Tutorial Sheet-3

First Law of Thermodynamics

1. A gas in a closing system is taken through a cyclic process. First it is heated isochoric ally from state a to state b whereupon its pressure increases from P_a to P_b. Then it is compressed adiabatically (bc) to its final pressure P_a. Finally it is allowed to expand isobarically from state c to state a.

Process ab : Heat absorption of 100 kJ

Process bc : Work done on the gas = 70 kJ

Process ca : Heat rejection of 120 kJ

U_a = 150 kJ. Determine 1. U_b 2. U_c 3. W_{ca}.

[Ans.: 250 kJ, 320 kJ, 50 kJ]

2. A system undergoes state change from A → B → C as shown in figure . It receives 50 kJ of heat during the process BC.

   Taking data from figure.

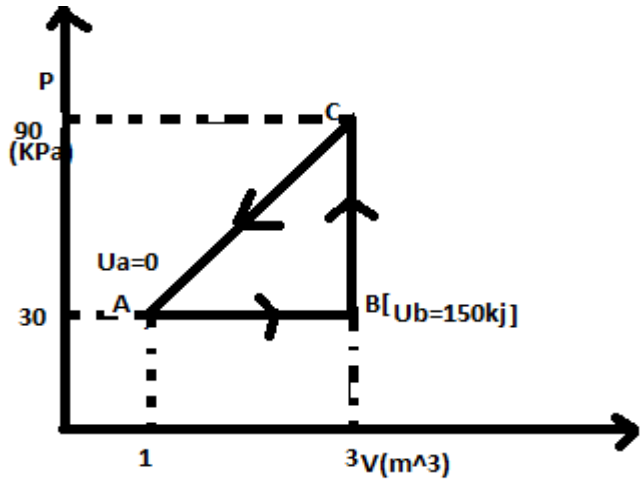
   Evaluate

   (i) U_C

   (ii) Q_{AB}

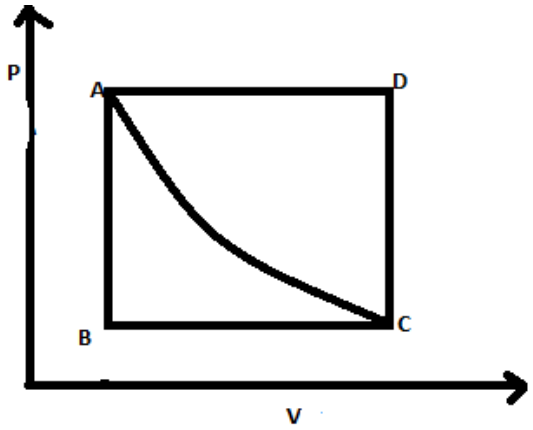
   (iii) Q_{CA}

   (iv) W_{cycle}



[**Ans. 80 kJ, 90 kJ, –kJ, 60 kJ]**

3. A system (an ideal gas enclosed in a cylinder by a frictionless, weightless piston) changes its state from A to C via path ADC and in that process it take up 100 kJ of heat and does 50 kj of work on the surroundings. If it would follow ABC, the amount of work done by the system would have been 150 kJ. Calculate Q_{ABC}. Now the system returns from state C to state A, via the curved path as a result of 15 kJ of work done on the system. Calculate Q_{CA}. If $U_B - U_A = 30$ kJ, calculate Q_{AB} and Q_{BC}.



[Ans. –65 kJ, –65 kJ, 45 kJ, 20 kJ]

4. A system undergoes different process AB, BC, CD etc. (figure 4) where upon its internal energy changes due ot obvious reason.

Given : $Q_{DA} = -5$kJ

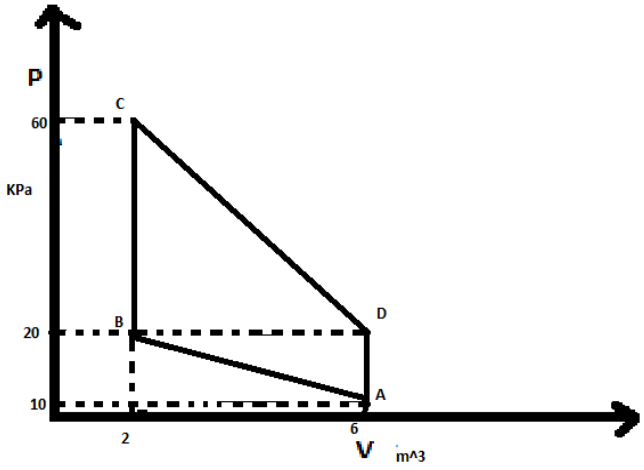
$U_A = 10$ kJ

$U_B = 30$ kJ

$U_C = 200$ kJ

Determine

(i) U_D (ii) Q_{CD} (iii) Q_{AB} (iv) Q_{BC}



[Ans. –15 kJ, –25 kJ, –40 kJ,170 kJ]

5. A 3 kg mass of a gas enclosed in cylinder-piston assembly is allowed to expand in accordance with $PV^{1.2}$ = Const. where upon its initial state 0.22 m^3/500 kPa changes to a final pressure of 100 kPa. Assuming the expansion to be quasi-static, calculate Q, ΔU and W. Given that the specific internal energy changes in accordance with

$u = 3.56\ PV + 84.$

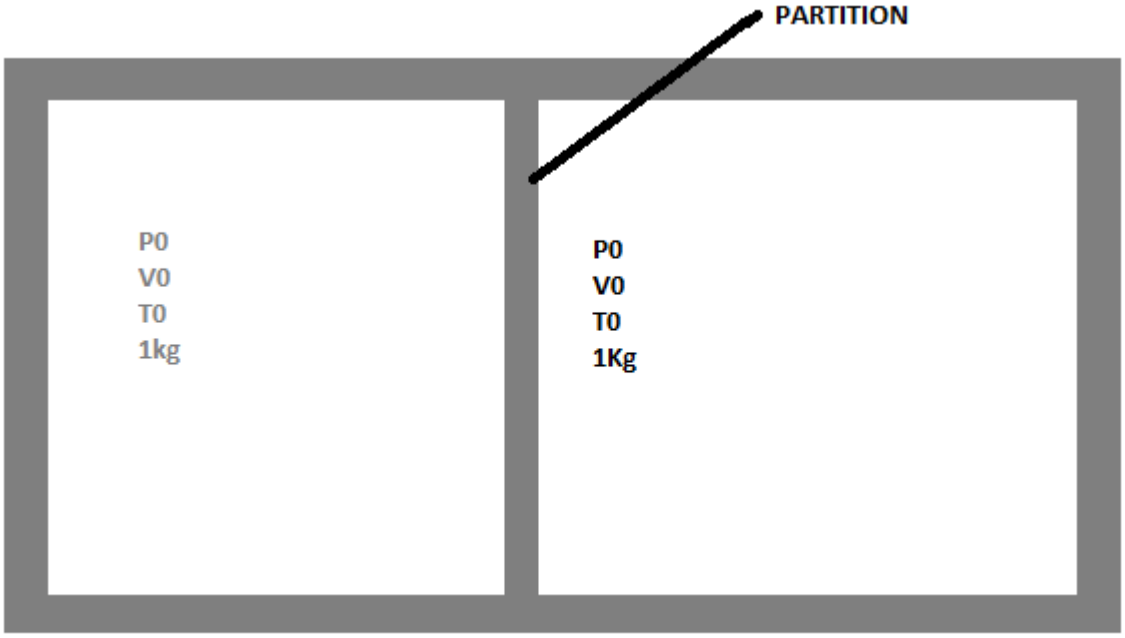
If during another run the gas takes up 30 kJ of heat from the surroundings while it changes from state 1 to state 2. Determine the work transfer for this process.

[Ans. 36.72 kJ, –90.78 kJ, 127.5 kJ, 120.78 kJ]

6. A fluid is confined in a cylinder by a spring loaded frictionless piston so that the pressure in the fluid is a linear function of volume. i.e. P = a + bV. Internal energy of the fluid is given by U = 34 + 3.14 PV where U is in kJ, P is in KPa, V is in KPa, V is in m^3. If the fluid changes from initial state of P_1 = 170 kPa, V_1 = 0.03 m^3 to a final state of P_2 = 400 kPa, V_2 = 0.06 m^3, find the direction and magnitude of heat and work.

[Ans. 68.085 kJ, 8.55 kJ]

7. A rectangular box shown in figure has a partition which slides without friction along the length of the box. Initially the two chambers of the box has 1 kg each of the an ideal gas (γ = 5/3) at pressure (P_0),Volume (V_0) and Temperature (T_0). The chamber on the left is slowly heated by an electric heater. The walls of the box and partition are thermally insulated. The gas in the left chamber expands pushing the partition untill the final pressure in both chambers is $\frac{243P_0}{32}$. Determine the final temperature of gas in each chamber in terms of T_0 and also find work done by the gas in right chamber in terms of R & T_0.



[Ans. $T_1 = 12.93\ T_0$, $T_2 = 2.25T_0$, $W = +1.875RT_0$]

8. A gas undergoes a thermodynamic cycle consisting of the following process : (i) Process 1 - 2; Constant pressure P = 1.4 bar, $V_1 = 0.024\ m^3$, $w_{12} = 10.5$ kJ (ii) Process 2 - 3; Compression with PV = constant, $U_3 = U_2$ (iii) Process 3 - 1; Constant volume, $U_1 - U_3 = -26.4$ kJ. These are no significant changes in KE and PE. (a) Sketch the cycle on a PV diagram. (b) Calculate the net work for the cycle in kJ. (c) Calculate the heat transfer for process 1-2. (d) Show that $\sum_{Cycle} Q = \sum_{Cycle} W$.

[Ans. (b) –8.28 kj (c) 36.9 kJ]

9. A cylinder contains 0.45 m^3 of a gas at 1×10^5 N/m^5 N/m^2 and 80°C. The gas is compressed to a volume of 0.13 m^3, the final pressure being 5×10^5 N/m^2. Determine:

   (i) The mass of gas

   (ii) The value of index n for compression.

   (iii) The increase in internal energy of the gas

   (iv) The heat received or rejected by the gas during compression.

   Take $\gamma = 1.4$, R = 294.2 J/kg K **[Ans. 0.433 kg, 1.296, 49.9 kJ, 17.54 kJ]**

10. The properties of a certain fluid are related as follows:

$u = 196 + 0.718\ t$

$Pv = 0.287(t + 273)$

where u is the specific internal energy (kJ/kg), t is in °C, P is pressure (KN/m^2) and v is specific volume (m^3/kg). For this fluid find C_P and C_V.

[Ans. C_V = 0.718 kJ/kg°C, C_P = 1.005 kJ/kg°C]

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