$$\Rightarrow T = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$$

$$= \frac{\dfrac{P_1 V}{2RT_1} \times T_1 + \dfrac{P_2 V}{2RT_2} \times T_2}{\dfrac{P_1 V}{2RT_1} + \dfrac{P_2 V}{2RT_2}} = \frac{P_1 + P_2}{\dfrac{P_1 T_2 + P_2 T_1}{T_1 T_2}}$$

$$= \frac{(P_1 + P_2)T_1 T_2}{P_1 T_2 + P_2 T_1} = \frac{(P_1 + P_2)T_1 T_2}{\lambda} \quad \text{as } P_1 T_2 + P_2 T_1 = \lambda$$

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

$$= \frac{1.5 P_2 V}{2RT_2} R \left[\frac{T_2 - (P_1 - P_2)T_1 T_2}{P_1 T_2 - P_2 T_1} \right] = \frac{1.5 P_2 V}{2T_2} \left(\frac{P_1 t_2{}^2 - P_1 T_1 T_2}{\lambda} \right)$$

$$= \frac{1.5 P_2 V}{2T_2} \times \frac{T_2 P_1 (T_2 - T_1)}{\lambda} = \frac{3 P_1 P_2 (T_2 - T_1)V}{4\lambda}$$

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   For right side
Pressure = P   Let initial Temperature = T_2
Volume = V
No. of moles = n(1mole)
Let initial Temperature = T_1

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

$$\Rightarrow \frac{PV}{2} = (1)RT_1 \qquad\qquad \Rightarrow T_2 = \frac{PV}{2n_2 R} \times 1$$

$$\Rightarrow T_1 = \frac{PV}{2(\text{moles})R} \qquad\qquad \Rightarrow T_2 = \frac{PV}{4(\text{moles})R}$$
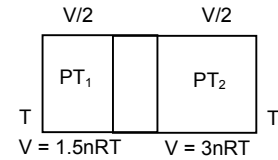
(c) Let the final Temperature = T
Final Pressure = R
No. of mole = 1 mole + 2 moles = 3 moles

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

(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

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

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