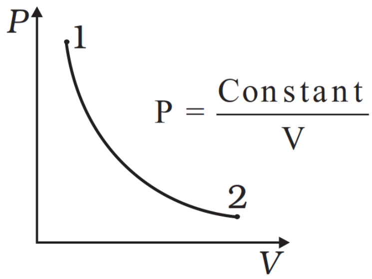
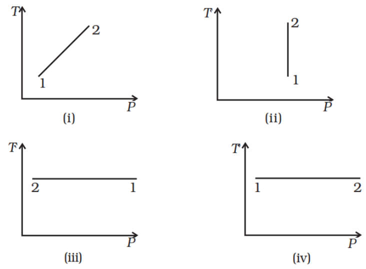
KD EDUCATION ACADEMY [9582701166]

Time : 5 Hour | STD 11 Science Physics | Total Marks : 200

kd 90+ ch-11 thermodynamics

* **Choose The Right Answer From The Given Options.[1 Marks Each]** [16]

1. Consider P-V diagram for an ideal gas shown in: 

Out of the 

following diagrams which represents the T-P diagram?

(A) (iv) (B) (ii) (C) (iii) (D) (i)

Ans. :

c. (iii)

Explanation:

According to P-V diagram at constant tempreature, P increase as V decrease. So, it is Boyei's law in option (iii) and (iv). If P increase at constant tempreature, volume V decrease. as in (iii) T-P diagram, P is smaller at 2 and larger at 1, which tallies with option c.

2. An engine has an efficiency of $\frac{1}{6}$ when the temperature of sink is reduced by 62°C, its efficiency is doubled, temperature of the source is:

(A) 37°C. (B) 62°C. (C) 99°C. (D) 124°C.

Ans. :

c. 99°C.

3. If 150J of heat is added to a system and the work done by the system is 110J, then change in internal energy will be:

(A) 40J. (B) 110J. (C) 150J. (D) 260J.

Ans. :

a. 40J.

4. For a gas, $\gamma = 1.4$. Then Atomicity, C_P and C_V of the gas are:

(A) Monoatomic, $\frac{5}{2}R, \frac{3}{2}R$ (B) Monoatomic, $\frac{7}{2}R, \frac{5}{2}R$

(C) Diatomic, $\frac{7}{2}R, \frac{5}{2}R$ (D) Triatomic, $\frac{7}{2}R, \frac{5}{2}R$

Ans. :

c. Diatomic, $\frac{7}{2}R$, $\frac{5}{2}R$

Explanation:

From $\gamma = \left(1 + \frac{2}{n}\right) = 1.4$

We get n = 5, which is the number of degrees of freedom of a diatomic gas.

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

$C_P = \left(\frac{n}{2} + 1\right)R = \frac{7}{2}R$

5. Specific heat capacity depends on:

(A) Nature of the substance.
(B) On its mass.
(C) On its temperature.
(D) Both (a) and (c).

Ans. :

d. Both (a) and (c).

6. An ideal gas having molar specific heat capacity at constant volume is $\frac{3}{2}R$ the molar specific heat capacities at constant pressure is:

(A) $\frac{1}{2}R$
(B) $\frac{5}{2}R$
(C) $\frac{7}{2}R$
(D) $\frac{9}{2}R$

Ans. :

a. $\frac{5}{2}R$

7. If m is the mass, θ is temperature and 'a' is specific heat, then thermal capacity K is given by:

(A) $K = ms\theta$
(B) $K = m\theta$
(C) $K = \frac{ms}{\theta}$
(D) $K = ms$

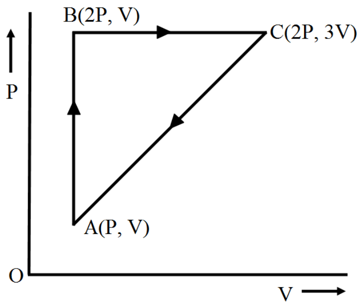
Ans. :

d. $K = ms$

Explanation:

Thermal capacity = Mass × Specific heat = m × s

8. An ideal gas is taken through a cycle ABCA as shown in Fig. The work done during the



cycle is:

(A) $\frac{1}{2}PV$
(B) 2PV
(C) 4PV
(D) PV

Ans. :

d. PV

Explanation:

Work done = Area of ΔABC

$= \frac{1}{2}BC \times AB = \frac{1}{2}(3V - V)(2P - P)$

$W = PV$

9. The SI unit of mechanical equivalent of heat (J) is:

(A) Joule/ calorie. (B) Calorie.

(C) Calorie × erg. (D) Erg/ calorie.

Ans. :

a. Joule/ calorie

Explanation:

SI unit of J is joule/ calorie.

10. An ideal heat engine exhausting heat at 27°C is to have 25% efficiency. It must take heat at:

(A) 127°C. (B) 227°C.

(C) 327°C. (D) 673°C.

Ans. :

a. 127°C.

11. A system is provided with 200 cal of heat and the work done by the system on the surroundings is 40J. Then, its internal energy:

(A) Increases by 600J.

(B) Decreases by 800J.

(C) Increases by 800J.

(D) Decreases by 50J.

Ans. :

c. Increases by 800J.

Explanation:

Given, dQ = +200cal = 200 × 4.2 = 840J, dW = +40J

From first law of thermodynamics,

dQ = dW + dW

dU = dQ - dW = 840 - 40 = 800J.

12. 110J of heat are added to a gaseous system and its internal energy increases by 40J, then the amount of work done is:

(A) 150J (B) 70J (C) 110J (D) 40J

Ans. :

b. 70J

Explanation:

Form dU + DW = dQ

dW = dQ - du

= 110 - 40 = 70J

13. In an adiabatic change, the pressure P and temperature T of a diatomic gas are related by the relation $\mathrm{P} \propto \mathrm{T}^{c}$ where c equals:

(A) $\frac{5}{3}$ (B) $\frac{2}{5}$ (C) $\frac{3}{5}$ (D) $\frac{7}{2}$

Ans. :

d. $\frac{7}{2}$

Explanation:

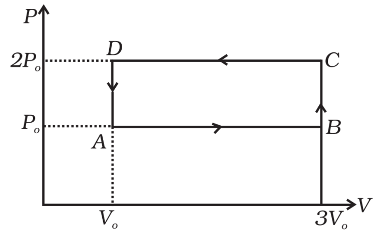
Equation of adiabatic change is,

$\therefore \mathrm{P} \propto \mathrm{T}^{\frac{-\gamma}{(1-\gamma)}}$

For diatomic gas, $\gamma = \frac{7}{5}$

$\mathrm{P} \propto \mathrm{T}^{\frac{7}{2}}$

14. An ideal gas undergoes cyclic process ABCDA as shown in given PV diagram. The amount of work done by the gas is:



(A) $6\mathrm{P}_0\mathrm{V}_0$ (B) $-2\mathrm{P}_0\mathrm{V}_0$ (C) $+2\mathrm{P}_0\mathrm{V}_0$ (D) $+4\mathrm{P}_0\mathrm{V}_0$

Ans. :

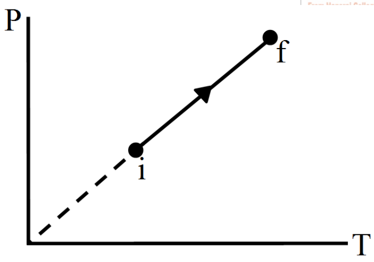
d. $+4\mathrm{P}_0\mathrm{V}_0$

Explanation:

The direction of arrows is anticlockwise so work done is negative equal to the area of loop $= -(3\mathrm{V}_0 - \mathrm{V}_0)(2\mathrm{P}_0 - \mathrm{P}_0) = -2\mathrm{P}_0\mathrm{V}_0$ verifies the option (b). New work implies external work is done on the system.

15. An ideal gas goes from the state i to the state f as shown in figure. 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.



Ans. :

c. Is zero.

Explanation:

Work done by the gas during the process,

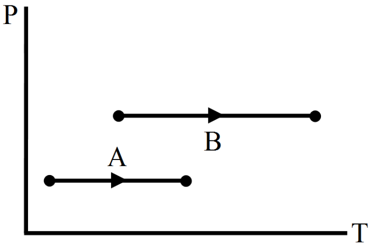
$\Delta \mathrm{W} = \mathrm{P}\Delta \mathrm{V}$

Here,

P = Pressure

$\Delta \mathrm{V}$ = change in volume.

Since the process described in the figure is isochoric, P = kT. As volume remains constant $(\Delta \mathrm{V} = 0)$, $\Delta \mathrm{W} = 0$.

16. Consider two processes on a system as shown in figure. 

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.

Ans. :

c. $\Delta W_1 < \Delta W_2$.

Explanation:

Work done by the system, $\Delta W = P\Delta V$

Here,

P = Pressure in the process

ΔV = Change in volume during the process

Let V_i and V_f be the volumes in the initial states and final states for processes A and B, respectively. Then,

$\Delta W_1 = P_1 \Delta V_1$

$\Delta W_2 = P_2 \Delta V_2$

But $\Delta V_2 = \Delta V_1, \left[\left(V_{f_1} - V_{i_1}\right) = \left(V_{f_2} - V_{i_2}\right)\right]$

$\Rightarrow \frac{\Delta W_1}{\Delta W_2} = \frac{P_1}{P_2}$

$\Rightarrow \Delta W_1 < \Delta W_2 \; [\because P_2 > P_1]$

***** **Given Section consists of questions of 2 marks each.** **[28]**

17. Air pressure in a car tyre increases during driving. Explain.

Ans. : Volume of a car tyre is fixed. During driving, temperature of the gas increases while its volume remains constant. So, according to Charle's law, at constant volume (V),

Pressure (P) $\propto$ Temperature (T)

Therefore, pressure of gas increases

18. Calculate the fall in temperature of helium initially at 15°C, when it is suddenly expanded to 8 times of its volume. Given $\gamma = \frac{5}{3}$.

Ans. : $T_1 = 273 + 15 = 278k, T_2 = ?$

$V_2 = 8V_1, \gamma = \frac{5}{3}$

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

$T_2 = T_1 \left(\frac{V-1}{V_2}\right)^{\gamma-1}; T_2 = 288\left(\frac{V_1}{8V_1}\right)^{\frac{5}{3}-1}$

$$\log T_2 = \log 288 + \frac{2}{3}\log\left(\frac{1}{3}\right) = 1.8573$$

$$T_2 = \text{antilog } 1.8573 = 71.99K$$

Fall in temperature of helium,

$$T_1 - T_2 = 288 - 71.99 = 216.01K$$

19. A steam engine intakes steam at 200°C and after doing work exhausts it directly in air at 100°C. Calculate the percentage of heat used for doing work. Assume the engine to be an ideal engine.

Ans. : Here, T_1 = 200°C = 473K and T_2 = 100°C = 373K

$\therefore$ Efficiency of engine $\eta = \frac{W}{Q_1} = \left(\frac{T_1 - T_2}{T_1}\right)$

$= \frac{473-373}{473}$

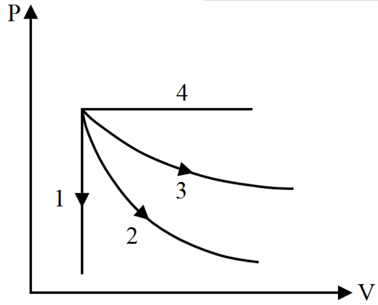
$= \frac{100}{473} = 0.21$

$\therefore W = 0.21$

$Q_1 = 21\%$ of Q_1

Thus, engine will convert 21% of heat used for doing work.

20. Identify and name the thermodynamic processes marked as 1, 2, 3 and 4 as shown in figure.



Ans. :

i. Isochoric process as it occurs at constant volume.

ii. Adiabatic process because its slope is steeper than the process indicated by 3, which is isothermal process.

iii. Isothermal process.

iv. Isobaric process as it occurs at constant pressure.

21. A carnot engine absorbs 100 calories per cycle from its source at 1600K. Its efficiency is 60%. Find the temperature of the sink and work done per cycle. Given J = 4.2J/ cal.

Ans. : $Q_1 = 100\text{cal}, T_1 = 1600K,\ \eta = 60\% = \frac{3}{5}$

For glass, $\eta = 1 - \frac{T_2}{T_1}$,

$\frac{3}{5} = 1 - \frac{T_2}{1600}$

$T_2 = 640K$

As, $\eta = \frac{W}{Q_1}, W = \eta Q_1$

$= \frac{3}{5} \times 100 = 60\text{cal.}$

$W = 60 \times 4.2J$

$= 252J$

22. Two samples of gas initially at the same temperature and pressure are compressed from volume V to $\frac{V}{2}$. One sample is compressed isothermally and the other adiabatically. In which case will the pressure be higher? Explain.

Ans. : Let P_a and P_i be the final pressure during adiabatic and isothermal compression respectively. In case isothermal compression.

$PV = P_i\left(\frac{V}{2}\right)$ or $P_i = 2P \ldots (i)$

In case of adiabatic compression,

$PV^{\gamma} = P_i\left(\frac{V}{2}\right)^{\gamma}$ or $P_a = 2^{\gamma}P \ldots (ii)$

$\therefore \frac{P_a}{P_i} = \frac{2^{\gamma}}{2} > 1$, because $\gamma > 1$

$\therefore P_a > P_i$

Hence, final pressure during adiabatic compression is greater than the pressure during isothermal compression.

23. Temperature in the freezer of a refrigerator is being maintained at -13°C and room temperature on a particular day was 42°C. Calculate the coefficient of performance of the refrigerator.

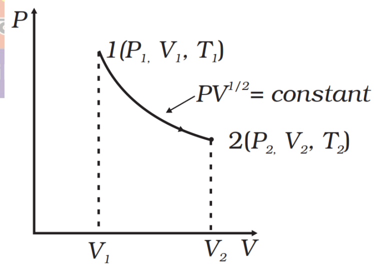
Ans. : Here, temperature of colder body T_2 = -13°C = 260K and temperature of hotter surroundings T_1 = 42°C = 315K.

$\therefore$ Coefficient of performance of refrigrator $\beta = \frac{T_2}{T_1 - T_2}$

$= \frac{260}{315-260}$

$= \frac{260}{55} = 4.73$

24. Consider a P-V diagram in which the path followed by one mole of perfect gas in a cylindrical container is shown in Fig.



Find the work done when the gas is taken from state 1 to state 2.

Ans. : $\therefore PV^{\frac{1}{2}}$ = constant = K (given) or

Work done for process from 1 to 2

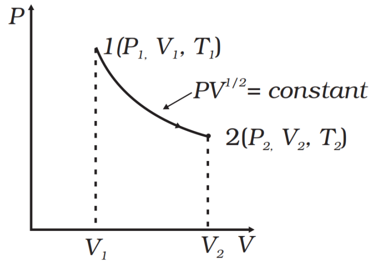
$$WD = \int_{V_1}^{V_2} P.dV = \int_{V_1}^{V_2} \frac{K}{V^{\frac{1}{2}}} dV = K\int_{V_1}^{V_2} V^{-\left(\frac{1}{2}\right)} dV$$

$$WD = K\left[\frac{V^{\frac{1}{2}}}{\frac{1}{2}}\right]_{V_1}^{V_2} = 2K\left[\sqrt{V_2} - \sqrt{V_1}\right]$$

WD form $V_1 to V_2, i.e, dW = 2P_1 V_1^{\frac{1}{2}}\left[\sqrt{V_2} - \sqrt{V_1}\right]$

$= 2P_2 V_2^{\frac{1}{2}}\left[\sqrt{V_2} - \sqrt{V_1}\right]$

25. Consider a P-V diagram in which the path followed by one mole of perfect gas in a cylindrical container is shown in Fig.



Find the work done when the gas is taken from state 1 to state 2.

Ans. : $\therefore PV^{\frac{1}{2}}$ = constant = K (given) or

Work done for process from 1 to 2

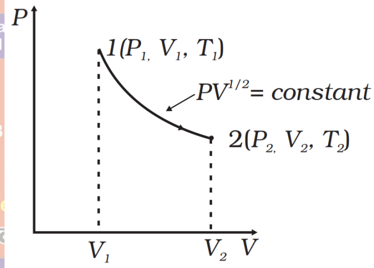
$$WD=\int_{v_1}^{v_2} P.dV=\int_{v_1}^{v_2}\frac{K}{V^{\frac{1}{2}}}dV=K\int_{v_1}^{v_2}V^{-\left(\frac{1}{2}\right)}dV$$

$$WD=K\left[\frac{V^{\frac{1}{2}}}{\frac{1}{2}}\right]_{v_1}^{v_2}=2K\left[\sqrt{V_2}-\sqrt{V_1}\right]$$

WD form $V_1 to V_2, i.e, dW=2P_1V_1^{\frac{1}{2}}\left[\sqrt{V_2}-\sqrt{V_1}\right]$

$$=2P_2V_2^{\frac{1}{2}}\left[\sqrt{V_2}-\sqrt{V_1}\right]$$

26. Consider a P-V diagram in which the path followed by one mole of perfect gas in a cylindrical container is shown in Fig.



What is the ratio of temperature $\frac{T_1}{T_2}, if V_2=2V_1$?

Ans. : $\therefore\ PV^{\frac{1}{2}}$ = constant = K (given) or $P_1V_1^{\frac{1}{2}}=P_2V_2^{\frac{1}{2}}=K and\ P=\frac{K}{V^{\frac{1}{2}}}$

from gas equation of ideal gas PV nRT

$$\Rightarrow T=\frac{PV}{nR}=\frac{P\sqrt{V}\sqrt{V}}{nR}=\frac{K\sqrt{V}}{nR}$$

$$T_1\frac{K\sqrt{V_1}}{nR} and T_2=\frac{K\sqrt{V_2}}{nR}$$

$$\frac{T_1}{T_2}=\frac{\frac{K\sqrt{V_1}}{nR}}{\frac{K\sqrt{V_2}}{nR}}=\frac{\sqrt{V_1}}{\sqrt{V_2}}=\sqrt{\frac{V_1}{2V_1}}\ (\because\ V_2=2V_1 given)$$

$$\therefore\ \frac{T_1}{T_2}=\frac{1}{\sqrt{2}}\ ....(ii)$$

required ratio is $1:\sqrt{2}$

27. 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?

Ans. : Initial State ‘I’ Final State ‘f’

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

where P_1 → Initial Pressure; P_2 → Final Pressure.

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

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

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

Ans. : dQ = 10J

$dV = A \times 10cm^3 = 4 \times 10cm^3 = 40 \times 10^{-6}cm^3$

$dw = Pdv = 100 \times 10^3 \times 40 \times 10^{-6} = 4cm^3$

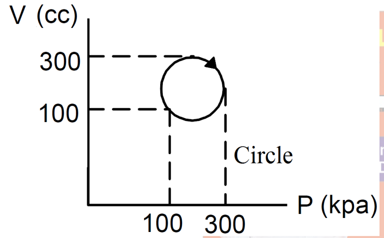
du = ?

10 = du + dw

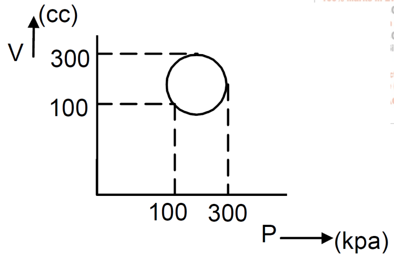
⇒ 10 = du + 4

⇒ du = 6J.

29. Calculate the heat absorbed by a system in going through the cyclic process shown in figure.



Ans. :



Heat absorbed = work done = Area under the graph

In the given case heat absorbed = area of the circle

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

30. The pressure of a gas changes linearly with volume from 10kPa, 200cc to 50kPa, 50cc.
   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?

Ans. : $P_1 = 10kpa = 10 \times 10^3 pa$

$P_2 = 50 \times 10^3 pa$

$V_1 = 200cc$

$V_2 = 50cc$

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

b. $dQ = 0 \Rightarrow 0 = du + dw$

$\Rightarrow du = -dw = 4.5J$

*** Given Section consists of questions of 3 marks each.** **[63]**

31. During India-Pakistan war, a soldier discovered that his lead bullet just melted when stopped by an obstacle. Calculate the velocity of the bullet if its temp. was 47.6°C. Given: melting point of lead = 327°C. Specific heat of lead = 0.03 cal $g^{-1}°C^{-1}$, latent heat of fusion of lead = 6 cal g^{-1} and J = 4.2 × 10^7 erg car^{-1}. Assume that no heat is lost.

Ans. : Increase in temperature,

$\theta = (327 - 47.6)°C = 279.4°C$

Let m be the mass of the bullet.

Heat required,

$Q = mS\theta + mL$

or $Q = m(S\theta + L)$

$= m(0.03 \times 279.4 + 6)$

$= 14.38m$ cal

Work done, $W = \frac{1}{2}mv^2$

Where v is the velocity of bullet,

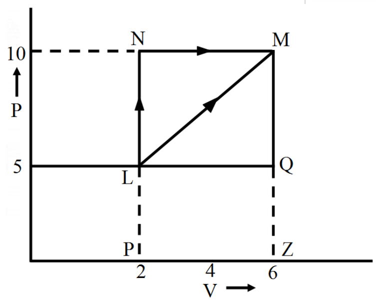
Now, $W = JQ$

$\therefore \frac{1}{2}mv^2 = 4.2 \times 10^7 \times 14.38m$

$v^2 = 2 \times 4.2 \times 10^7 \times 14.38$

$v = 3.48 \times 10^4 cm\ s^{-1}$

32. An ideal gas changes its state from L to M by two path LNM and LM.



i. Is the work done same for two paths?

ii. The internal energy of gas at L is 20J and the amount of heat needed to change its state through LM is 400J. What is the internal energy of gas at M?

Ans. :

i. $W_{LN} = PdV = 0$

$W_{NM} = P[V_M - V_M] = 10[6 - 2] = 40J$

$W_{LMN} = W_{NM} = 0 + 40 = 40J$

Along LM W_{LM} = Area under the curve LM

= Area of $\Delta LMQ +$ Area of rectangle LQZP.

$= \frac{1}{2} \times LQ \times MQ + LP \times PZ$

$= \frac{1}{2} \times 4 \times 5 + 5 \times 4$

$= 10 + 20 = 30\text{J}$

So work done is less along LM.

ii. $\quad U_L = 20\text{J}$

$\Delta Q = 400\text{J}$

$dQ = dU + dW$

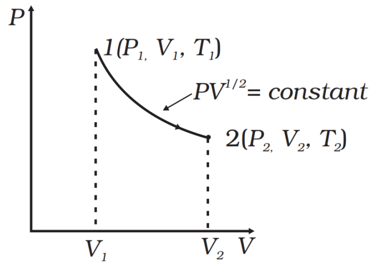
$= (U_M - U_L) + \Delta W_{LM}$

$U_M = dQ + U_L - \Delta W_{LM}$

$= 400 + 20 - 30$

$= 390\text{J}$

33. Consider a P-V diagram in which the path followed by one mole of perfect gas in a



cylindrical container is shown in Fig. Given the internal energy for one mole of gas at temperature T is (3/2) RT, find the heat supplied to the gas when it is taken from state (1) to (2) with $V_2 = 2V_1$.

Ans. : $\therefore\ PV$ = constant = K (given) or $P_1 V_1^{\frac{1}{2}} = P_2 V_2^{\frac{1}{2}} = K$ and $P = \frac{K}{V^{\frac{1}{2}}}$

Given that internal energy U of gas is

$U = \left(\frac{3}{2}\right)RT$

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

$\therefore\ T_2 = \sqrt{2}T_1$, from part (b)

$\Delta U = \frac{3}{2}R\left[\sqrt{2}T_1 - T_1\right] = \frac{3}{2}RT_1\left(\sqrt{2} - 1\right)$

Form part (a) $dW = 2P_1V^{\frac{1}{2}}\left(\sqrt{V_2} - \sqrt{V_1}\right)$

$\because\ V_2 = 2V_1$ (given)

so, $\sqrt{V_2} = \sqrt{2}\sqrt{V_1}$ then

$dW = 2P_1V_1^{\frac{1}{2}}\left(\sqrt{2}\sqrt{V_1} - \sqrt{V_1}\right)$

$= 2P_1V_1\sqrt{V_1}\left[\sqrt{2} - 1\right]$

$dW = 2P_1V_1\left(\sqrt{2} - 1\right)$

$dW = 2nRT_1\left(\sqrt{2} - 1\right)\ \left(\therefore\ P_1V_1 = nRT_1\right)$

$\therefore\ n = 1 \therefore\ dW = 2RT_1\left(\sqrt{2} - 1\right)$

$\therefore\ dQ = dW + dU = 2RT_1\left(\sqrt{2} - 1\right) + \frac{3}{2}RT_1\left(\sqrt{2} - 1\right)$

$= \left(\sqrt{2} - 1\right)RT_1\left[2 + \frac{3}{2}\right]$

$dQ = -\left(\sqrt{2} - 1\right)RT.$

34. 200J of work is done on a gas to reduce its volume by compressing it. If this change is done under adiabatic conditions, find out the change in internal energy of the gas and also the amount of heat absorbed by the gas.

Ans. : In adiabatic changes, dQ = 0

$\therefore \mathrm{dQ} = \mathrm{dU} + \mathrm{dW} = 0$

$\mathrm{dU} = -\mathrm{dW} = -(-200\mathrm{J}) = 200\mathrm{J}$

Internal energy increases by 200J. Heat absorbed is zero.

35. Prove that the slope of P-V graph for an adiabatic process is γ times that of the isothermal process.

Ans. : For isothermal process, PV = constant

Differentiating, VdP + PDV = 0

$\therefore \frac{\mathrm{dP}}{\mathrm{dV}} = -\frac{\mathrm{P}}{\mathrm{V}}$

For adiabatic process, $\mathrm{PV}^{\gamma} =$ constant.

Differentiating,

$\mathrm{V}^{\gamma}\mathrm{dP} + \gamma \mathrm{PV}^{\gamma-1}\mathrm{dV} = 0$

$\therefore \frac{\mathrm{dP}}{\mathrm{dV}} = -\frac{\gamma \mathrm{P}}{\mathrm{V}}$

Comparing the two ratios, we can say, slope of adiabatic process is γ times the slope of isothermal process.

36. Two Carnot engines A and B are operated in series. The first one A receives heat at 800K and rejects to a reservoir at temperature T K The second engine B receives the heat rejected by the first engine and in turn rejects to a heat reservoir at 300K. Calculate the temperature T K for the following cases.

i. When the outputs of the two engines are equal.

ii. When the efficiencies of the two engines are equal.

Ans. : For engine A, $T_1 = 800\mathrm{K}$, $T_2 = \mathrm{T\,K}$

Effieciency, $\eta_{\mathrm{A}} = 1 - \frac{\mathrm{T}_2}{\mathrm{T}_1} = 1 - \frac{\mathrm{T}}{800}$

Also, $\frac{\mathrm{Q}_2}{\mathrm{Q}_1} = \frac{\mathrm{T}_2}{\mathrm{T}_1} = \frac{\mathrm{T}}{800}$

Work output, $\mathrm{W}_{\mathrm{A}} = \mathrm{Q}_1 - \mathrm{Q}_2 = \eta_{\mathrm{A}} \times \mathrm{Q}_1 \left[\because \eta_{\mathrm{A}} = 1 - \frac{\mathrm{Q}_2}{\mathrm{Q}_1}\right]$

Or $\mathrm{W}_{\mathrm{a}} = \left(1 - \frac{\mathrm{T}}{800}\right)\mathrm{Q}_1$

For engine B, $\mathrm{T}_1' = \mathrm{T\,K},\ \mathrm{T}_2' = 300\mathrm{K}$

Efficiency, $\eta_{\mathrm{B}} = 1 - \frac{\mathrm{T}_2'}{\mathrm{T}_1'} = 1 - \frac{300}{\mathrm{T}}$

Work output, $\mathrm{W}_{\mathrm{B}} = \mathrm{Q}_1' - \mathrm{Q}_2' = \eta_{\mathrm{B}} \times \mathrm{Q}_1' = \left(1 - \frac{300}{\mathrm{T}}\right)\mathrm{Q}_1'$

Since, the engine B absorbs the heat rejected by the engine A, so

$\mathrm{Q}_1' = \mathrm{Q}_2 \therefore \mathrm{W}_{\mathrm{B}} = \left(1 - \frac{300}{\mathrm{T}}\right)\mathrm{Q}_2$

i. When output of the two engins are equal,

$\mathrm{W}_{\mathrm{A}} = \mathrm{W}_{\mathrm{B}}$

$$\left(1-\frac{T}{800}\right)Q_1=\left(1-\frac{300}{T}\right)Q_2$$

$$\left(1-\frac{T}{800}\right)=\left(1-\frac{300}{T}\right)\frac{Q_2}{Q_1}=\left(1-\frac{300}{T}\right)\frac{T}{800}$$

On solving, we get T = 550K

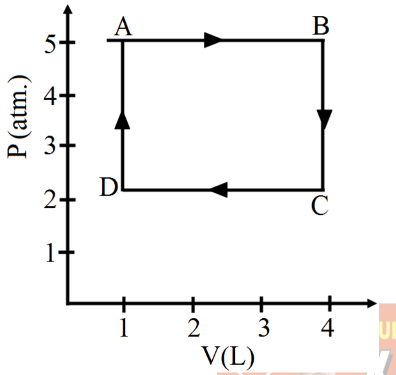
ii. When the efficiencies are equal, $\eta_A=\eta_B$

$$1-\frac{T}{800}=1-\frac{300}{T}$$

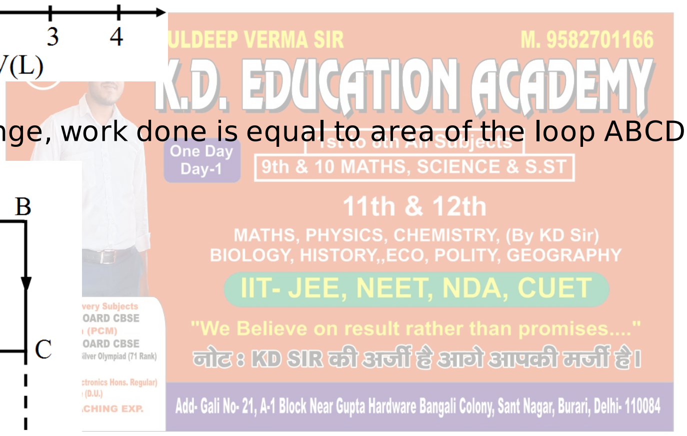
$$T^2=24\times10^4$$

$$\therefore T=489.9K$$

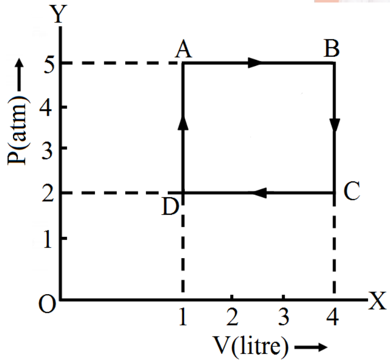
37. One mole of an ideal gas undergoes a cyclic change ABCD. From the given diagram, calculate the net work done in the process. 1 atmosphere = 10° dyne



cm^{-2}.



Ans. : In a cyclic change, work done is equal to area of the loop ABCD.



As the loop is traced in clockwise direction, work done is positive.

W = area ABCD = DC × DA

Now, DC = 4 - 1 = 3 litre = 3×10^3 cm^3

DA = 5 - 2 = 3 atm = 3×10^6 dyne cm^{-2}

$\therefore$ W = DC × DA

= $3\times10^3\times3\times10^6=9\times10^9$ erg.

38. Calculate the fall in temperature when a gas initially at 72°C is expanded suddenly to eight times its original volume. Given y $=\frac{5}{3}.(\therefore V_2=8x\text{ c.c.})$

Ans. : Let, V_1 = x c.c.;

T_1 = 273 + 72 = 345K;

$\gamma=\frac{5}{3}$;

T_2 = ?

Using the relation $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$$\therefore T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$= 345 \times \left(\frac{x}{8x}\right)^{\frac{2}{3}}$$

$$= 345 \times \left(\frac{1}{8}\right)^{\frac{2}{3}}$$

Taking $\log$ both sides, we get

$$\log T_2 = \log\ 345 - \frac{2}{3}\log 8$$

$$= 2.5378 - \frac{2}{3}(0.9031)$$

$$= 2.5378 - 0.6020$$

$$= 1.9358$$

$$T_2 = 86.26\ K$$

$\therefore$ Fall in temperature = 345 - 86.26 = 258.74K.

39. State first law of thermodynamics. What are its limitations? Why $C_p > C_v$?

Ans. : According to first law of thermodynamics, the total heat energy change dQ is the sum of internal energy change dU and work done dW.

i.e. dQ = dU + DW

Limitations:

First law do not tell us,

i. The quick or slow nature of a process.

ii. Whether the process is possible or not. $C_p > C_v$ because for constant pressure process, both volume and temperature are altered and for constant volume process only temperature varies.

40. A refrigerator is to maintain eatables kept inside at 9°C. If room temperature is 36°C, calculate the coefficient of performance.

Ans. : Temperature inside the refrigerator, T_1 = 9°C = 282K

Room temperature, T_2 = 36°C = 309K

Coefficient of performance = $T_1/T_2 - T_1$

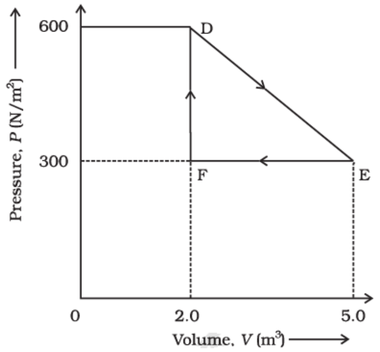
= 282/309 - 282

= 282/27

= 10.44

Therefore, the coefficient of performance of the given refrigerator is 10.44.

41. A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in Fig.



Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the total work done by the gas from D to E to F.

Ans. : Total work done by the gas from D to E to F = Area of $\Delta \mathrm{DEF}$

Area of $\Delta \mathrm{DEF} =$ (1/2)DE × EF

Where,

DF = Change in pressure

= 600N/m^2 - 300N/m^2

= 300N/m^2

FE = Change in volume

= 5.0m^3 - 2.0m^3

= 3.0m^3

Area of $\Delta \mathrm{DEF} =$ (1/2) × 300 × 3 = 450J

Therefore, the total work done by the gas from D to E to F is 450J.

42. A refrigerator transfers 250J heat per second from -23°C to 25°C. Find the power consumed, assuming no loss of energy.

Ans. : Here, Q_2 = 250J s^{-1}

T_2 = -23°C = -23 + 273 = 250K

T_1 = 25°C = 25 + 273 = 298K

We know, $\beta = \frac{\mathrm{Q_2}}{\mathrm{W}} = \frac{\mathrm{T_2}}{\mathrm{T_1 - T_2}}$

$\therefore \mathrm{W} = \frac{\mathrm{Q_2(T_1 - T_2)}}{\mathrm{T_2}}$

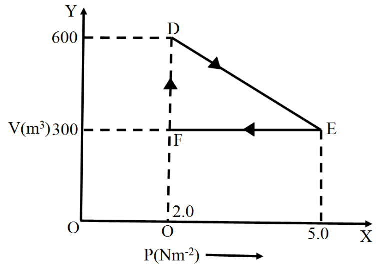
$\mathrm{W} = \frac{250(298-250)}{250} = \frac{250 \times 48}{250}$

$\mathrm{W} = 48\mathrm{J\ s}^{-1}$

43.

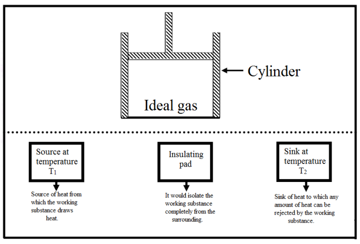
i. Describe a Carnot's cycle.

ii. A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in below figure. Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the work done by the gas from D to E to F.



Ans. :

i. Sadi Carnot devised an ideal cycle of operation of heat engine, which came to be known as Carnot cycle which is a set of four devices- a source at a high temperature (say T_1), a sink at a low temperature (say T_2), a non-conducting base and a cylinder with a working substance (a perfect gas) frictionless piston made of conducting base and non-conducting walls and piston.



ii. Change in pressure, dP = 5.0 - 2.0 atm = 3.0×10^5 Nm^{-2}

Change in volume dV = 600 - 300 = 300 cc = 300×10^{-6} m^3

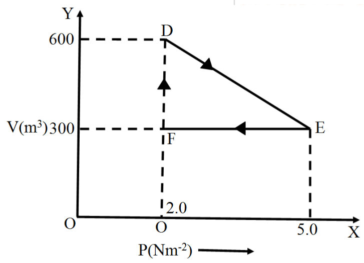
Work done by the gas from D to E to F

= Area of $\Delta\mathrm{DEF}$

$= \frac{1}{2} \times \mathrm{dP} \times \mathrm{dV}$

$= \frac{1}{2} \times 3.0 \times 10^5 \times 300 \times 10^{-6}\,\mathrm{m}^3$

$= 45 \times 10^6 \times 10^{-6} = 45\mathrm{J}$



44. The temperature of equal masses of three different liquids A, B and C are 12°C, 19°C and 28°C respectively. The temperature when A and B are mixed is 16°C. When B and C are mixed, the temperature is 23°C. What would be the temperature when A and C are mixed?

Ans. : Let S_A, S_B, S_C be the specific heats of liquids A, B and C respectively.

When A and B are mixed,

$$\mathrm{mS_A}(16 - 12) = \mathrm{mS_B}(19 - 16)$$

$$\mathrm{S_A} = \frac{3}{4}\mathrm{S_B} \ldots (\mathrm{i})$$

When B and C are mixed,

$$\mathrm{ms_B}(23 - 19) = \mathrm{mS_C}(28 - 23)$$

$S_B = \frac{5}{4}S_C \ldots \text{(ii)}$

From (i) and (ii),

$S_A = \frac{15}{16}S_C$

Substituting in (iii), we get

$\frac{15}{16}(\theta - 12)S_C = (28 - \theta)S_C$ or $\theta = 22.0^\circ C.$

45. What are 'Super heated water' and 'Super cooled vapour'?

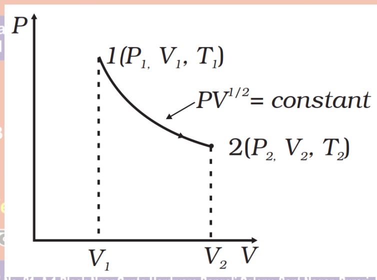
Ans. : Water in liquid phase at a temperature above 100°C and a pressure more than 1atm is called as super heated water. In a pressure cooker, water is heated at a pressure more than 1atm and temperature above 100°C. Steam below temperature 100°C is called super-cooled vapour.

46. State law of equi-partition of energy. Use this law to calculate specific heats of monoatomic, diatomic and triatomic gases.

Ans. : According to the equi partition of energy, each degree of freedom will contribute an equal energy of $\frac{1}{2}R$ per mole. In mono, di and triatomic gases hawing 3, 5 and 6 or 7 degrees of freedom, the internal energy will be $\frac{3}{2}R$, $\frac{5}{2}RT$ and $\frac{6}{2}RT$ or $\frac{7}{2}RT.$

Using dU = nC_VdT for mole, we get $C_V = \frac{3}{2}R, \frac{5}{2}R,$ and 3R or $\frac{7}{2}R$ for the three gases respectively.

47. Consider a P-V diagram in which the path followed by one mole of perfect gas in a



cylindrical container is shown in Fig. Given the internal energy for one mole of gas at temperature T is (3/2) RT, find the heat supplied to the gas when it is taken from state (1) to (2) with $V_2 = 2V_1$.

Ans. : $\therefore\ PV =$ constant = K (given) or $P_1V_1^{\frac{1}{2}} = P_2V_2^{\frac{1}{2}} = K$ and $P = \frac{K}{V^{\frac{1}{2}}}$

Given that internal energy U of gas is

$U = \left(\frac{3}{2}\right)RT$

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

$\therefore\ T_2 = \sqrt{2}T_1$, from part (b)

$\Delta U = \frac{3}{2}R\left[\sqrt{2}T_1 - T_1\right] = \frac{3}{2}RT_1\left(\sqrt{2} - 1\right)$

Form part (a) $dW = 2P_1V^{\frac{1}{2}}\left(\sqrt{V_2} - \sqrt{V_1}\right)$

$\because\ V_2 = 2V_1$ (given)

so, $\sqrt{V_2} = \sqrt{2}\sqrt{V_1}$ then

$dW = 2P_1V_1^{\frac{1}{2}}\left(\sqrt{2}\sqrt{V_1} - \sqrt{V_1}\right)$

$= 2P_1V_1\sqrt{V_1}\left[\sqrt{2} - 1\right]$

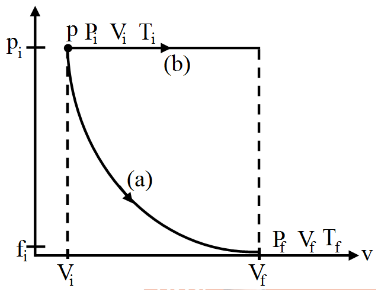
$$dW = 2P_1V_1\left(\sqrt{2}-1\right)$$
$$dW = 2nRT_1\left(\sqrt{2}-1\right)\ \left(\because\ P_1V_1 = nRT_1\right)$$
$$\therefore\ n = 1 \therefore\ dW = 2RT_1\left(\sqrt{2}-1\right)$$
$$\therefore\ dQ = dW + dU = 2RT_1\left(\sqrt{2}-1\right) + \tfrac{3}{2}RT_1\left(\sqrt{2}-1\right)$$
$$= \left(\sqrt{2}-1\right)RT_1\left[2+\tfrac{3}{2}\right]$$
$$dQ = -\left(\sqrt{2}-1\right)RT.$$

48. The initial state of a certain gas is (P_i , V_i , T_i). It undergoes expansion till its volume becoms V_f . Consider the following two cases:

a. The expansion takes place at constant temperature.

b. The expansion takes place at constant pressure.

Plot the P-V diagram for each case. In which of the two cases, is the work done by the gas more?

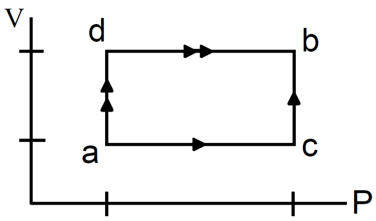


Ans. :

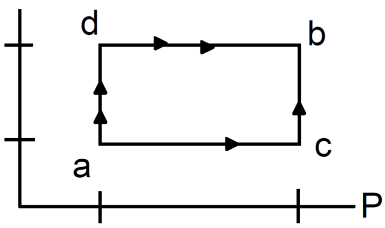
a. The expension from V_i to Vf tempreature T_i remains constant so isothermal expension i.e. $P_iV_i = P_fV_f$ constant T.

b. The expension is at constant pressure p_i so isobaric process so graph P-V will be parallel to V axis till its volume becomes V_f As the area enclosed by graph (a) is less than (b) with volume axis so W.D. by process (b) is more than of (a).

49. When a system is taken through the process abc shown in figure. 80J of heat is absorbed by the system and 30J of work is done by it. If the system does 10J of work during the process adc, how much heat flows into it during the process?



Ans. :



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

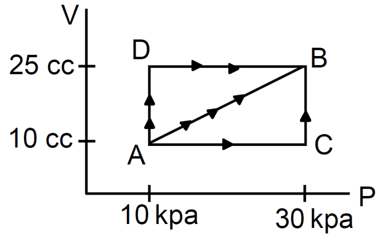
In abc $\Delta Q = 80J,\ \Delta W = 30J$

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

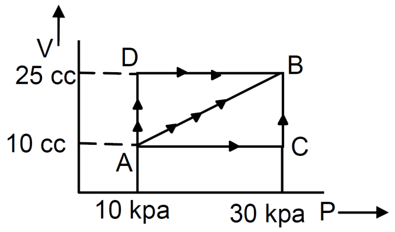
Now in adc, $\Delta W = 10J$

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

50. Figure. 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.



Ans. : In path ACB,

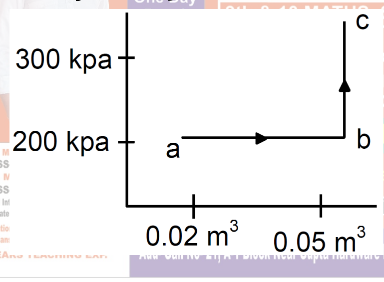


$W_{AC} + W_{BC} = 0 + pdv = 30 \times 10^3 (25 - 10) \times 10^{-6} = 0.45J$

In path AB, $W_{AB} = \frac{1}{2} \times (10 + 30) \times 10^3 \times 15 \times 10^{-6} = 0.30J$

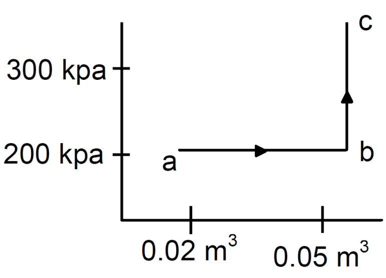
In path ADB, $W = W_{AD} + W_{DB} = 10 \times 10^3 (25 - 10) \times 10^{-6} + 0 = 0.15J$

51. A substance is taken through the process abc as shown in figure. If the internal energy of the substance increases by 5000J and a heat of 2625cal is given to the system,



calculate the value of J.

Ans. :



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

$\Delta U = 5000J$

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

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

$\Rightarrow 2625J = 6000 + 5000J$

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

* **Given Section consists of questions of 5 marks each.** **[85]**

52. A person of mass 60kg wants to lose 5kg by going up and down a 10m high stairs. Assume he burns twice as much fat while going up than coming down. If 1kg of fat is burnt on expending 7000 kilo calories, how many times must he go up and down to reduce his weight by 5kg?

Ans. : Gravitational potential energy (PE) of an object at height (h) is mgh. The energy losses by person in the form of fat will be utilised to increase PE of the person. As it is given that he burns twice as much fat while going up than coming down. Thus, the calorie consumed by the person in going up is mgh, and calorie consumed by the person in comming down is 1/ 2 mgh

According to the problem, height of the stairs = h = 10 m

Work done to burn 5kg of fat

= (5kg) (7000 × 10^3 cal) (4.2J/ cal)

= 147 × 10^6J

Work done towards burning of fat in one trip (up and down the stairs)

$$= \mathrm{mgh} + \frac{1}{2}\mathrm{mgh} = \frac{3}{2}\mathrm{mgh}$$

$$= \frac{3}{2}(60\mathrm{kg})(10\mathrm{m}/\ \mathrm{s}^2)(10m) = 9 \times 10^3\mathrm{J}$$

(as only half the work done while coming down is useful in burning fat)

∴ Number of times, the person has to go up and down the stairs (no. of trips required)

$$\mathrm{N} = \frac{147\times10^6\mathrm{J}}{9\times10^3\mathrm{J}} = 16.3 \times 10^3\mathrm{times}$$

53. In an experiment on the specific heat of a metal, a 0.20kg block of the metal at 150°C is dropped in a copper calorimeter (of water equivalent 0.025kg) containing 150 c.c. of water at 27°C. The final temperature is 40°C. Calculate the specific heat of the metal. If heat losses to the surroundings are not negligible, is your answer greater or smaller than the actual value of specific heat of the metal?

Ans. : Here, mass of metal,

m = 0.20kg = 200g

Fall in temperature of metal,

$$\Delta\mathrm{T} = 150 - 40 = 110^\circ\mathrm{C}$$

If C is specific heat of the metal, then heat lost by the metal,

$$\Delta\mathrm{Q} = \mathrm{mC}\Delta\mathrm{T} = 200 \times \mathrm{C} \times 110 \ldots (\mathrm{i})$$

Volume of water = 150 c.c.

(∵ density of water is 1g/ cc)

∴ Mass of water, m' = 150g

Water equivalent of calorimete

W = 0.025kg = 25g

Rise in temperature of water and calorimeter

$$\Delta\mathrm{T}' = 40 - 27 = 13^\circ\mathrm{C}$$

Heat gained by water and calorimeter,

$$\Delta\mathrm{Q}' = (\mathrm{m}' + \mathrm{W})\Delta\mathrm{T}'$$

$$= (150 + 25) \times 13$$

$$= 175 \times 13 \ldots (\mathrm{ii})$$

As $\Delta Q = Q'$

$\therefore$ From (i) and (ii), 200 × C × 110

= 175 × 13

$C = \frac{175 \times 13}{200 \times 110} = 0.1$

If some heat is lost to the surroundings, value of C so obtained will be less than the actual value of C.

54. A Carnot engine is working between ice point and steam point. It is desired to increase its efficiency by 20% (a) by changing temperature of hot reservoir alone, (b) by changing temperature of colder reservoir only. Calculate the change in temperature in each case.

Ans. : Here, T_1 = 100°C = 373K and T_2 = 0°C = 273K

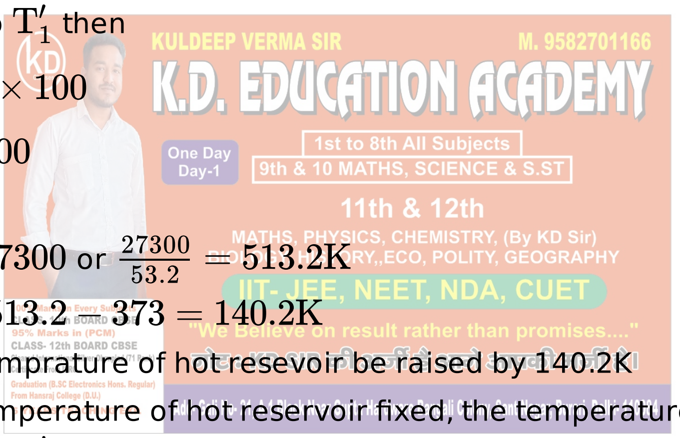
$\eta = \frac{T_1 - T_2}{T_1} = \frac{373 - 273}{373}$

$= \frac{100}{373} = 0.268$

As we want to increase its efficiency by 20%, hence new efficiency is,

$\eta' = 26.\% + 20\% = 46.8\%$

a. If keeping temperature of colder reservoir fixed the temperature of hot reservoir is changed to T_1' then



$46.8 = \frac{T_1' - 273}{T_1'} \times 100$

$\Rightarrow 46.8T_1' = 100$

$T_1' - 27300$

$\Rightarrow 53.2T_2' = 27300$ or $\frac{27300}{53.2} = 513.2K$

$\therefore T_1' - T_1 = 513.2 - 373 = 140.2K$

It means that temprature of hot resevoir be raised by 140.2K

b. If keeping temperature of hot reservoir fixed, the temperature of colder reservoir is changed to T_2', then

$46.8 = \frac{T_1 - T_2'}{T_1} \times 100$

$= \frac{373 - T_2'}{373} \times 100$

$\therefore 373 \times 46.8 = 373 \times 100 - 100T_2'$

$\Rightarrow 100T_2' = 373 \times (100 - 46.8)$

$= 373 \times 53.2$

$\Rightarrow T_2' = \frac{373 - 53.2}{100} = 198.4K$

$\therefore T_2 - T_2' = 273 - 198.4$

$= 74.6K = 74.6^\circ C.$

It means that temparture of colder reservoir be lowered by 74.6°C.

55. A lead bullet penetrates into a solid object and melts. Assuming that 50% of the K.E. was used to heat it, calculate the initial speed of the bullet. The initial temperature of bullet is 27°C and its melting point is 327°C. Latent heat of fusion of lead = 2.5×10^4 J kg^{-1} and specific heat capacity of lead = 125J $kg^{-1}K^{-1}$.

Ans. : Here, let m be the mass of the bullet. Heat required to raise its temperature fiom 27°C to 327°C.

$\because 372^\circ\mathrm{C} = 600\mathrm{K}$

$27^\circ\mathrm{C} = 300\mathrm{K}$

$\Delta\mathrm{Q}_1 = \mathrm{mc}\Delta\mathrm{T} = 125 \times \mathrm{m} \times (600 - 300)$

$= (3.75 \times 10^4)\mathrm{m\ J}$

If v is initial velocity of the bullet, then K.E. of bullet $= \frac{1}{2}\mathrm{mv}^2$

As heat developed $= \frac{1}{2}\mathrm{K.E.} = \frac{1}{2} \times \frac{1}{2}\mathrm{mv}^2$

$\therefore 3.75 \times 10^4\mathrm{m} + 2.5 \times 10^4\mathrm{m} = \frac{1}{4}\mathrm{mv}^2$

$6.25 \times 10^4\mathrm{m} = \frac{1}{4}\mathrm{mv}^2$

$\Rightarrow \mathrm{v} = \sqrt{4 \times 6.25 \times 10^4}$

$\Rightarrow \mathrm{v} = 5 \times 10^2\mathrm{m/s}$

56. Calculate the heat required to convert 0.6kg of ice at -20°C, kept in a calorimeter to steam at 100°C at atmospheric pressure. Given the specific heat capacity of ice = 2100J $\mathrm{kg}^{-1}\mathrm{K}^{-1}$, specific heat capacity of water is 4186J $\mathrm{kg}^{-1}\mathrm{K}^{-1}$, latent heat of ice = 3.35×10^5J kg^{-1}, and latent heat of steam = 2.256 × 106J kg^{-1}.

Ans. : Heat required to convert ice at -20°C to 0°C

$\mathrm{Q}_1 = \mathrm{m\ s}_{\mathrm{ice}}\Delta\mathrm{T}_1 = 0.6 \times 2100 \times [0 - (-20)]$

$= 25200\mathrm{J}$

Heat required to melt ice at 0°C to water at 0°C

$\mathrm{Q}_2 = \mathrm{m\ L}_{\mathrm{ice}} = 0.6 \times (3.35 \times 10^5)$

$= 201000\mathrm{J}$

Heat required to convert water at 0°C to water at 100°C

$\mathrm{Q} - 3 = \mathrm{ms}_{\mathrm{w}}\Delta\mathrm{T} - 2 = 0.6 \times 4186 \times (100 - 0)$

$= 251160\mathrm{J}$

Heat required to convert water at 100°C to steam at 100°C.

$\mathrm{Q}_4 = \mathrm{m\ L}_{\mathrm{steam}} = 0.6 \times 2.256 \times 10^6$

$= 1353600\mathrm{J}$

Total heat spent $\mathrm{Q}_1 + \mathrm{Q}_2 + \mathrm{Q}_3 + \mathrm{Q}_4$

$= 1830960 = 1.8 \times 10^6\mathrm{J}$

57. A person of mass 60kg wants to lose 5kg by going up and down a 10m high stairs. Assume he burns twice as much fat while going up than coming down. If 1kg of fat is burnt on expending 7000 kilo calories, how many times must he go up and down to reduce his weight by 5kg?

Ans. : Gravitational potential energy (PE) of an object at height (h) is mgh. The energy losses by person in the form of fat will be utilised to increase PE of the person. As it is given that he burns twice as much fat while going up than coming down. Thus, the calorie consumed by the person in going up is mgh, and calorie consumed by the person in comming down is 1/ 2 mgh

According to the problem, height of the stairs = h = 10 m

Work done to burn 5kg of fat

= (5kg) (7000 × 10^3 cal) (4.2J/ cal)

= 147 × 10^6J

Work done towards burning of fat in one trip (up and down the stairs)

$= \mathrm{mgh} + \frac{1}{2}\mathrm{mgh} = \frac{3}{2}\mathrm{mgh}$

$= \frac{3}{2}(60\mathrm{kg})(10\mathrm{m/\,s}^2)(10m) = 9 \times 10^3\mathrm{J}$

(as only half the work done while coming down is useful in burning fat)

∴ Number of times, the person has to go up and down the stairs (no. of trips required)

$\mathrm{N} = \frac{147 \times 10^6\mathrm{J}}{9 \times 10^3\mathrm{J}} = 16.3 \times 10^3\mathrm{times}$

58. In a refrigerator one removes heat from a lower temperature and deposits to the surroundings at a higher temperature. In this process, mechanical work has to be done which is provided by an electric motor. If the motor is of 1KW power, and heat is transferred from –3°C to 27°C, find the heat taken out of the refrigerator per second assuming its efficiency is 50% of a perfect engine.

Ans. : Carton's engine is perfect heat engine operating between two tempreature T_1 and T_2 (source and sink). Refrigerator is aiso carnot's engine working in reverse order its efficiency in η

$\eta = 1 - \frac{\mathrm{T}_2}{\mathrm{T}_2} = 1 - \frac{273-3}{273+27} = 1 - \frac{270}{300} = -.9 = 1 = \frac{1}{10}$

Efficiency of refrigerator's 50 % of perfect engine

∴ Efficiency of refrigerator = 50% of 1 = 0.5

Net efficiency = η' = 0.5 × 0.1 = 0.05

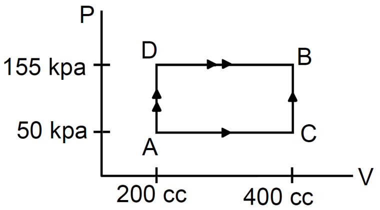
∴ Cofficient of performence $\beta = \frac{\mathrm{Q}_2}{\mathrm{W}} = \frac{1-\eta'}{\eta'}$

$\beta = \frac{1-0.05}{0.05} = \frac{0.95}{0.05} = 19$

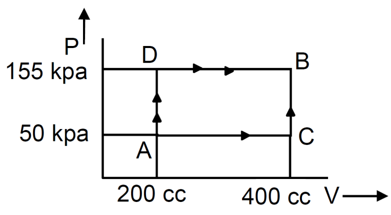
Q2 = 19% W .D. by motor on refrigerator

= 19 × 1KW =19KJ/ s

59. 50cal 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. Find the quantity of heat to be supplied to take it from A to B via ADB.



Ans. : In path ACB,



dQ = 50 × 4.2 = 210J

dW = WAC + WCB = 50 × 10^3 × 200 × 10^{-6} = 10J

dQ = dU + dW

⇒ dU = dQ - dW = 210 - 10 = 200J

In path ADB, dQ = ?

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

dW = WAD + WDB = 0 + 155 × 103 × 200 × 10^{-6} = 31J

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

60. A thermally insulated, closed copper vessel contains water at 15°C. When the vessel is shaken vigorously for 15 minutes, the temperature rises to I 7°C. The .mass of the vessel is 100g and that of the water is 200g. The specific heat capacities of copper and water are 420Jkg^{-1} K^{-1} and 4200Jkg^{-1} K^{-1} 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?

Ans. : $\mathrm{t_1} = 15^\circ\mathrm{C},\ \mathrm{t_2} = 17^\circ\mathrm{C}$

$\Delta\mathrm{t} = \mathrm{t_2} - \mathrm{t_1} = 17 - 15 = 2^\circ\mathrm{C} = 2 + 273 = 275\mathrm{K}$

m_v = 100g = 0.1kg

m_w = 200g = 0.2kg

cu_g = 420J/ kg k^{-1}

W_g = 4200J/ kg k^{-1}

   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

   $\Rightarrow \mathrm{dw} = 100 \times 10^{-3} \times 420 \times 2 + 200 \times 10^{-3} \times 4200 \times 2$

   $= 84 + 84 \times 20 = 84 \times 21 = 1764\mathrm{j}.$

   c. dQ = 0, dU = -dw = 1764. [since dw = -ve work done on the system]

61. A 100kg block is started with a speed of 2.0ms^{-1} 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 2.0ms^{-1} 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 2.0ms^{-1} 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.

Ans. : Here,

m = 100kg

u = 2.0m/s

v = 0

u_k = 0.2

a. Internal energy of the belt-block system will decrease when the block will lose its KE in heat due to friction. Thus,

KE lost $= \frac{1}{2}\mathrm{mu}^2 - \frac{1}{2}\mathrm{mv}^2$

$= \frac{1}{2}\mathrm{m}(\mathrm{u}^2 - \mathrm{v}^2)$

$= \frac{1}{2} \times 100 \times (2^2 - 0^2)$

$= 200\mathrm{J}$

b. Velocity of the frame is given by

$\mathrm{u_f} = 2.0\mathrm{m/s}$

$\mathrm{u}' = \mathrm{u} - \mathrm{u_f} = 2 - 2 = 0$

$\mathrm{v}' = 0 - 2 = -2\mathrm{m/s}$

KE lost $= \frac{1}{2}\mathrm{mu}'^2 - \frac{1}{2}\mathrm{mv}'^2$

$= \frac{1}{2}\mathrm{m}(0^2 - \mathrm{v}'^2)$

$= \frac{1}{2} \times 100 \times (0^2 - 2^2)$

$= 200\mathrm{J}$

c. Force of friction is given by,

$\mathrm{f} = \mu_\mathrm{k}\mathrm{R}$

$\Rightarrow \mathrm{f} = 0.2 \times \mathrm{mg} = 0.2 \times 100 \times 10 = 200\mathrm{N}$

Retardation $= \frac{\mathrm{f}}{\mathrm{m}} = \frac{200}{100} = 2\mathrm{ms}^{-2}$

Distance moved by the block will be as seen from the frame = s

$\mathrm{v}'^2 - \mathrm{u}'^2 = 2\mathrm{as}$

$\Rightarrow 2^2 - 0^2 = 2 \times 2\mathrm{s}$

$\Rightarrow \mathrm{s} = 1\mathrm{m}$

Work done by the force responsible for accelarating as seen from the frame

$= \mathrm{fs}$

$= 200 \times 1 = 200\mathrm{J}$

Work done by the belt to give it a final velocity of 2m/ s

$= \frac{1}{2}\mathrm{mv}'^2$

$= \frac{1}{2} \times 100 \times (2)^2$

$= 200\mathrm{J}$

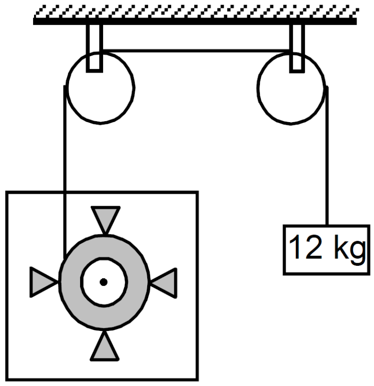
Total work done bv external force as seen from the frame 200 + 200 = 400J.

62. Figure. shows a paddle wheel coupled to a mass of 12kg through fixed frictionless pulleys. The paddle is immersed in a liquid of heat capacity 4200JK^{-1} kept in an adiabatic container. Consider a time interval in which the 12kg block falls slowly through 70cm.

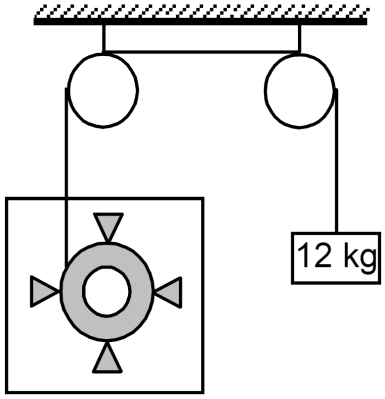
a. How much heat is given to the liquid?

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.



Ans. :



a. Heat is not given to the liquid. Instead the mechanical work done is converted to heat. So, heat given to liquid is z.

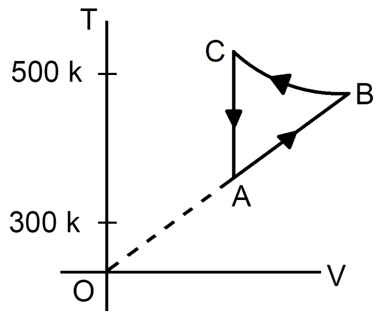
b. Work done on the liquid is the PE lost by the 12kg mass = mgh = 12 × 10 × 0.70 = 84J

c. Rise in temp at Δt, We know, $84 = ms\Delta t$

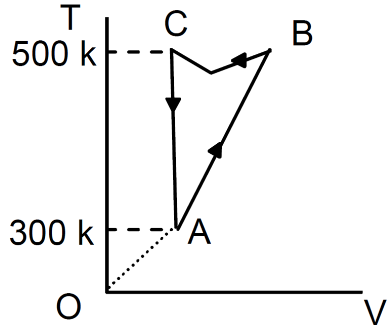
$$\Rightarrow 84 = 1 \times 4200 \times \Delta t (\text{for 'm'} = 1\text{kg})$$

$$\Rightarrow \Delta t = \frac{84}{4200} = 0.02k$$

63. Consider the cyclic process ABCA, shown in figure. performed on a sample of 2.0 mol of an ideal gas. A total of 1200J of heat is withdrawn from the sample in the process. Find the work done by the gas during the part BC.



Ans. :



n = 2 mole

dQ = -1200J

dU = 0 (During cyclic Process)

$$dQ = dU + d_{wc}$$

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

$$\Rightarrow -1200 = nR\Delta T + W_{BC} + 0$$

$$\Rightarrow -1200 = 2 \times 8.3 \times 200 + W_{BC}$$

$$\Rightarrow W_{BC} = -400 \times 8.3 - 1200 = -4520J.$$

64. Calculate the increase in the internal energy of 10g of water when it is heated from 0°C to 100°C and converted into steam at 100kPa. The density of steam= 0.6kg/ m^{-3}. Specific heat capacity of water = 4200J/ kg^{-1}°C^{-1} and the latent heat of vaporization of water = 2.25 × 10^{6}J/kg^{-1}.

Ans. : $\mathrm{Mass} = 10g = 0.01kg$

$$P = 10^{5}Pa$$

$$dQ = Q_{H_2O}0^\circ - 100^\circ + Q_{H_2O} - \mathrm{steam}$$

$$= 0.01 \times 4200 \times 100 + 0.01 \times 2.5 \times 10^{6}$$

$$= 4200 + 25000 = 29200$$

$$dW = P \times \Delta V$$

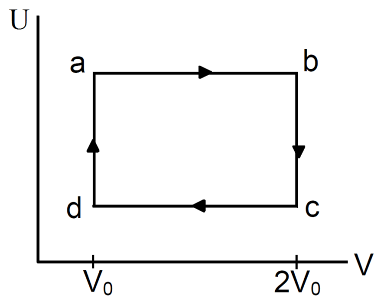
$$\Delta = \frac{0.01}{0.6} - \frac{0.01}{1000} = 0.01699$$

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

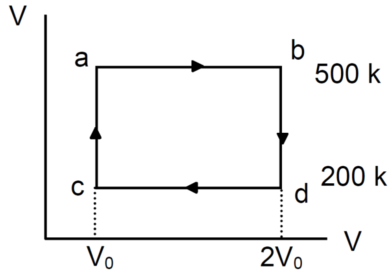
$$dQ = dW + dU \text{ or } dU = dQ - dW$$

$$= 29200 - 1699 = 27501 = 2.75 \times 10^{4}J$$

65. Figure. shows the variation in the internal energy U with the volume V of 2.0mol of an ideal gas in a cyclic process abcda. The temperatures of the gas at b and c are 500K and 300K respectively. Calculate the heat absorbed by the gas during the process.



Ans. :



Given n = 2moles

dV = 0

in ad and bc.

Hence dW = dQ

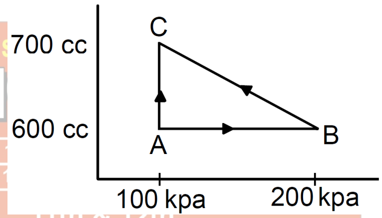
dW = dW_{ab} + dW_{cd}

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

= nR × 2.303 × log2(500 - 300)

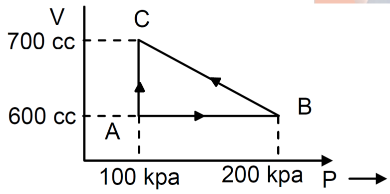
= 2 × 8.314 × 2.303 × 0.301 × 200 = 2305.31J

66. A gas is taken through a cyclic process ABCA as shown in figure. If 2.4 cal of heat is



given in the process, what is the value of J?

Ans. :



dQ = 2.4cal = 2.4J Joules

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

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

$$- 100 \times 10^3 \times 200 \times 10^{-6}$$

$$= \left(\frac{1}{2}\right) \times 300 \times 10^3 \times 200 \times 10^{-6} - 20 = 30 - 20 = 10\mathrm{J}$$

du = 0 (in a cyclic process)

dQ = dU + dW ⇒ 2.4J = 10

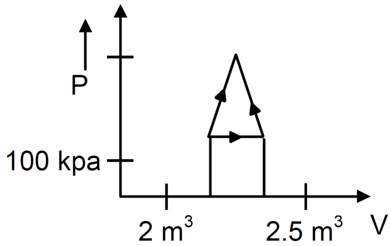
$$\Rightarrow \mathrm{J} = \frac{10}{2.4} \approx 4.17\mathrm{J/Cal}$$

67. A gas is initially at a pressure of 100kPa and its volume is 2.0m^3. Its pressure is kept constant and the volume is changed from 2.0m^3 to 2.5m^3. Its volume is now kept constant and the pressure is increased from 100kPa to 200kPa. 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?

Ans. :



a. $P_1 = 100\text{KPa}$

$V_1 = 2\text{m}^3$

$\Delta V_1 = 0.5\text{m}^3$

$\Delta P_1 = 100\text{KPa}$

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.

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

68. Find the change in the internal energy of 2kg of water as it is heated from 0°C to 4°C. The specific heat capacity of water is 4200Jkg^{-1} K^{-1} and its densities at 0°C and 4°C are 999.9kgm^{-3} and 1000kgm^{-3} respectively. Atmospheric pressure = 10^{-6}Pa.

Ans. : Given M = 2kg, 2t = 4°C, Sw = 4200J/Kg^{-1} k^{-1}

⇒ f_0 = 999.9kg/m^3, f_4 = 1000kg/m^3, P = 10^{5}Pa.

Net internal energy = dv

dQ = DU + dw

$\Rightarrow \text{ms}\Delta Q\phi = \text{dU} + \text{P}(\text{v}_0 - \text{v}_4)$

$\Rightarrow 2 \times 4200 \times 4 = \text{dU} + 10^5(\text{m} - \text{m})$

$\Rightarrow 33600 = \text{dU} + 10^5\left(\frac{\text{m}}{\text{V}_0} - \frac{\text{m}}{\text{V}_4}\right)$

$= \text{dU} + 10^5(0.0020002 - 0.002) = \text{dU} + 10^5\ 0.0000002$

$\Rightarrow 33600 = \text{du} + 0.02 \Rightarrow \text{du} = (33600 - 0.02)\text{J}$

* Case study based questions [8]

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

Ans. : When a tyre bursts, adiabatic expansion of air takes place. The pressure inside the tyre is greater than the atmospheric pressure of the surrounding due to which the expansion of air occurs with some work done against the surrounding leading to decrease in the internal energy of the air present inside the tyre. This decrease of internal energy leads to fall in temperature of the inside air. Hence, the air coming out is cooler than that of the surrounding.

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

Ans. : When we rub our hands, they become warm. In this process, heat is supplied to the hands due to the friction between the hands.

----- "Itni shiddat se maine tumhe (success) paane ki koshish ki hai,ki har zarre ne mujhe tumse milane ki saazish ki hai -----