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* Introduction:-

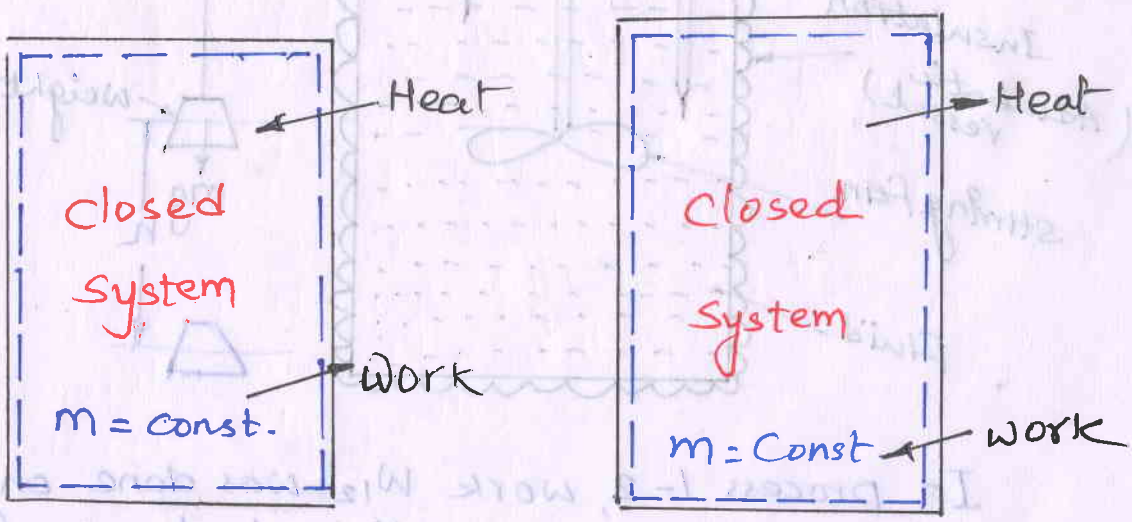
The first law can simply be stated as follow

" During an interaction between a system and its surroundings, the amount of energy gained by the system must be exactly equal to the amount of energy lost by the surroundings "

Energy gained by system = Energy lost by the surrounding

Energy can cross the boundary of a closed system in two forms: Heat and work

Energy which enters a system as heat and may leave the system as work or Energy which enters the system as work and may leave the system as heat as



* First Law of thermodynamics for a closed system undergoing a cycle

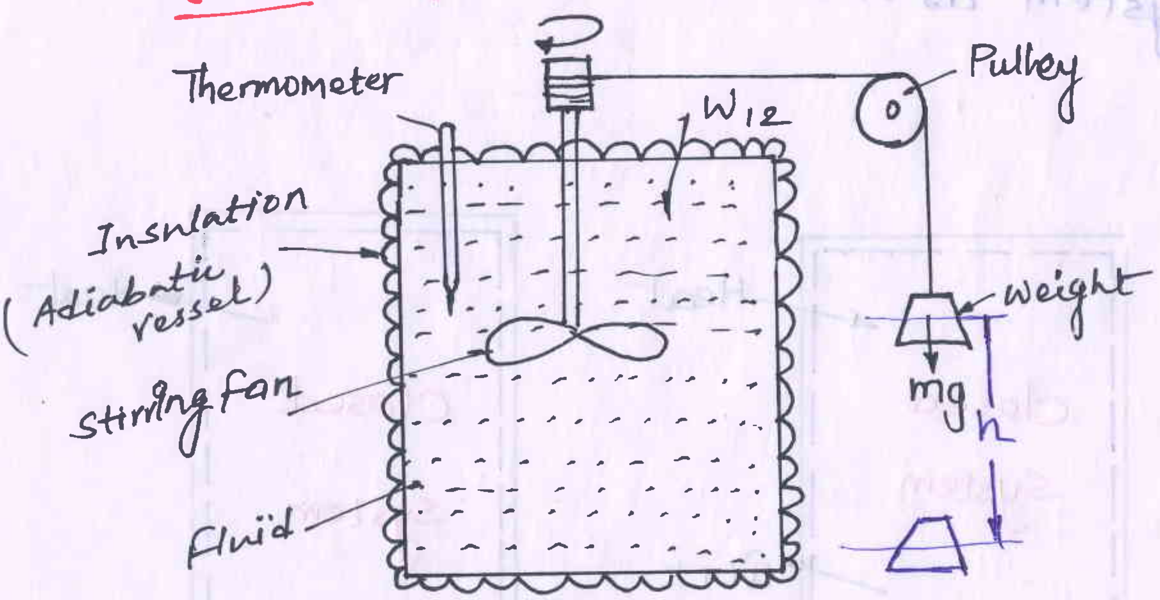
The first Law of thermodynamics can be stated as follows

1) "When a system undergoes a thermodynamic cycle then the net heat added to the system from the surroundings is equal to net work done by the system on its surrounding" or $\oint \delta Q = \oint \delta W$, where $\oint$ cyclic integration represents the sum for a complete cycle.

2) " Heat and work are mutually convertible but energy can neither be created nor destroyed, the total energy involved with an energy conversion remain constant.

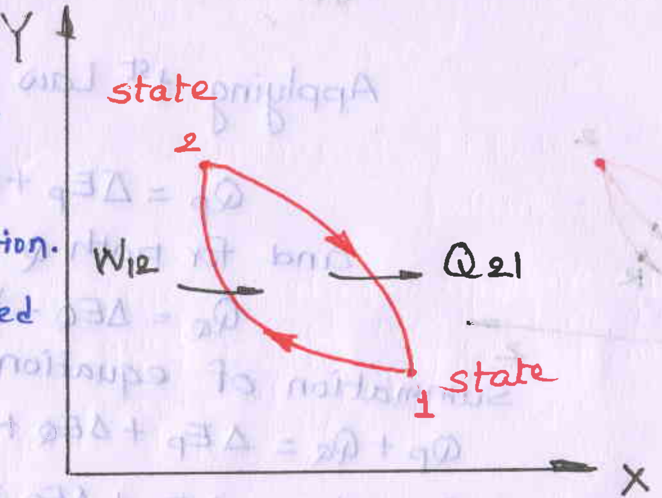
3) There is not any machine which can produce energy without corresponding source of energy

Joule's experiment



In process 1-2, work W_{12} was done on the system by means of a paddle wheel (by falling weight in downward and stirring fan rotates through wheel) The amount of work mg falling through a height h, caused a rise in the temperature of the fluid. The system was initially at temperature t_1, the same as that of atmosphere, and after work transfer, temperature rise t_2 at const. 1 atm

Then system was placed in contact with surroundings by removing insulation. Heat was transferred from the fluid to the surrounding in process 2-1, until the original state of the fluid was restored.



" The algebraic sum of net heat and work interactions between a system and its surrounding in a thermodynamic cycle is zero"

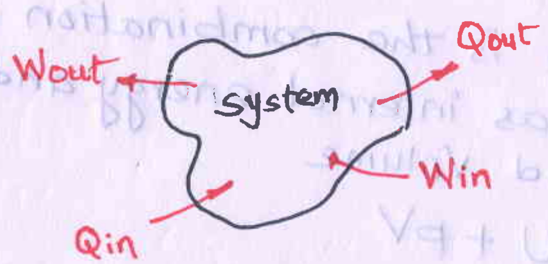
* First Law of thermodynamics for a closed system undergoing a change of state

$$\sum_{cycle} W = \sum_{cycle} Q$$

$$\oint \delta Q = \oint \delta W$$

→ Net Heat transfer

$\delta Q = Q_{out} - Q_{in}$



→ Net Work transfer

$\delta W = W_{out} - W_{in}$

$$\oint (\delta Q - \delta W) = 0$$

$$\oint (\delta Q - \delta W) = \oint x$$

[where X is point function
X Internal Energy
$\oint x = 0$]

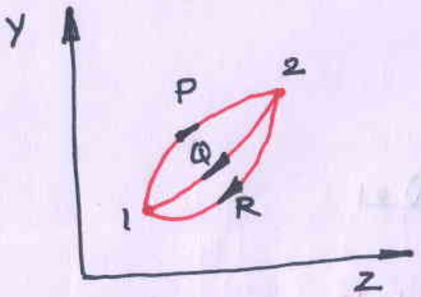
$$\delta Q - \delta W = dx$$

$$Q_{12} - W_{12} = \int_1^2 dE = E_2 - E_1$$

2.2

Internal Energy:- A property of a system where change in a process executed by the system equal to differance between the heat and work interaction by ~~ste~~ systen, with it surrounding

* Energy (Internal Energy) - A property of a system



Applying 1^{st} Law of Thermodynamic for path P

$$Q_P = \Delta E_P + W_P$$

and for path Q

$$Q_Q = \Delta E_Q + W_Q$$

summation of equation

$$Q_P + Q_Q = \Delta E_P + \Delta E_Q + W_P + W_Q$$

$$Q_P - W_P = \Delta E_P + \Delta E_Q + W_Q - Q_Q$$

The processes P and Q making cycle

$$\oint \delta Q = \oint W$$

$$W_P + W_Q = Q_P + Q_Q$$

$$Q_P - W_P = W_Q - Q_Q$$

$$\Delta E_P = -\Delta E_Q$$

Similarly, system is returned from state 2 to state 1 by following path R instead of path Q

$$\Delta E_P = -\Delta E_R$$

$$\therefore \Delta E_Q = \Delta E_R$$

* Enthalpy:-

The enthalpy is the combination of two properties as internal energy and produt of pressure and Volume

$$H = U + PV$$

Specific enthalpy (h) $= H/\text{mass}$

$$h = u + pv$$

→ enthalpy of constant pressure process

$$dQ = du + pdv$$

$$dQ = d(u + pv) = dh$$

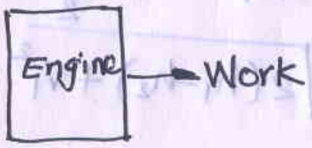
– enthalpy of constant volume process

$$dQ = du + pdv$$

$$dQ = du + 0 = du$$

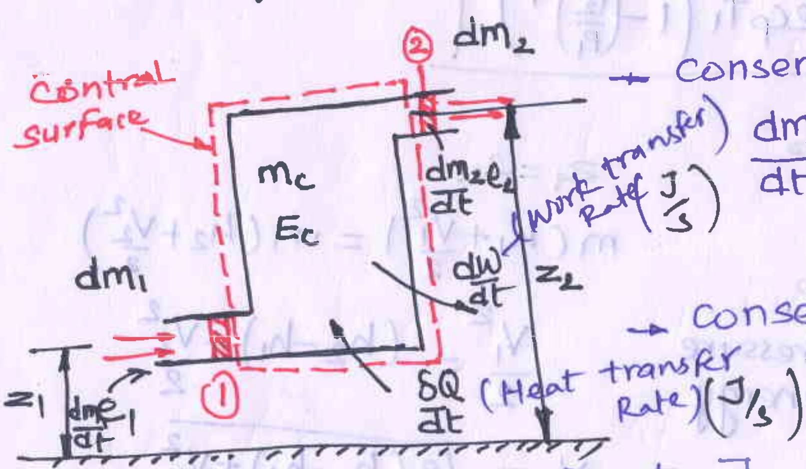
* Perpetual Motion Machine of first kind PMM-1

A device that violates the First Law of themodynamics is called a perpentual motion of the first kind (PMM-1)



The system or machine continuously produces mechanical work without receiving any energy, which violates the first law of thermodynamics states the general principple of the conservation of energy

* steady Flow Energy Equation



→ conservation of mass

$$\frac{dm_1}{dt} = \frac{dm_c}{dt} + \frac{dm_2}{dt}$$

→ conservation of energy

$$\begin{bmatrix}\text{Energy entering}\\ \text{to C.V}\end{bmatrix} + \begin{bmatrix}\text{Heat}\\ \text{entering}\\ \text{C.V}\end{bmatrix} = \begin{bmatrix}\text{Energy}\\ \text{Leaving}\\ \text{C.V}\end{bmatrix} + \begin{bmatrix}\text{work}\\ \text{transferred}\\ \text{from c.v.}\end{bmatrix} + \begin{bmatrix}\text{Increase}\\ \text{of energy}\\ \text{within c.v}\end{bmatrix}$$

$$\frac{dm_1}{dt} e_1 + \frac{\delta Q}{dt} = \frac{dm_2}{dt} e_2 + \frac{\delta W}{dt} + \frac{dE_c}{dt}$$

$$e = (\underbrace{u}_{\text{intermolecul energy}} + \underbrace{pv}_{\text{flow energy}} + \underbrace{\frac{V^2}{2}}_{\text{K.E.}} + \underbrace{gz}_{\text{Potential energy}})$$

2.3

where $e = \frac{E}{dm}$ Energy per unit mass, Internal Energy

steady flow process $\frac{dE_c}{dt} = 0$, $\frac{dm_c}{dt} = 0 \Rightarrow \frac{dm_1}{dt} = \frac{dm_2}{dt} = \frac{dm}{dt}$

$$\frac{dm}{dt}\left(u_1 + P_1 v_1 + \frac{V_1^2}{2} + gz_1\right) + \frac{\delta Q}{dt} = \frac{dm}{dt}\left(u_2 + P_2 v_2 + \frac{V_2^2}{2} + gz_2\right) + \frac{\delta W}{dt}$$

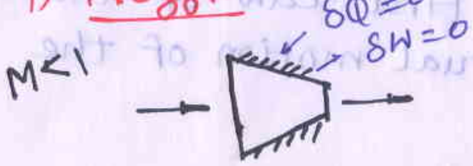
$\dot{m} = \frac{dm}{dt}$

$$\boxed{\dot{m}\left(h_1 + \frac{V_1^2}{2} + gz_1\right) + \frac{\delta Q}{dt} = \dot{m}\left(h_2 + \frac{V_2^2}{2} + gz_2\right) + \frac{\delta W}{dt}}$$

$$m\left(h_1 + V_1^2/2 + gz_1\right) + \delta Q = m\left(h_2 + V_2^2/2 + gz_2\right) + \frac{\delta W}{dt}$$

* Engineering application of steady flow energy Eq^n.

1) Nozzle



$z_1 = z_2$ (Axis of Nozzle Horizontal)

$$m\left(h_1 + \frac{V_1^2}{2}\right) = m\left(h_2 + \frac{V_2^2}{2}\right)$$

Pressure energy $\xrightarrow{\text{Conversion}}$ kinetic energy

$$\frac{V_2^2}{2} = (h_1 - h_2) + \frac{V_1^2}{2}$$

$$V_2 = \sqrt{2(h_1 - h_2) + V_1^2}$$

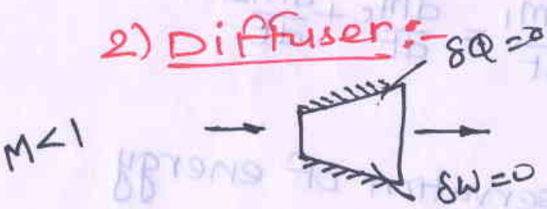
If $V_1 <<< V_2$

$$V_2 = \sqrt{2(h_1 - h_2)}$$

$$V_2 = \sqrt{2c_p(T_1 - T_2)} \qquad \left(\frac{P_2}{P_1}\right)^{\frac{r-1}{r}} = \left(\frac{T_2}{T_1}\right)$$

$$\boxed{V_2 = \sqrt{2c_pT_1\left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{r-1}{r}}\right)}}$$

2) Diffuser:-



$z_1 = z_2$

$$m\left(h_1 + \frac{V_1^2}{2}\right) = m\left(h_2 + \frac{V_2^2}{2}\right)$$

Kinetic energy $\xrightarrow{\text{conversion}}$ Pressure energy

$$\frac{V_1^2}{2} = (h_2 - h_1) + \frac{V_2^2}{2}$$

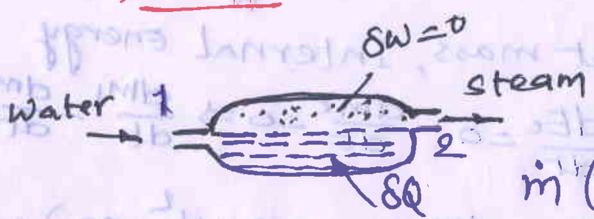
$$V_1 = \sqrt{2(h_2 - h_1) + V_2^2}$$

$$V_2 <<< V_1$$

$$V_1 = \sqrt{2(h_2 - h_1)}$$

$$\boxed{V_1 = \sqrt{2c_pT_1\left(\left(\frac{P_2}{P_1}\right)^{\frac{r-1}{r}} - 1\right)}}$$

3) Boiler:-



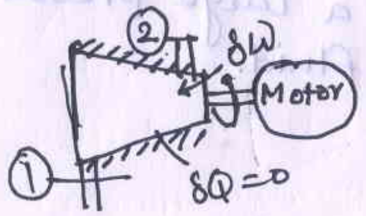
$z_1 = z_2$

$V_1 = V_2$ ($\because a_1 = a_2$, Area)

$$\dot{m}(h_1) + \delta Q = \dot{m}h_2$$

$$\boxed{Q_{12} = \dot{m}(h_2 - h_1)}$$

4) Compressor :-



$z_1 \triangleq z_2$

$V_1 \triangleq V_2$

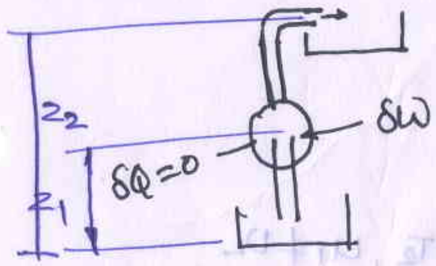
$\delta Q = 0$

$$m(h_1) + 0 = m h_2 + W_{12}$$

$$W_{12} = m(h_1 - h_2)$$

where $h_2 > h_1$ $\therefore$ W is negative

5) Centrifugal water pump



$$m\left(u_1 + P_1 v_1 + \frac{V_1^2}{2} + z_1 g\right) + 0$$
$$= m\left(u_2 + P_2 v_2 + \frac{V_2^2}{2} + g z_2\right) + \delta W$$

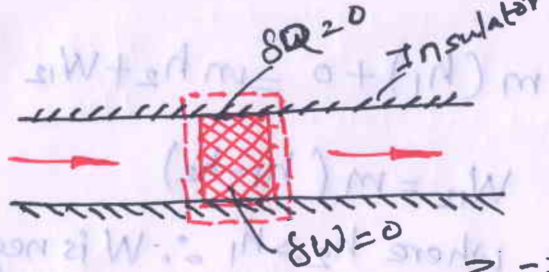
$$u_1 = u_2$$

$$m\left(P_1 v_1 + \frac{V_1^2}{2} + g z_1\right) = m\left(u_2 + P_2 v_2 + \frac{V_2^2}{2} + g z_2\right) + W$$

5

2-4

* Throttling device :-



It is the flow restriction device that cause a Large pressure drop in the fluid.

$$z_1 = z_2, \; V_1 = V_2$$

$$m\left(h_1 + \frac{V_1^2}{2} + g z_1\right) + \delta Q = m\left(h_2 + \frac{V_2^2}{2} + g z_2\right) + \delta W$$

$$m h_1 = m h_2 \Rightarrow h_1 = h_2$$

for ideal gas $h = C_p T$

$$C_p T_1 = C_p T_2$$

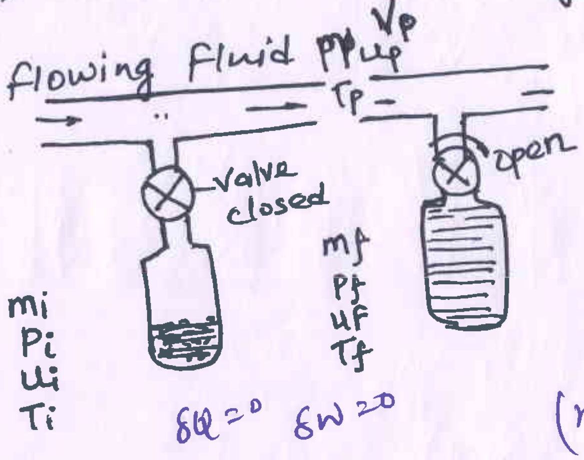
$$T_1 = T_2$$

for ideal gas $u = f(T)$

$u_1 = u_2$, for real gas $T_1 \neq T_2, \; u_1 \neq u_2$

$$u_1 + P_1 v_1 = u_2 + P_2 v_2$$

* Bottle or tank filling or Emptying process



$$e_p = \left(h_p + \frac{V_p^2}{2}\right)$$

Energy balance

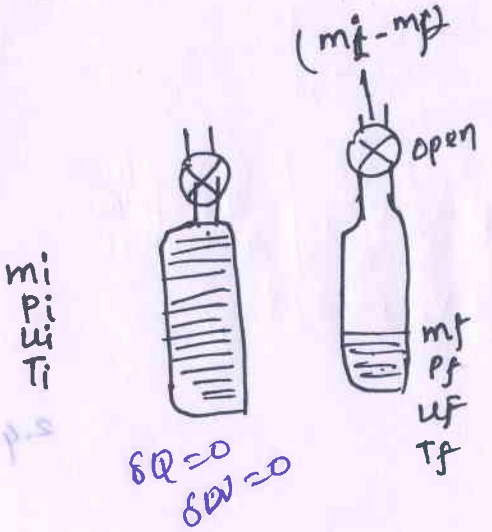
$$(m_f - m_i)\left(h_p + \frac{V_p^2}{2}\right) + Q = (m_f u_f - m_i u_i) + W$$

$$Q = 0 \quad W = 0$$

$$(m_f - m_i)\left(h_p + \frac{V_p^2}{2}\right) = m_f u_f - m_i u_i$$

$$(m_f - m_i) h_p = m_f u_f - m_i u_i \quad (KE = 0)$$

$$\boxed{m_f h_p = m_f u_f} \quad \begin{pmatrix} m_i = 0 \\ \text{empty} \end{pmatrix}$$



Energy balance

$$(m_f - m_i)\left(h_p + \frac{V_p^2}{2}\right) + Q = (m_f u_f - m_i u_i) + W$$

$$m_f u_f - m_i u_i = (m_f - m_i)\left(h_p + \frac{V_p^2}{2}\right)$$

$$\boxed{m_i u_i = m_i h_p} \quad (m_f = 0 \text{ fully empty})$$