Reversible and Irreversible Processes for The Ideal Gas

1. Reversible non-flow Processes:

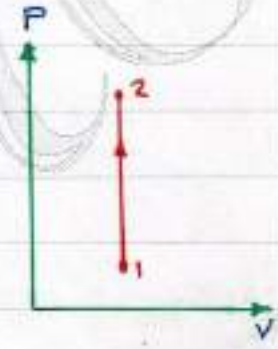
a. Constant volume Process (Isometeric)

from the non-flow E.E.

$$Q = W + \Delta U$$

$$W = \int p\, dV \quad , \quad V = c \Rightarrow dV = 0$$

$$\therefore W = 0 \Rightarrow Q = \Delta U$$



$$\boxed{Q = m C_v (T_2 - T_1)}$$

b. Constant Pressure Process (Isobaric)

from the NFEE

$$Q = W + \Delta U$$

$$W = P_2 V_2 - P_1 V_1$$

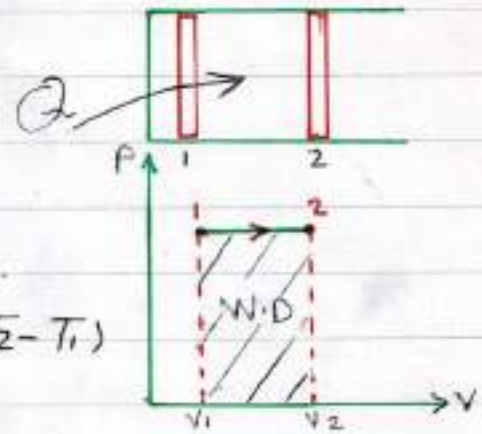
$$= m R (T_2 - T_1)$$

$$\Delta U = m C_v (T_2 - T_1)$$

$$Q = m R (T_2 - T_1) + m C_v (T_2 - T_1)$$

$$= m (R + C_v)(T_2 - T_1)$$

$$= m C_p (T_2 - T_1) = \Delta H = m (h_2 - h_1)$$



$$\boxed{Q = m C_p (T_2 - T_1)}$$

c. Constant temperature process (Isothermal)

from NFEE :

$$Q = W + \Delta U$$

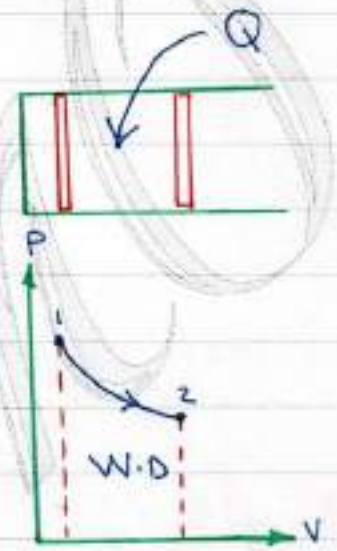
$$w = \int_1^2 p\, dv$$

we have $\frac{P_1 V_1}{T_1} = C$, since $T = C$

$\therefore P_1 V_1 = C \Rightarrow p = \frac{C}{V}$

$$w = \int_1^2 \frac{C}{V}\, dV = C \ln \frac{V_2}{V_1}$$

$$W = PV \ln \frac{V_2}{V_1} = mRT_1 \ln \frac{V_2}{V_1}$$



$U_2 - U_1 = mC_v(T_2 - T_1)$, $T_2 = T_1 \Rightarrow \Delta U = 0$

$$\boxed{\therefore Q = PV \ln \frac{V_2}{V_1} = PV \ln \frac{P_1}{P_2} = mRT \ln \frac{P_1}{P_2}}$$

Ex: 1 kg of nitrogen (Molecular weight 28) is compressed reversibly and isothermally from 1.01 bar, 20°C to 4.2 bar. Calculate the work done and the heat flow during the process. Assume nitrogen to be a perfect gas.

Sol: $R = R_o/M = 8.314/28 = 0.297$ kJ/kg K

$$W = RT \ln \frac{P_1}{P_2} = 0.297 * 293 * \ln \frac{1.01}{4.2} = 124 \frac{kJ}{kg} \text{ (comp.)}$$

$Q = W = -124$ kJ/kg

Heat rejected $= +124$ kJ/kg

d. Adiabatic Process :

In this process the System must be in thermal insulated, to prevent the heat transfer between the System and Surrounding.

To find the Relation between P & V:
from the non-flow E.E

$$Q = W + \Delta U$$

adiabatic process $\Rightarrow Q = 0$

$$dQ = dU + dW \Rightarrow dq = du + dw$$
$$dU = m C_v dT \Rightarrow du = C_v dT$$
$$dW = p\, dV \Rightarrow dw = p\, dv$$

per unit mass

$$\therefore dq = C_v dT + p\, dv$$
$$pv = RT \Rightarrow p = RT/v$$

$$\therefore dq = C_v dT + RT \frac{dv}{v} = 0$$

$$0 = C_v dT + RT \frac{dv}{v}$$
$$0 = C_v \frac{dT}{T} + R \frac{dv}{v}$$

$$0 = \frac{dT}{T} + \frac{R}{C_v} \cdot \frac{dv}{v} \quad , \quad \frac{R}{C_v} = \gamma - 1$$

$$0 = \frac{dT}{T} + (\gamma-1)\frac{dv}{v}$$

$$\int 0 = \int_{T_1}^{T_2} \frac{dT}{T} + (\gamma-1)\int_{v_1}^{v_2} \frac{dv}{v}$$

$$\ln T + (\gamma-1)\ln V = C \quad , \quad T = \frac{Pv}{R}$$

$$\ln\left(\frac{Pv}{R}\right) + (\gamma-1)\ln v = C$$

$$\ln \frac{Pv \cdot v^{\gamma-1}}{R} = C$$

$$\frac{P v^{\gamma}}{R} = e^{C} \Rightarrow P v^{\gamma} = R e^{C} = C$$

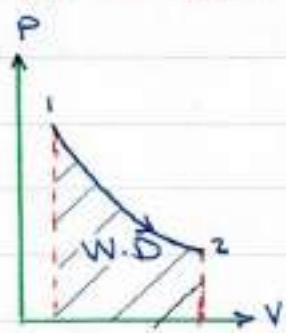
$$\therefore \boxed{PV^{\gamma} = C}$$ adiabatic process

the non-flow energy

$$Q = W + \Delta U \quad , Q = 0 \text{ (adiabatic)}$$

$$W = -\Delta U$$

$$= m C_v (T_1 - T_2) = m\left(\frac{R}{\gamma-1}\right)(T_1 - T_2)$$



$$W = \frac{mR(T_1 - T_2)}{\gamma - 1}$$

$$\boxed{W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}}$$ ~ Adiabatic work

The Relation Between P,V and T in Adiabatic Process:-

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} = C$$

$$\frac{P_1}{P_2} = \frac{V_2}{V_1} \cdot \frac{T_1}{T_2} \quad \text{--- (1)}$$

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma} \quad \text{--- (2)}$$

Sub. eq (1) in eq (2)

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

$$\therefore \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} \quad \text{--- (3)}$$

Sub eq (2) in eq (3) , where $\frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{1/\gamma}$

$$\frac{T_1}{T_2} = \left[\left(\frac{P_1}{P_2}\right)^{\frac{1}{\gamma}}\right]^{\gamma-1} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\therefore \boxed{\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}}$$

the relation between P, V and T for adiabatic process

Ex: Air at 1.02 bar, 22°C, initially occupying a cylinder volume of 0.015 m³, is compressed reversibly and adiabatically by a piston to a pressure of 6.8 bar. Calculate the final temperature, the final volume, and the work done on the mass of air in the cylinder.

Sol:

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{or} \quad T_2 = T_1 * \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_2 = 295 * \left(\frac{6.8}{1.02}\right)^{\frac{1.4-1}{1.4}} = 295 * 6.67^{0.286}$$

$$= 507.5\ K$$

(Where $T_1 = 22 + 273 = 295$, $\gamma = 1.4$)

Final temperature $= 507.5 - 273 = 234.5\ °C$

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma} \quad \text{or} \quad \frac{V_1}{V_2} = \left(\frac{P_2}{P_1}\right)^{1/\gamma}$$

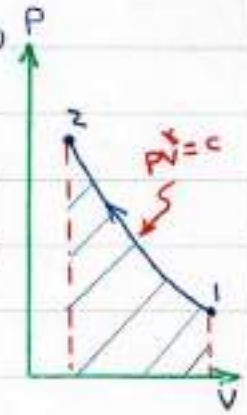
$$\therefore \frac{0.015}{V_2} = \left(\frac{6.8}{1.02}\right)^{1/1.4} \Rightarrow V_2 = 0.00388\ m^3$$

$W = U_1 - U_2$ (adiabatic process)

$= C_v(T_1 - T_2)$ (Per kg of gas)

$= 0.718(295 - 507.5) = -152.8$ kJ/kg

$\therefore$ Work input per kg $= 152.8$ kJ/kg



$$m = \frac{P_1 V_1}{R T_1} = \frac{1.02 * 10^5 * 0.015}{0.287 * 10^3 * 295} = 0.0181\ kg$$

Total work done $= 0.0181 * 152.8 = 2.76$ kJ

e. Polytropic Processes:

This general case of expansion or compression of a substance according to the law $PV^n = C$. It is called a polytropic expansion or compression or a polytrope.

It is should be noted that the value of the constant "C" will change with each change of condition. So also will the value of "n" which is called the "index" of the expansion or compression or the polytropic exponent.

$$PV^n = C$$

The non-flow energy equation

$$Q = W + \Delta U$$

$$W = \int P\,dV = C \cdot \int \frac{dV}{V^n} = PV^n \int (V^{-n})\,dV$$

$$W = PV^n \left[\frac{V^{-n+1}}{-n+1} \right]_1^2 = \frac{P_2 V_2^n \cdot V_2^{-n+1} - P_1 V_1^n \cdot V_1^{-n+1}}{-n+1}$$

$$W = \frac{P_2 V_2 - P_1 V_1}{-n+1}$$

$$W = \frac{P_1 V_1 - P_2 V_2}{n-1}$$

$$W = \frac{mR(T_1 - T_2)}{n-1}$$

$$\Delta U = m C_v (T_2 - T_1) = -m C_v (T_1 - T_2)$$

$$\Delta U = -m(R/\gamma - 1)(T_1 - T_2)$$

$$\therefore \quad Q = \frac{mR(T_1 - T_2)}{n-1} - m\frac{R}{\gamma - 1}(T_1 - T_2)$$

$$= mR(T_1 - T_2)\left(\frac{1}{n-1} - \frac{1}{\gamma - 1}\right)$$

$$= mR(T_1 - T_2)\left(\frac{\gamma - 1 - n + 1}{(n-1)(\gamma - 1)}\right)$$

$$= mR(T_1 - T_2)\left(\frac{\gamma - n}{(n-1)(\gamma - 1)}\right)$$

$$= (mR(T_1 - T_2)/n-1)(\gamma - n/\gamma - 1)$$

$$\boxed{\therefore \quad Q = \left(\frac{\gamma - n}{\gamma - 1}\right) \cdot W}$$

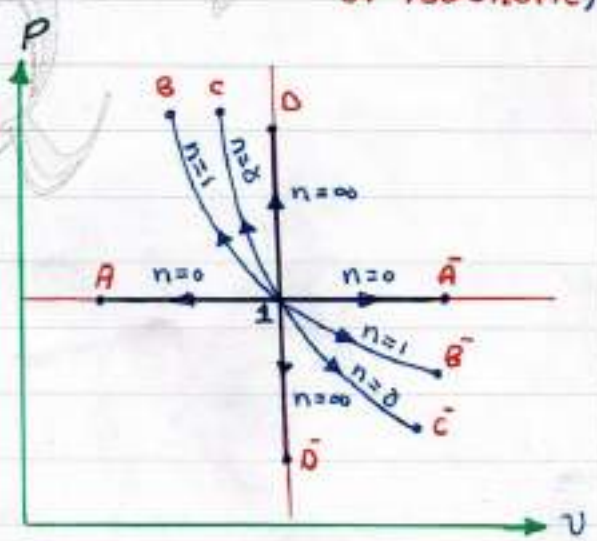
In a polytropic process the value of (n) depends on the a mount of heat added or rejected and on the work done during the process

$$PV^n = C$$

When:

1. $n=0 \rightarrow PV^0=C \rightarrow P=C$ (isobaric)
2. $n=1 \rightarrow PV^1=C \rightarrow PV=C$ (isothermal $T=C$)
3. $n=\gamma \rightarrow PV^\gamma=C \rightarrow Q=0$ (adiabatic)
4. $n=\alpha \rightarrow PV^\alpha=C \rightarrow P^{\frac{1}{\alpha}}.V=C \rightarrow V=C$ (isometeric or isochoric)

- Processes :



$1 \rightarrow A$ Cooling at $P=C$
$1 \rightarrow \bar{A}$ Heating at $P=C$

$1 \rightarrow \bar{B}$ Expansion at $T=C$
$1 \rightarrow B$ Compression at $T=C$

$1 \rightarrow C$ Adiabatic compression ($PV^\gamma=C$)
$1 \rightarrow \bar{C}$ " Expansion

$1 \rightarrow D$ Heating at $V=C$
$1 \rightarrow \bar{D}$ Cooling " "

- Work and the hyperbolic process :-

The hyperbolic process is a particular case of the polytropic process, ($PV^n = C$), being the case When ($n = 1$). Thus, the law for the hyperbolic process is,

$$\boxed{PV = C}$$

For ahyperbolic change from state 1 to state 2.

$$P_1 V_1 = P_2 V_2$$

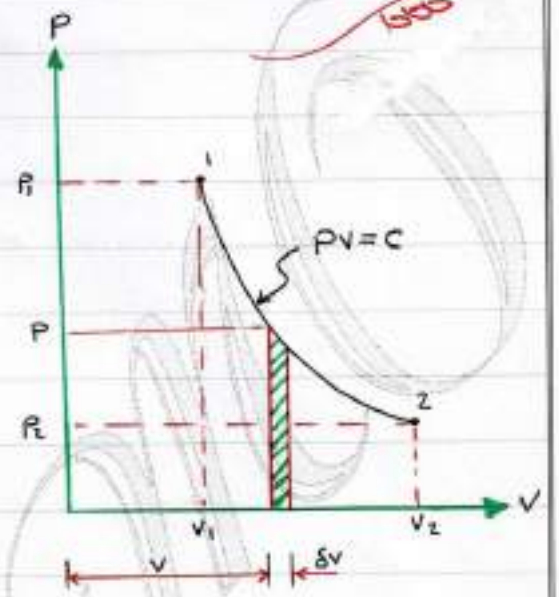
An expression for the work done during a polytropic process has already been determined,

$$\text{Work done} = \frac{P_1V_1 - P_2V_2}{n-1}$$

for hyperbolic process, $P_1V_1 = P_2V_2$ & $n = 1$

$$\therefore \text{Work done} = \frac{P_1V_1 - P_2V_2}{n-1} = \frac{0}{0}$$

$\therefore$ to compute the work done. It is necessary to determine the area under curve.



$$\text{work done} = \int_{V_1}^{V_2} P\,dV$$

$$PV = C \Rightarrow P = C/V$$

$$W = C\int_{V_1}^{V_2} \frac{dV}{V} = C\left[\ln V\right]_{V_1}^{V_2}$$

$$W = C\left[\ln V_2 - \ln V_1\right]$$

$$= C \ln \frac{V_2}{V_1} = PV \ln \frac{V_2}{V_1}$$

$$\therefore \quad \boxed{W = PV \ln \frac{V_2}{V_1}}$$

Ex:

A gas is compressed hyperbolically from a pressure and volume of 100 kN/m² and 0.056 m³, respectively. to a volume of 0.007 m³. Determine the final pressure and the work done on the gas.

Sol: since the gas is compressed hyperbolically, then

$$P_1V_1 = P_2V_2 \quad \text{or} \quad P_2 = 100 * \frac{0.056}{0.007} = 800 \text{ kPa}$$

$$\text{work done} = P_1V_1 \ln \frac{V_2}{V_1} = 100 \times 10^3 \times 0.056 \times \ln \frac{0.007}{0.056}$$

$$= -11.65 \text{ kJ}$$

work done on the gas = 11.65 kJ

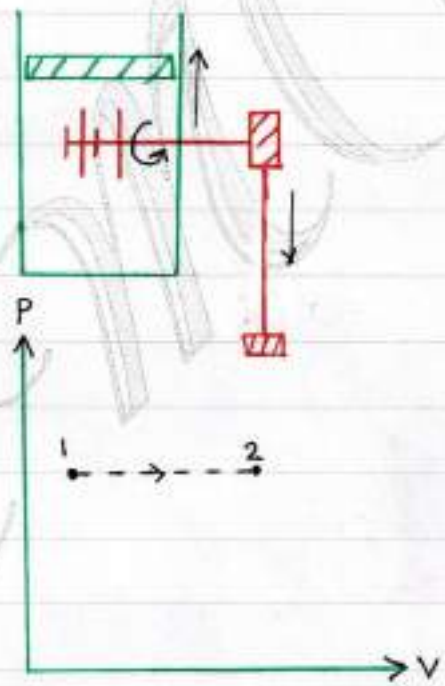
2. Irreversible Processes (Closed System)

a. Paddle work (P=C)

W_p = Paddle work

from NFEE

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



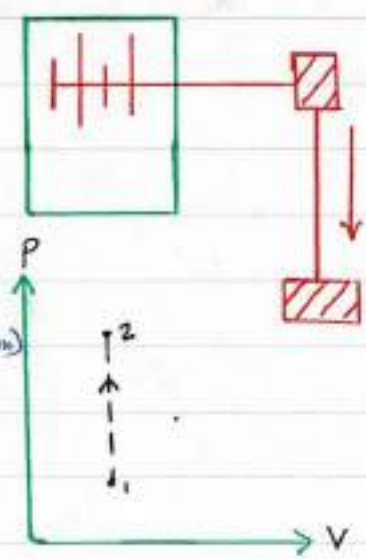
Q may be equal to zero if the process is very fast or insulated.

$$\Delta U = mC_v(T_2 - T_1)$$

$$W \equiv P(V_2 - V_1) = mR(T_2 - T_1)$$

W_p = -ve since it is done on the System.

b. Paddle work (V=C)



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

$W = 0$ (V=C) , $Q = 0$

$$\Delta U = mC_v(T_2 - T_1)$$

$W_p \equiv$ -ve (done on the System)

3. Reversible Processes (Open System)

a. Constant Pressure Process: (such as condenser)

$$gz_1 + P_1V_1 + U_1 + \frac{1}{2}C_1^2 + q = gz_2 + P_2V_2 + U_2 + \frac{1}{2}C_2^2 + w$$

$$P_1 = P_2$$

$$w - q = (P_1V_1 - P_2V_2) + (U_1 - U_2) + \frac{1}{2}(C_1^2 - C_2^2)*10^{-3} + g(Z_1 - Z_2)*10^{-3}$$

or

$$\dot{W} - \dot{Q} = \dot{m}[w - q]$$

b. Constant temperature process:

$P = \text{Constant}$

$T = C$, $P_1V_1 = P_2V_2$, $U_1 = U_2$

$$\therefore W = q + \left[g(Z_1 - Z_2) + \frac{1}{2}(C_1^2 - C_2^2)\right]*10^{-3}$$

or $$w = \int_1^2 P\,dv = Pv \ln\frac{V_2}{V_1} = mRT \ln\frac{V_2}{V_1}$$

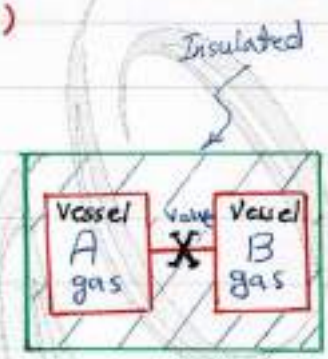
c. Polytropic Process:

from Steady flow Energy Equation SFEE.

$$W - q = (P_1V_1 - P_2V_2) + (U_1 - U_2) + \frac{1}{2}(C_1^2 - C_2^2)*10^{-3} + g(Z_1 - Z_2)*10^{-3}$$

4. Irreversible Processes (Open System)

a. Unresisted, or free, expansion :



$$Q = W + \Delta U$$

$Q = 0$ (adiabatic) , $W = 0$

$\therefore \Delta U = 0 \Rightarrow u_2 = u_1$ (Per 1 kg)

$$C_v T_2 = C_v T_1$$

$\therefore T_1 = T_2$ (Irreversible)

Ex: Air at 20 bar is initially contained in vessel "A" as shown in the fig. above, the volume of which can be assumed to be $1 m^3$. The valve X is opened and the air expands to fill vessels A and B. Assuming that the vessels are of equal volume, Calculate the final pressure of the air.

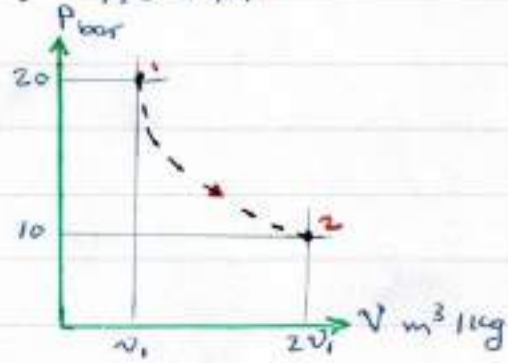
Sol:

$\because$ Free expansion $\Rightarrow T_1 = T_2$

for a perfect gas $pV = mRT$, $P_1 V_1 = P_2 V_2$

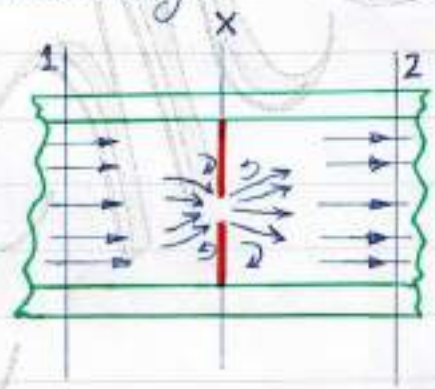
$V_2 = V_A + V_B = 1 + 1 = 2 m^3$, $V_1 = 1 m^3$

$$P_2 = P_1 \cdot \frac{V_1}{V_2} = 20 * \frac{1}{2} = 10 \text{ bar}$$



b. Throttling Process :

A flow of fluid is said to be throttled when there is som restriction to the flow. When the velocities before and after the restriction are either equal or negligibly small, and when there is a negligible heat loss to the surroundings.



from SFEE :

$$gz_1 + P_1v_1 + u_1 + \frac{1}{2}C_1^2 + q = gz_2 + P_2v_2 + u_2 + \frac{1}{2}C_2^2 + w$$

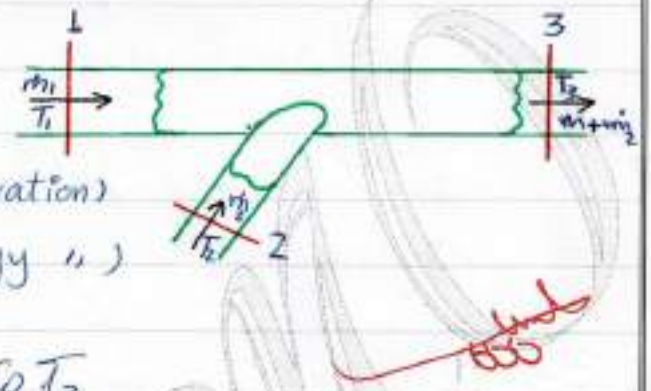
$z_1 = z_2$, $w = 0$, $Q = 0$, $C_1 \simeq C_2$

$$\therefore \quad P_1v_1 + u_1 = P_2v_2 + u_2$$

$$h_1 = h_2 \Rightarrow C_p T_1 = C_p T_2$$

$$\therefore T_1 = T_2 \quad \text{(Irreversible)}$$

c. Adiabatic mixing :



$m_1 + m_2 = m_3$ (mass conservation)

$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$ (energy ")

$$\dot{m}_1 C_p T_1 + \dot{m}_2 C_p T_2 = \dot{m}_3 C_p T_3$$

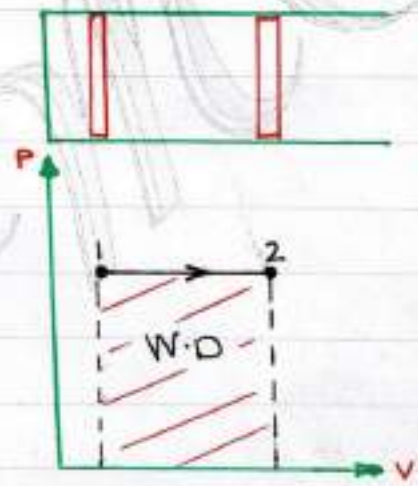
for the same gases mixing C_p = Constant

$$\dot{m}_1 T_1 + \dot{m}_2 T_2 = \dot{m}_3 T_3$$

$$\boxed{\dot{m}_1 T_1 + \dot{m}_2 T_2 = (\dot{m}_1 + \dot{m}_2) T_3}$$

Ex: 0.05 kg of air is heated at constant pressure of 2bar until the volume occupied is $0.0658\ m^3$. Calculate the heat supplied and work done, when the initial temperature is 130°C. Take $C_p = 1.005$ kJ/kg.K, $R = 0.287$ kJ/kg.K

Sol: the non-flow energy equation



$$Q = W + \Delta U$$

$$W = \int_1^2 P \cdot dV = P(V_2 - V_1)$$

$$= mR(T_2 - T_1)$$

$$\Delta U = (U_2 - U_1) = mC_v(T_2 - T_1)$$

$$\therefore Q = mC_p(T_2 - T_1)$$

$$P_2V_2 = mRT_2 \Rightarrow T_2 = P_2V_2/mR$$

$$T_2 = 2 * 10^2 * 0.0658 / 0.05 * 0.287$$

$$= 912\ K$$

$$T_1 = 130 + 273 = 403\ K$$

$$Q = 0.05 * 1.005 * (912 - 403)$$

$$= 25.6\ kJ$$

$$W = mR(T_2 - T_1) = 0.05 * 0.287 * (912 - 403)$$

$$= 7.3\ kJ$$

OR $W = P(V_2 - V_1)$, $V_1 = mRT_1/P_1 = 0.0289\ m^3$

$$\therefore W = 2 * 10^2 (0.0658 - 0.0289) = 7.38\ kJ$$

$$\Delta U = mC_v(T_2 - T_1) = 0.05 * (1.005 - 0.287)(912 - 403)$$

$$= 18.27\ kJ$$

$$Q = W + \Delta U = 7.38 + 18.27 = 25.65\ kJ$$

Ex: A constant pressure adiabatic System contain 0.13 kg of air at 1.3 bar. The System recives paddle work. The temperature of air rises from 29 to 185°C. Find the total work. mechanical work, change in internal energy and enthalpy. Take $R = 0.287$, $\gamma = 1.4$.

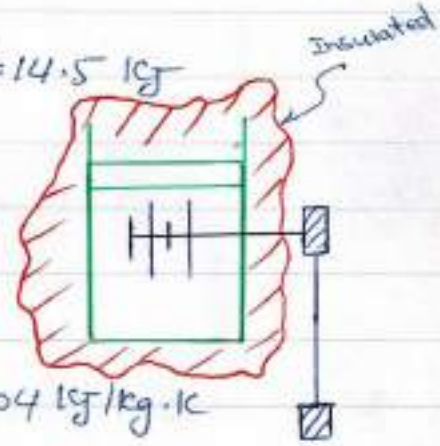
Sol: $Q = W + \Delta U + W_p$, $Q = 0$ (adiabatic)

$W = mR(T_2 - T_1) = 0.13 * 0.287 * (185 - 29) = 5.82$ kJ

$\Delta U = m C_v (T_2 - T_1)$

$C_v = \frac{R}{\gamma - 1} = \frac{0.287}{1.4 - 1} = 0.7175$

$\Delta U = 0.13 * 0.7175 * (185 - 29) = 14.5$ kJ



$Q = W + \Delta U + W_p$

$0 = 5.82 + 14.5 + W_p$

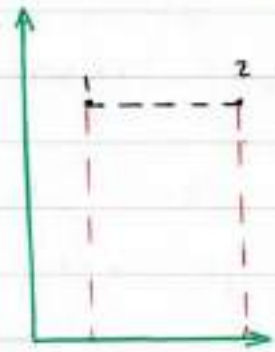
$W_p = -20.32$ kJ

$C_p = \gamma R / \gamma - 1 = \frac{1.4 * 0.287}{1.4 - 1} = 1.004$ kJ/kg.K

$\Delta H = m C_p (T_2 - T_1)$

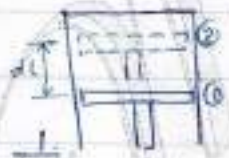
$= 0.13 * 1.004 * (185 - 29)$

$= 20.3$ kJ



Ex: Air at 1.02 bar and 22°C initialy occuping a cylinder of 0.015 m^3, is compressed reversibly and adiabaticaly by a piston to a pressure of 6.8 bar. Calculate the final volume, the final temperature and the work done on the mass of air in the Cylinder.

Sol: $Q = 0$ (adiabatic)



$\therefore \quad W = -\Delta U$

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$V_2 = \left(\frac{P_1}{P_2}\right)^{\frac{1}{\gamma}} \cdot V_1 = \left(\frac{1.02}{6.8}\right)^{\frac{1}{1.4}} * 0.015$

$= 3.86 * 10^{-3} \ m^3$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow$

$T_2 = \left(\frac{6.8}{1.02}\right)^{\frac{0.4}{1.4}} * (22+273)$

$= 507.25 \ K$

$\Delta U = m C_v (T_2 - T_1)$

$m = P_1 V_1 / RT = 1.02 * 10^2 * 0.015 / 0.287 * 295 = 0.018 \ kg$

$\Delta U = 0.01807 * 0.717 \ (507.25 - 295) = 2.749 \ kJ$

$W = -\Delta U = -2.749 \ kJ$

(Sheet No. 3)

Q1: Oxygen (molecular weight 32) expands reversibly in a Cylinder behind a piston at constant pressure of 3 bar. The initial volume is $0.01\ m^3$ and finaly is $0.03\ m^3$, the initial temperature is $17\ ^\circ C$. Calculate the work done by the Oxygen and the Heat flow to or from the Cylinder walls during the expansion. Take $C_p = 0.917\ kJ/kg \cdot K$.

Ans. [6 kJ , 21.25 kJ]

Q2: $0.05\ m^3$ of a perfect gas at 6.3 bar undergoes a reversible isothermal process to a pressure of 1.05 bar. Calculate the heat flow to or from the gas.

Ans. [56.4 kJ]

Q3: 1 kg of air at 1 bar, $15\ ^\circ C$ is compressed reversibly adiabatically to a pressure of 4 bar. Calculate the final temperature and the work done on the air.

Ans. [$155\ ^\circ C$, 100.5 kJ/kg]

Q4: 1 kg of air at 1.02 bar, $20\ ^\circ C$ is compressed reversibly according to a Law $PV^{1.3} = constant$, to a pressure of 5.5 bar. Calculate the work done on the air and the heat flow during the compression.

Ans. [$133.5\ \frac{kJ}{kg}$, $-33.38\ \frac{kJ}{kg}$]

Q5:- Nitrogen (molecular weight 28) expands reversibly in a perfectly thermally insulated Cylinder from 3.5 bar, 200°C to a volume of $0.09 m^3$. If the initial volume occupied was $0.03 m^3$, Calculate the work done during the expansion. Assume nitrogen to be aperfect gas and take $C_v = 0.741$ kJ/kg·K Ans. [9.31 kJ]

Q6: 0.05 kg of Carbon dioxide ($M = 44$), occupying a volume of $0.03 m^3$ at 1.025 bar, is compressed reversibly until the pressure is 6.15 bar. Calculate the final temperature, the work done on the CO_2, and the heat flow to or from the Cylinder walls.

a. When the process is according to a law $PV^{1.4} = C$.

b. " " " " isothermal.

c. " " " takes place in a perfectly thermally insulated Cylinder. $\gamma = 1.3$

Ans. [270°C, 5.138 kJ, 1.713 kJ, 52.6°C, 5.51 kJ, -5.51 kJ, 219°C, 5.25 kJ, 0 kJ]

Q7: 225 kg/h of air at 40°c enter amixing chamber where it mixes with 540 kg/h of air at 15°c. Calculate the temperature of the air leaving the chamber, assuming steady flow conditions. Assume that the heat loss is negligible.

Ans. [22.4°C]

Q8: Aquantity of gas occupying $0.14 m^3$ at a pressure of $1.4 MN/m^2$ and temperature of 300°C is expanded adiabatically to $280 kN/m^2$. $C_v = 0.74 kJ/kg.K$, $C_p = 1.04 kJ/kg.K$, determine:

a. the mass of gas
b. the temperature of the gas after expansion.
c. the work done during the expansion.

Ans. [a. 1.14 kg b. 87°C c. 180 kJ]

Process	P,V,T	Work(W)	Heat(Q)	Internal Energy (Δu)
Isometric V=C	$P_1/P_2=T_1/T_2$	0	$mC_v(T_2-T_1)$	$mC_v(T_2-T_1)$
Isobaric P=C	$V_1/V_2=T_1/T_2$	$P(V_2-V_1)$	$mC_p(T_2-T_1)$	$mC_v(T_2-T_1)$
Isothermal T=C	$P_1V_1=P_2V_2$	$PV.Ln(V_2/V_1)$	$PV.Ln(V_2/V_1)$	0
Adiabatic $Pv^{\gamma}=C$	$(T_1/T_2)=(V_2/V_1)^{(\gamma-1)}$ $=(P_1/P_2)^{(\gamma-1)/\gamma}$	$(P_1V_1-P_2V_2)/\gamma-1$ OR $mR(T_1-T_2))/\gamma-1$	0	$mC_v(T_2-T_1)$
Polytropic $Pv^n=C$	$(T_1/T_2)=(V_2/V_1)^{(n-1)}$ $=(P_1/P_2)^{(n-1)/n}$	$(P_1V_1-P_2V_2)/n-1$ OR $mR(T_1-T_2))/n-1$	$mC_v(\gamma-n/1-n)(T_2-T_1)$	$mC_v(T_2-T_1)$