Heat transfer

if non-adiabatic boundary ⇒ temp. between of system & surround dependent

from state 1 to state 2 → work depends on path

⇒ dw is inexact

dw depends on (state 1, 2 & Path)

For energy conservation between state 1 & 2 other form of energy must be involved as different path requires different work and the energy of final state is same.

⇒ This form of energy is done to temp. difference between system & surrounding

↓ defined as heat

heat a form of energy transfer across a boundary by virtue of a temperature difference

temp. difference act like → Potential difference or force

① Conduction :- heat transfer between two bodies in direct contact.

⇒ heat transfer by conduction.

② Radiation :- → heat transfer in two bodies seperated by empty space or gases (called radiation), via electromagnetic waves.

③ Connection :- heat transfer between a wall & a fluid system in motion.

direction of heat from high to low temp. +Q → −Q

energy transfer due to temp. difference → heat
other form of energy transfer → work

heat may not always cause temp. rise.
(eg. ice-melting, boiling etc)
temp. rise may happen due to work transfer.
work is not a property of system.

→ No heat transfer
adiabatic but work can be performed.
boundary

heat unit (SI) Joule
rate of heat / work kW or W

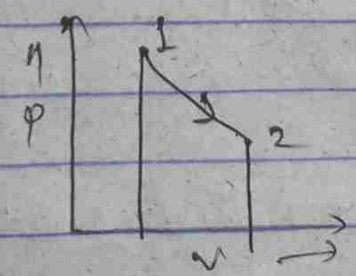
Heat transfer → a path function
heat flow quantified by → work flow

different work, different heat } but Q - W is conserved
Q - W is same for all path.

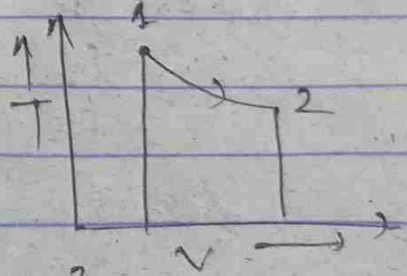
$$\int_1^2 dQ = Q_{1\to 2} \text{ or } {}_1Q_2$$

displacement work.

$$W_{1\to 2} = \int_1^2 p\,dV$$ → only valid in quasi-static process.



$$W_{1\to 2} = \int_1^2 p\,dV$$



$$Q_{1\to 2} = \int_1^2 T\,dS$$

it must also be valid for quasi-static process.

dQ is an inexact fn.

$$dQ = T dX$$

$$\Rightarrow \quad dX = \frac{1}{T} dQ$$

$X \longrightarrow$ extensive, exact fn.

Specific heat and latent heat

Specific heat → heat require to raise unit mass temp. by an unit

$$c = \frac{Q}{m \cdot \Delta t} \quad \left(J/kgK\right)$$

heat is not a property

⇒ specific heat quantified by exchange of heat

For gases

at constant pressure, C_p

at constant volume, C_v

$\Rightarrow mc \Rightarrow$ heat capacity

Latent heat ⇒ amount of heat require for phase change / mass. at constant pressure & temp.

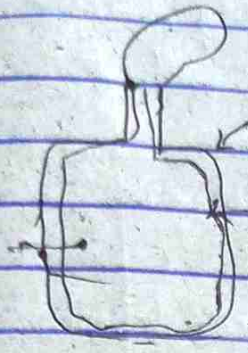
solid to liquid → fusion.

liquid to vapour → vapourization

solid to vapour → sublimation.

$V_i = 0$

$V_f = 0.5\ m^3$



work by ballon to atmosphere

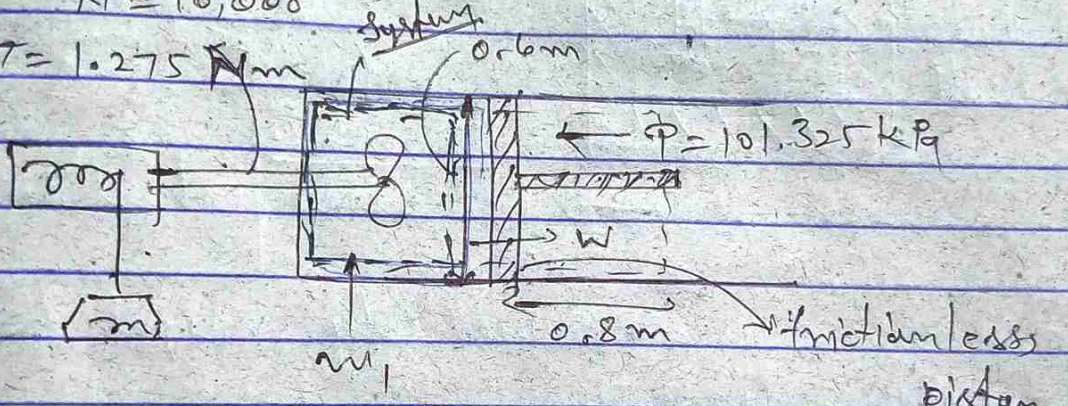
$$W_d = \int_{Ballon} pdv + \int_{Bottle} pdv$$

$$W_d = P_{atm}\,\Delta V$$

$$= 101.325 \times 0.5 = 50.66\ kJ$$

Ex. $N = 10{,}000$

$T = 1.275\ N\text{-}m$



stirring work on system

$= T\theta = 2\pi NT$

$= 2 \times \pi \times 10^4 \times 1.275$

$= 80\ kJ$

piston work by system -

$pdv = 101.325 \times 10^3 \times .8 \times \pi/4 (.6)^2$

$= 22.9\ kJ$

Net work on system

$= 57.1\ kJ$

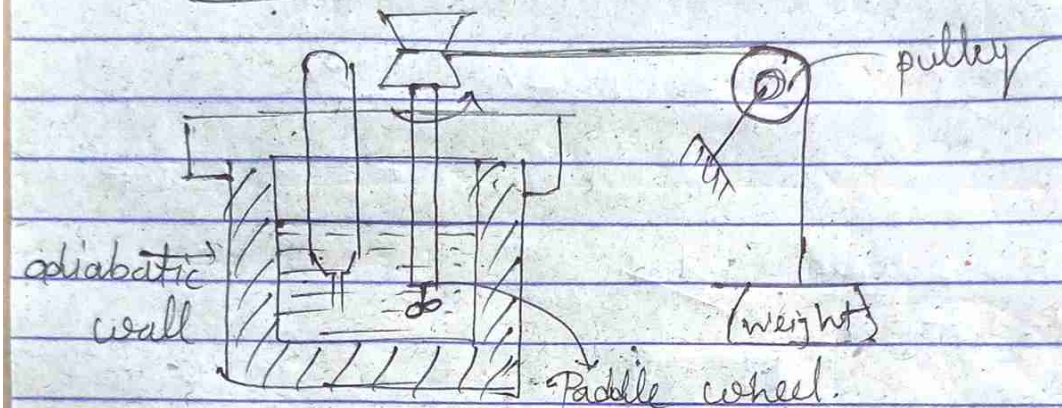
First Law of thermodynamics

First law for a closed system undergoing a cycle.

transfer of heat or work ⟶ may causes same effect

heat & work ⟶ energy, which is conserved

energy may enter system as heat and leave as work or vice-versa.



⟶ by paddle wheel on system

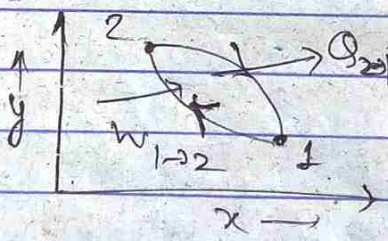
⇓

measured by weight fall

$T_i = T_1$

$T_f = T_2$

} P = Constant = 1 atm



1 to 2 by work thermally then open the system under heat 2 to 1

In cycle heat transfer ∝ work transfer

for many process

$$(\Sigma W)_{cycle} = J\,(\Sigma Q)_{cycle}$$

J ⟵ Joule's equivalent

$\oint dW = J \oint dQ$

in SI unit both work & heat has same unit $\Rightarrow$ $J = 1$ Nm/J

equivalence of work & heat

Joule $\rightarrow$ heat is a form of energy.

First law for a closed system undergoing A change of state.

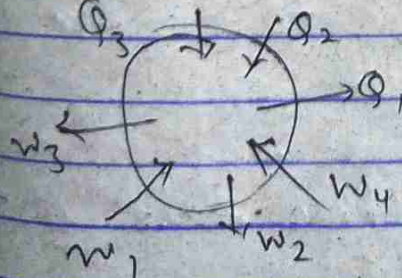
$(\Sigma W)_{cycle} = (\Sigma Q)_{cycle}$ $\rightarrow$ only in cyclic process.

if change in state
$\Rightarrow$ heat will be stored in the system
to
Q & W $\rightarrow$ heat & work transfer from/to system

Net energy to system is
$Q - W$ that is increase system energy

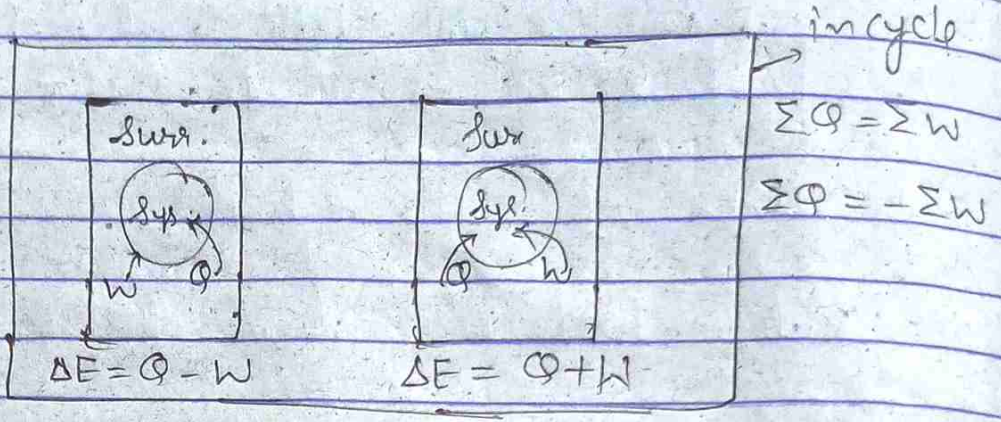
$Q - W = \Delta E$

$\Rightarrow Q = \Delta E + W$



$\Rightarrow Q_3 + Q_2 - Q_1$
$= \Delta E + (W_2 + W_3 - W_1 - W_4)$

$$Q + W = \Delta E$$



Energy - A property of the system :-

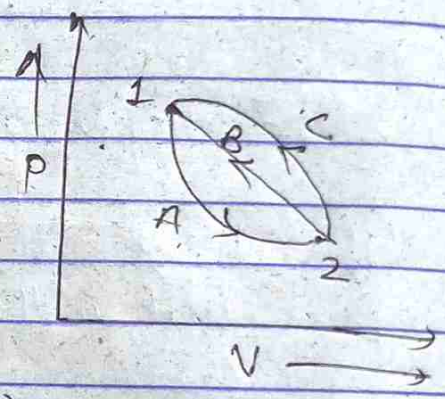
1 → 2 → 1

Cyclic process

$$\Delta E_A = Q_A + W_A$$

for path B.

$$\Delta E_B = Q_B + W_B$$



together $(\Sigma W)_{cycle} = (\Sigma Q)_{cycle}$

$$W_A + W_B = -(Q_A + Q_B)$$

together

$$(\Sigma W)_{cycle} = -(\Sigma Q)_{cycle}$$

$$W_A + W_B = -(Q_A + Q_B)$$

$$\Rightarrow W_A + Q_A = -(Q_B + W_B)$$

$$\Rightarrow \Delta E_A = -\Delta E_B$$

if system has taken path c to return

$$\Delta E_A = -\Delta E_C$$

$$\Rightarrow \Delta E_B = \Delta E_C$$

$\Rightarrow$ change in energy between two state is path independent.

energy for energy state is unique
and energy in point function.

E → extensive, but $\frac{E}{m} = e$ → intensive property

Different Forms of stored energy

Thermodynamic → Science of energy transfer & its effect on properties.

Energy is capacity of doing work.
it has two forms.

1. Energy in transit → work & heat (observed at boundary path fn.)
2. Energy in storage.
   - ~~Int~~ Internal energy (point fn.) define state.

hence, property of a system

U → internal energy → store energy.

two method

- macroscopic energy mode
  - macroscopic energy: K.E. $\left(\frac{mv^2}{2}\right)$ & potential energy
- microscopic energy mode
  - energy stored in the molecular & atomic structure (internal energy) (U)
  - translational, rotational K.E., vibrational, electronic energy, chemical & molecular energy

$$\varepsilon = \varepsilon_{trans.} + \varepsilon_{rot.} + \varepsilon_{vib.} + \varepsilon_{chem.} + \varepsilon_{electron} + \varepsilon_{nuclear}$$

if N is molecules.
then total internal energy = $N\varepsilon$

for ideal gas no intermolecular forces of attraction & repulsion.
then internal energy depends on temp. alone.

$U = f(T)$ → for an ideal gas

other form of energy.
→ magnetic energy, electrical energy & surface energy.
↳ in absence of these energies.

total energy $E = \underbrace{E_k + E_p}_{\text{macro}} + \underbrace{U}_{\text{micro}}$

in absence of motion & gravity.

$E_k = 0 \quad E_p = 0$

$$\Rightarrow \boxed{E = U}$$

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

in differential form

$$dU = dQ + dW$$

$dW = dW_{pdv} + dW_{shaft} + dW_{dielectric} + \dots$

⇒ when only pdv work.

$$dU = dQ - pdv$$

$$\Rightarrow \boxed{Q = \Delta U + \int pdv.}$$

Specific Heat at Constant volume

$$C_v = \left(\frac{\partial U}{\partial T}\right)_V$$ for constant volume process

$$(\Delta U)_v = \int_{T_1}^{T_2} C_v \, dT$$

Enthalpy

$$h = u + pv$$

↑ intensive

Internal energy change is equal to the heat transformed in a constant volume process involving no work other than pdv work. Constant pressure with no other work than pdv in such process. in a closed system.

$$dQ = du + pdv$$

$$(dQ)_p = du + d(pV) \rightarrow \text{Const. Pressure}$$

$$= d(u + pV)$$

$$= dh$$

$h = u + pV$ for ideal gas enthalpy

$h = u + RT$ → internal energy $f(T)$

$\Rightarrow h = f(T)$

total enthalpy $H = mh$ | $H = U + pV$

total enthalpy (Specific heat at Constant pressure)

specific heat at constant pressure (C_p)

rate of ↑ change of enthalpy with respect to temperature

$$C_p = \left(\frac{dh}{dT}\right)_p \text{ at constant pressure}$$

$$(\Delta h)_p = \int_{T_1}^{T_2} C_p \, dT$$

xx Energy of isolated system

$dQ = 0, \quad dW = 0$

$E = 0 \Rightarrow E = \text{Constant}$

Energy of isolated system is always constant.

Perpetual Motion machine of of the first kind (PMMS)

First Law → general energy conservation.

so No machine can provide work without some other form of energy disappearing.

similarly, no mechine consume work continously without some other form of energy appearing.

Eg. mass of gas compressed without friction.

initial state → final state

$0.3\ m^3$ & $0.105\ MPa$ → $0.15\ m^3$ & $0.105\ MPa$

$Q = 37.6\ kJ$

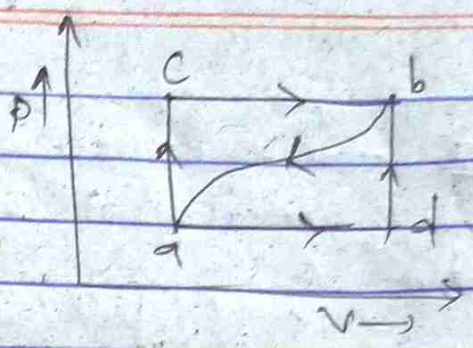
$\Delta U = ?$

$\Delta U = (\Delta Q)_{\text{into sys.}} + (\Delta W)_{\text{on sys.}}$

$= -37.6\ kJ - \int_{0.3}^{0.15} V dp$

$= -37.6\ kJ + 0.15 \times 1.05 \times 10^5$

$= -37.6 + 15.75 = -21.85\ kJ$



(a) state $a \rightarrow b$

along acb $\longrightarrow$ $Q = 84\,kJ$ (heat absorbed by system)

$W = -32\,kJ$ (work done by system.

$Q_{adb} = ?$ $\quad W_{adb} = -10.5\,kJ$

(b) $b \rightarrow a \rightarrow W_{b\rightarrow a} = 21\,kJ$

$Q_{b\rightarrow a} = ?$

(a) $\Delta U = Q + W = \underbrace{84 - 32}_{52} = -10.5 + Q_{adb}$

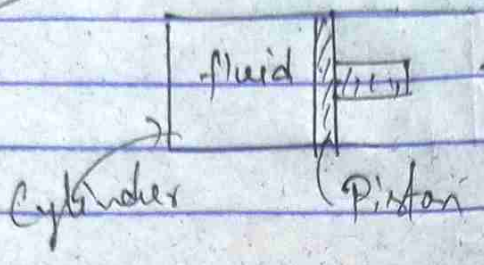
$\Rightarrow \quad Q_{adb} = 62.5\,kJ$

(b) $-\Delta U = -52 = Q_{b-a} + W_{b-a}$

$= 21 + Q_{b-a}$

$Q_{b-a} = -73.00\,kJ$

Ex-3:



→ undergoes a cyclic process contain 4 step.

During Cycle $\Sigma Q = -170$ KJ

process	Q (KJ/m)	W (KJ/m)	ΔE (KJ/m)
a - b	0	- 2170	- 2170
b - c	21,000	0	21,000
c - d	-2100	- 34,500	- 36,600
d - a	- 35,900	53,670	17,770

Rate of work

Output = 17000 KJ/min