ASSIGNMENT 2 **GOA COLLEGE OF ENGINEERING**

"Bhausaheb Bandodkar Technical Education Complex"

1. Define specific heat at constant volume & constant pressure.

→ Specific heat at constant volume is the amount of heat energy needed to raise the temperature of 1 unit mass of a substance by 1°C while its volume remains constant

Specific heat at constant pressure is the amount of heat energy needed to raise the temperature of 1 unit mass of a substance by 1°C while keeping its pressure constant.

2. Why only in constant pressure non-flow process, the enthalpy change is equal to the heat transfer?

→ This is because enthalpy ($H = U + PV$) by definition accounts for both the change in internal energy & work done by the system to expand or contract against the constant external pressure.

3. Write down the steady flow energy equation from application of first law of thermodynamics to open system.

→ $$Q - W = m\left[\left(h_2 + \frac{V_2^2}{2} + gz_2\right) - \left(h_1 + \frac{V_1^2}{2} + gz_1\right)\right]$$

where $Q$ = heat transfer, $m$ = mass flow

$W$ = rate of work done, $V_1, V_2$ = velocities.

$h$ = enthalpy, $z_1, z_2$ = height

$\frac{V_2^2}{2}$ = kinetic energy, $g$ = acc$^n$ due to gravity.

$gz$ = potential energy

4. Apply the first law of thermodynamics to following equipment.

(i) Boiler

A boiler is a steady flow device where water is converted into steam by adding heat from fuel combustion. When applying 1st law, we consider a control volume encompassing the boiler.

$$Q_{in} = m(h_2 - h_1)$$

This eq$^n$ means that the heat energy transferred to boiler is used to increase the enthalpy of water, transforming it into steam, with the heat added directly equal to the change in the waters enthalpy.

(ii) Condensor

When first law of Thermodynamics is applied to a condensor, the heat rejected by the condensing substance is equal to the change in its internal energy & work done by the substance to the surrounding.
But for a typical condensor operating at constant pressure, the heat rejected is the 1° energy transfer, driving the phase change from gas to liquid.

$$\Delta U = Q - W$$

(iii) Turbine

When the first law of Thermodynamics is applied to a turbine, which is a steady flow device, it states that the work done output is equal to the change in enthalpy of the fluid as it passes through, accounting for changes in kinetic & potential energy, though the latter 2 are often neglected.

$$Q_{in} - W_{out} + \Delta KE + \Delta PE = \Delta H$$

(iv) Pump

When the first law of thermodynamics is applied to a pump the work done on the fluid to increase its energy, plus the heat added equals the change in the fluid's enthalpy, KE & PE. For steady flow devices like pumps, this simplifies to the work input required to raise the fluids energy.

$$W_{pump} = m\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right]$$

5. A stationary mass of gas is expanded isothermally without friction from the initial state of volume $0.1 m^3$ & pressure of 0.105 MPa to a final volume of $0.4 m^3$. Find the final pressure. Also, calculate the work done & the heat transferred. Show the process on the Pressure-volume diagram.

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$V_1 = 0.1 m^3$ $P_1 = 0.105 MPa$ $\gamma = 1.4$

$V_2 = 0.4 m^3$ $P_2 = ?$

$P_1V_1 = P_2V_2$

$P_2 = P_1\left(\frac{V_1}{V_2}\right)$

$= 0.105 \times 10^6 \times \left(\frac{0.1}{0.4}\right)$

$= 105000 \times (0.25)$

$P_2 = 0.02625 MPa$

$W = P_1V_1 \ln \frac{V_2}{V_1}$

$= 0.105 \times 10^6 \times 0.1 \times \ln\left(\frac{0.4}{0.1}\right)$

$= 10500 \times \ln 4$

$= 10500 \times 1.38$

$W \approx 14558 J$

$\therefore$ final pressure is $0.02625 MPa$ & $W = 14558 J$

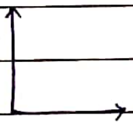
Heat transfer $(Q) = 14558 J$.

$\Delta U = Q - W$

$0 = Q - W$

$Q = W$

$Q = 14558 J$



6. A stationary mass of gas is expanded by a reversible adiabatic process from the initial state of volume $0.1 m^3$ & pressure of $0.105 MPa$ to a final volume of $0.4 m^3$. Find the final pressure. Take $\gamma = 1.4$. Also, calculate the work done & heat transferred. Show the process on P-V diagram.

$V_1 = 0.1 m^3$ $P_1 = 0.105 MPa$

$V_2 = 0.4 m^3$ $P_2 = ?$

$P_1V_1^\gamma = P_2V_2^\gamma$

$P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma$

$= 0.105 \times 10^6 \times \left(\frac{0.1}{0.4}\right)^{1.4}$

$= 45403 Pa$

$P_2 \approx 45.4 kPa$

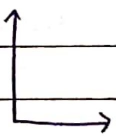
$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$

$= \frac{0.105 \times 10^6 \times 0.1 - 45.4 \times 10^3 \times 0.4}{1.4 - 1}$

$= \frac{10500 - 18161.2}{0.4} = \frac{-7661.2}{0.4}$

$W \approx -19153 J$

$Q = 0$ ($\because$ adiabatic)



7. Give the following statements of second law of thermodynamics

(i) Clausius statement.

→ It states that its impossible for a device to, in a cycle transfer heat from a cooler body to a hotter body without any external work being done on the system.

(ii) Kelvin-Plank statement

→ It states that its impossible to create a device that, operating in a cycle, takes heat from a single reservoir & converts it entirely into work.

8. Why second law of thermodynamics is called "law of degradation of energy?

→ This is because it states that in any energy conversion, some energy always becomes unavailable for useful work, typically as waste heat, leading to a decrease in the energy's quality or potential to perform work.

9. What do you mean by "absolute temperature scale"?

→ An absolute temperature scale is a thermodynamic temperature scale where zero corresponds to absolute zero.

10. Air initially at 75 kPa pressure, 1000 K temperature & occupying a volume of 0.12 m³ is compressed isothermally until the volume is halved & subsequently it undergoes further compression at constant pressure till the volume is halved again. Sketch the process on a p-v diagram & find the work transfer.

$V_1 = 0.12\ m^3$

$P_1 = 75\ kPa$

$T_1 = 1000\ K$

$\because$ Isothermal : $T_1 = T_2 = 1000\ K$

$V_2 = \dfrac{V_1}{2} = \dfrac{0.12}{2} = 0.06\ m^3$

$P_1 V_1 = P_2 V_2$

$P_2 = P_1\left(\dfrac{V_1}{V_2}\right) = \dfrac{75 \times 10^3 \times 0.12}{0.06} = 150\ kPa$

$P_3 = P_2 = 150\ kPa$ (const Pressure)

$V_3 = \dfrac{V_2}{2} = \dfrac{0.06}{2} = 0.03\ m^3$

(T=const) $W_{1-2} = P_1 V_1 \ln\left(\dfrac{V_2}{V_1}\right)$

$= 75 \times 10^3 \times 0.12 \times \ln(0.06/0.12)$

$= -6.237\ kJ$

(P=const) $W_{2-3} = P_2 (V_3 - V_2)$

$= 150 \times 10^3 (0.03 - 0.06)$

$= -4.5\ kJ$

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Total work transfer

$W_{total} = W_{1-2} + W_{2-3}$

$= -6.237 - 4.5$

$= -10.737 \text{ kJ}$

11. A stationary mass of gas is compressed without friction from an initial state of 0.3 m³ & 0.105 MPa to a final state of 0.15 m³ & 0.105 MPa, the pressure remaining constant during the process. There is a transfer of 37.6 kJ of heat from the gas during the process. How much does the internal energy of the gas change?

$V_1 = 0.3 \, m^3$ $\quad P_1 = 0.105 \text{ MPa}$ $\quad Q = 37.6 \text{ kJ}$

$V_2 = 0.15 \, m^3$ $\quad P_2 = 0.105 \text{ MPa}$

($P$ = const)

$W = P(V_2 - V_1)$

$= 0.105 \times 10^6 (0.15 - 0.3)$

$= -0.105 \times 10^6 \times 0.15$

$= -0.01575 \times 10^6$

$= -15.75 \times 10^3 \text{ J}$

$W = -15.75 \text{ kJ}$

$\Delta U = Q - W$

$= 37.6 + 15.75$

$= 53.35 \text{ kJ}$

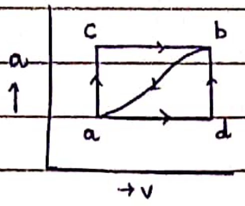
∴ Internal energy of the gas change is 53.35 kJ

12. When a system is taken from state a to state b, in Fig along path acb, 84 kJ of heat flow into the system & the system does 32 kJ of work.

(a) How much will the heat that flows into the system along path adb be, if the work done is 10.5 kJ?

(b) When the system is returned from b to a along the curved path, the work done on the system is 21 kJ. Does the system absorb or liberate heat & how much of the heat is absorbed or liberated?

(c) If $U_a = 0$ & $U_d = 42$ kJ, find the heat absorbed in the process of ad & db.




following table showing the method for each item & compute the net rate of work output in kW.

| Process | Q (KJ/min) | W (KJ/min) | ΔE (KJ/min) |
|---|---|---|---|
| a-b | 0 | 2170 | - |
| b-c | 21000 | 0 | - |
| c-d | -2100 | - | -36600 |
| d-a | - | - | - |

Sol$^n$

(a) Along path acb

$Q = +84\,kJ$ $\quad W = +32\,kJ$

Along path adb

$Q = ?$ $\quad W = +10.5\,kJ$

→ Along path acb :

$Q_{acb} = W + \Delta U$

$84 = 32 + \Delta U$

$\Delta U = 52\,kJ$ $\quad (\Delta U = U_b - U_a)$

→ Along path adb :

$Q_{adb} = W_{adb} + \Delta U$

$= 10.5 + 52$

$= 62.5\,kJ$

$Q_{ad} = 10.5 + 42 - 0$

$= 52.5\,kJ$

$Q_{db} = W + U_b - U_d$

$= 0 + 52 - 42$

$= 10\,kJ$

(b) Along curved path ba

$Q_{curved} = W + \Delta U$ $\quad (\Delta U = U_a - U_b)$

$Q = W + U_a - U_b$

$= -21 - 52$

$Q_{curved} = -73\,kJ$

∴ the system liberates $-73\,kJ$.

(c) $U_a = 0$, $\quad U_d = 42\,kJ$

$q_{ad} = W + \Delta U$

$= W + U.$

$= 10.5 + U_d - U_a$

$W_{adb} = W_{ad} + W_{db}^{\to 0}$

$10.5\,kJ = W_{ad}$

$U_d - U_a$

$U_b - U_a = 52 \Rightarrow U_b = 52\,kJ$