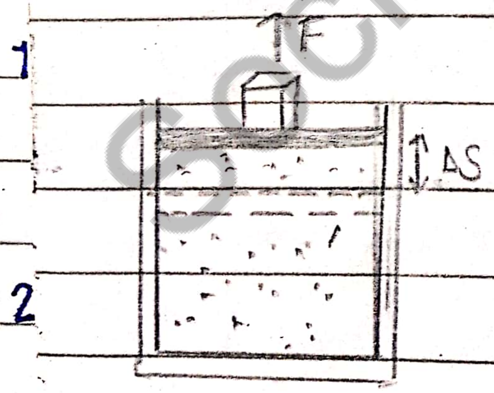
CHAPTER 10
THERMODYNAMICS

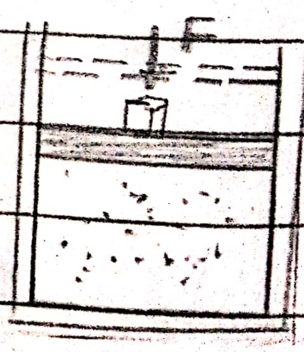
WORK

Work is defined as $\vec{F} \cdot \Delta\vec{S}$

TYPES OF THERMODYNAMIC WORK

WORK DONE BY THE SYSTEM	WORK DONE ON THE SYSTEM
when system as a whole expand system exert force on surrounding and displaces it	when the system as a whole contract
considered +ive	considered as -ive





HEAT, WORK AND THERMAL ENERGY

How heat, work and energy are closely related ?
Each one of them is fundamently related to temperature

Heat If the heat is given to a system, its temperature increases and if the heat is removed from the system, its temperature decreases

Work If we push the piston of the cylinder work is done on the system, it will hit the gas molecules, as a result K.E will increase which will increase the internal energy. This means, temperature will increase

Energy If heat energy is given to a system, the gas molecule will absorb the energy and increase their velocity, K.E will increase which will increase the internal energy and ultimately temperature will increase.

Work → Temperature ← Heat
↑
Energy

EQUIVALENCE OF HEAT

Count Rumford observed that heat could be produced in exhaustively by friction i.e mechanical work. He showed that heat liberated was not related with mass but mechanical work.

In 1845 Joule carried an experiment to measure very precisely the quantity of heat produced by a certain amount of mechanical work. He showed that when a given amount of work is done, the same amount of heat always produced, no matter what may be the process of transformation

given amount of work done $\Longrightarrow$ same amount of heat is produced

Work $\propto$ Quantity of heat

$$W \propto Q$$

$$W = JQ$$

J = Mechanical Equivalent of heat = Joule's constant

تاریخ ——————

Joule's Constant

"The ratio of the work done in joules to the heat produced in calories is called mechanical equivalent of heat"

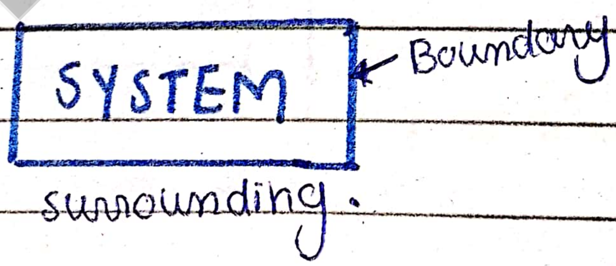
$$J = \frac{W}{Q} = \frac{J}{cal}$$

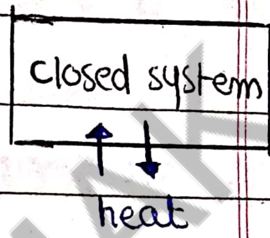
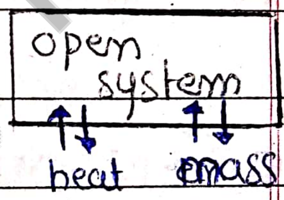
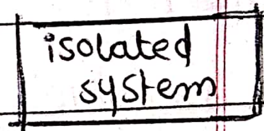
When 'Q' is measured in joule	When heat is measured in calorie
$J = \frac{W}{Q}$	$J = \frac{W}{Q}$
$J = \frac{1\ Joule}{1\ Joule}$	$J = \frac{1\ Joule}{0.239\ cal}$
$\boxed{J = 1}$	$\boxed{J = 4.18\ Joule/cal}$

THERMODYNAMIC SYSTEM

➡ A thermodynmic system is a system that include any thing whose thermodynamic properties are of interest.

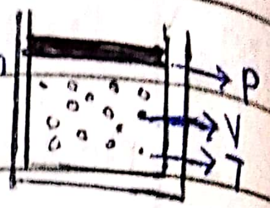
SYSTEM	SURROUNDING	BOUNDARY
The quantity of matter or region of space whose behaviour is being studied	Everthing other than system in the universe is called surrounding of the system.	A system is separated from surrounding by its boundary.



SYSTEM	MASS	HEAT	DIAGRAM
CLOSED SYSTEM	No transfer of mass across its boundary	Heat can be transferred from system to surrounding and vice versa	
OPEN SYSTEM	There is a transfer of mass across its boundary	transfer of energy can take place	
ISOLATED SYSTEM	No transfer of mass	No transfer of heat	
EXAMPLE			
	hot food in pressure cooker	boiling tea kettle	Tea contained in well insulating thermoflask

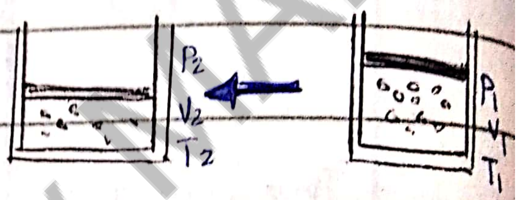
THERMODYNAMIC STATE

The particular condition when a system has specified value of pressure 'P', volume 'V' and temperature 'T' is called the state of the state



STATE VARIABLE

The variables or functions which determine physical state of the system are called state variables



HOMOGENEOUS SYSTEM	NON-HOMOGENEOUS SYSTEM
temperature, pressure & volume are the state variables.	state variables are composition of system, temperature, pressure and volume.

EQUATION OF STATE SYSTEM

$PV = nRT$ ⇒ ideal gas equation

The mathematical relationship b/w these state parameters is known as equation of state.

➡ Exact relation b/w these parameters is not known for solids, liquids & non-homogeneous substances

تاریخ ______

REVERISIBL PROCESS	IRREVERSIBLE PROCESS
A process is said to be reversible if it can be **retracted** exactly in reverse order without producing any in the surrounding	A process which **can not be retraced** in backward direction by reversing the controlling factors is said to be irreversible process.
It is **slow** process	It is **fast** process
There are **2 stages**, initial to final and final to initial	only **one stage** initial to final
It is in equilibrium in **all** stages	only initial and final stage is at equilibrium
Work obtained is **maximum**	Work obtained is **minimum**
Energy loss is **less**	Energy loss is **more**

FOR REVERSIBLE PROCESS

Initial State $\xrightarrow[Q+]{-W}$ Final State

- heat is added or absorbed (+Q)
- Work is done on the system (-W)

Final state $\xrightarrow[Q-]{+W}$ Initial State

- heat is given out (-Q)
- Work is done by the system (+W)

THERMODYNAMIC PROCESS

change in state of system brought about by a change in state variables. The process occurs when a system interact and exchange ener within surrounding.

CYCLIC PROCESS

A series of processes which bring the syst back to initial state is called cycle and the process is called cyclic process.

FIRST LAW OF THERMODYNAMICS

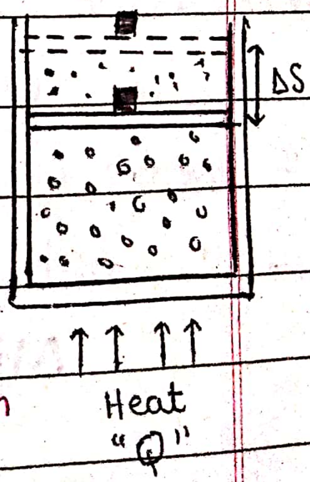
BASED ON: 1st law of thermodynamics is based on law of conservation of energy that energy can niether be created nor be destroyed.

⇒ It deals only with **heat energy**

STATEMENT

"In any thermodynamic process, when heat 'Q' is added to a system, this energy appears as in increase in the internal energy 'ΔU' stored in the system plus the work '**W**' done by the system on its surrounding"

MATHEMATICALLY



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

$$\Delta Q = (U_2 - U_1) + W$$

Heat is adding

$+Q \rightarrow$ $\boxed{\text{System}}$

heat is removed

$\boxed{\text{System}} \xrightarrow{-Q}$

Work done on the system

$-W \rightarrow$ $\boxed{\text{System}}$

Work done by system

$\boxed{\text{System}} \xrightarrow{+W}$

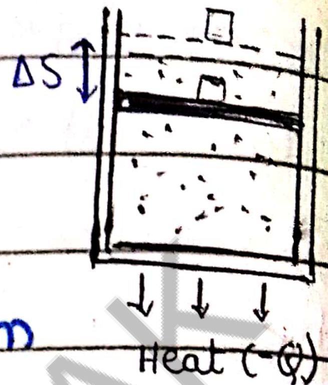
increase in 'U'

$+U \uparrow$ $\boxed{\text{System}}$

decrease in 'U'

$\boxed{\text{System}}$ $\downarrow -U$

When heat leaves the system internal energy will decrease, system will contract and work is done on the system then 1st law of thermodynamics can be written as:



$$\boxed{-Q = -\Delta U - W}$$

IMPORTANCE

1. The existance of an internal energy U as a state variable
2. The principle of conservation of energy
3. Heat as energy in transit

CHANGE IN INTERNAL ENERGY

change in internal energy of a system is equal to "energy flowing in as heat minus energy flowing out as work"

$$\Delta U = Q - W$$

- It is the energy **retained** by the system
When heat enters the system, a part of it is consumed in doing work and the remaining is internal energy $\Delta U = \Delta Q - \Delta W$

$70 - 100 - 30$

- Internal energy only depends upon the initial and final state of system.

Internal Energy of cyclic process is zero

~~If a state~~ $\Delta U = 0$

If a state of thermodynamics system is changed from state to state then change in internal energy of system is

$$\Delta U = U_B - U_A$$

U_A = initial internal energy

U_B = final internal energy

According to 1st law of Thermodynamics

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

$$\Delta U = \Delta Q - \Delta W \qquad [\because U_B - U_A = 0]$$

$$0 = \Delta Q - \Delta W$$

$$\Delta Q = \Delta W$$

→ All heat absorbed by system is used in doing work by the system.

ISOCHORIC PROCESS | ISOBARIC PROCESS

DEFINITION

Isochoric: The thermodynamic process during which **volume** of system remains constant

Isobaric: The thermodynamic process during which **pressure** is kept constant

CONSTRUCTION

A cylinder having (1) ideal gas (2) conducting base (3) insulating walls

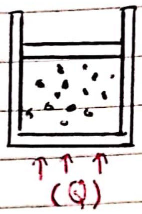
Isochoric: (4) Fixed insulating piston

Isobaric: (4) movable piston of cross-sectional area 'A'

WORKING

Isochoric:

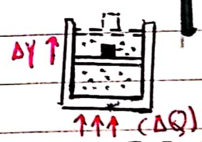
(1) heat is imparted to the gas 'ΔQ' (2) internal energy of the system increases due to which temperature increases (3) Force is exerted on the walls of the cylinder so internal pressure increases (4) Initial states of the system are P_1, V_1, T_1 which will change into P_2, V_1, T_2. Volume remains constant (5) system neither contracts nor expands, so work is neither done by the system nor on the system $\Delta W = 0$



Isobaric: we consider 2 cases:

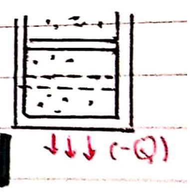
Isobaric expansion (work done by system)

heat is given to the system, internal energy increases and exert a force on the walls of cylinder, it will expands & piston moves upward. It cover some displacement ΔY so work is done



Isobaric compression

heat leaves the system $(-\Delta Q)$ internal energy decreases, gas will compress & piston will move downward, volume is reduced and system contracts so work is done on the system



MATHEMATICALLY

Isochoric:

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

$\Delta Q = \Delta U + 0 \Rightarrow \Delta Q = \Delta U$

Isobaric:

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

$\Delta Q = \Delta U + P(\Delta V)$

ΔV = increase in volume

$W = F \cdot d$

$W = (PA)(\Delta Y)$

$W = P(A\Delta Y)$

$W = P\Delta V$

CONCLUSION

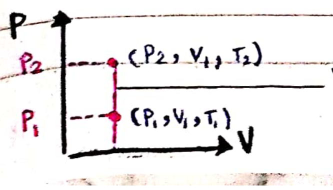
Isochoric:

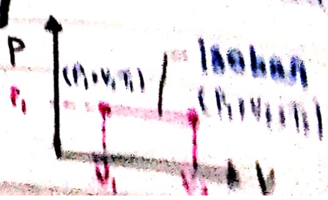
- The entire amount of heat supplied to gas is converted to internal energy.
- on adding heat to system, internal energy, pressure & temperature increase
- on removal of heat, internal energy decreases, system will cool down and pressure will fall.

Isobaric:

1. When gas expands, work is done by system, internal energy increases, temperature T_1 changes to T_2 and volume V_1 changes to V_2
2. When gas contracts, work is done on system, internal energy, temperature and volume decreases

P-V GRAPH





ISOTHERMAL PROCESS | ADIABATIC PROCESS

DEFINITION

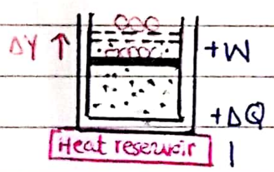
Isothermal Process	Adiabatic Process
The thermodynamic process in which **temperature** of system remains **constant**	The thermodynamic process during which **no heat** enters or leaves the system is called adiabatic process.

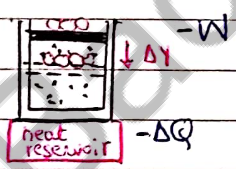
CONSTRUCTION

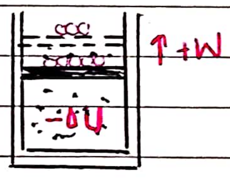
Isothermal Process	Adiabatic Process
A cylinder having **(1)** ideal gas **(2)** conducting base **(3)** Non-conducting walls **(4)** movable piston **(5)** heat reservoir at base of cylinder that mentains temp of gas at T_1	cylinder having **(1)** ideal gas **(2)** insulating wall, **(3)** insulating base **(3)** insulating movable piston

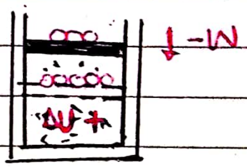
WORKING

Isothermal Expansion	Isothermal Compression	Adiabatic expansion	Adiabatic compression
let gas expand by decreasing pressure, internal energy of gas reduces which means its temperature is reduced so heat reservoir supply heat to gas so that temperature of system remains constant	The gas is compressed by increasing the pressure, piston will move downward, internal energy increases so temp increases. Heat reservoir allow the heat to leave so that temperature is mentained.	gas is expand by decreasing pressure so work done by the system, temp will decrease, internal energy decreases and the gas will be cooled	gas is compressed by increasing pressure so work is done on the system, temp will increase, internal energy increases, & gas will be heated









MATHEMATICALLY

Isothermal:

$\Delta Q = \Delta U + \Delta W$ $\qquad \Delta U = 0$

$\Delta Q = 0 + \Delta W$

$\Delta Q = \Delta W$

$V_1 < P_1$

$V_2 > P_2$

Adiabatic:

$\Delta Q = \Delta U + \Delta W$ $\qquad \Delta Q = 0$

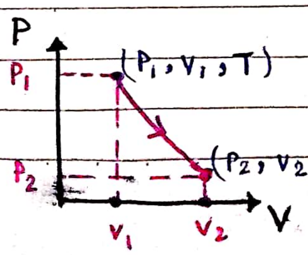
$0 = \Delta U + \Delta W$

$-\Delta U = \Delta W$

CONCLUSION

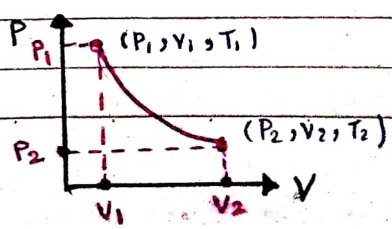
Isothermal Process	Adiabatic Process
1. If gas expand, work is done by the system, heat has to be supplied to the gas	**1.** If system does the work **+W** internal energy decreases $-\Delta U = \Delta W$
2. If gas contracts, work is done on system, heat has to leave the gas	**2.** If work is done on the system, then internal energy increases $\Delta U = -\Delta W$

P-V GRAPH



$P_1 > V_1$

$P_2 < V_2$



PRACTICAL EXAMPLES

ISOCHORIC PROCESS

1. Fire crackers.
2. Pressure cooker
3. Otto cycle (gasoline air-mixture is burnt in car's engine)

ISOBARIC PROCESS

1. Boiling of water
2. Freezing of water

ISOTHERMAL PROCESS

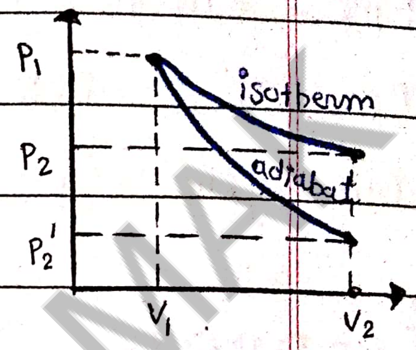
1. Refrigerator
2. heat pump

ADIABATIC PROCESS

1. Cloud formation in atmosphere
2. Abrupt burst of tire

Why curve of adiabatic process is steeper than the curve in isothermal process?

Initially at volume V_1 the pressure of both are same but at final volume V_2, the pressure of isothermal high whereas that of adiabat is very low. so due to variation in pressure curve of adiabat is steeper (sharp variation in temp)



Isothermal Process	Adiabatic Process
Initial states are P_1, V_1, T_1. When gas was expand, the pressure is decreased to P_2 and volume to V_2 while temp remains constant T_1	Initial states are P_1, V_1, T_1 when gas expands at volume V_2 pressure decreases to P_2', temp decreases to T_2 due to which internal energy decreases $T_2 < T_1$

MATHEMATICAL PROOF

$P_2 V_2 = nRT_1$	$P_2' V_2 = nRT_2$
$P_2 = \frac{nR}{V_2} T_1$	$P_2' = \frac{nRT_2}{V_2}$

$T_2 < T_1$

$P_2' < P_2$

تاریخ ________

MOLAR SPECIFIC HEAT OF GAS

DEFINITION (Heat capacity)

The amount of heat energy required to raise the temperature of any substance through a unit degree is called heat capacity

MATHEMATICALLY

$$\Delta Q \propto \Delta T$$

$$\Delta Q = C \Delta T$$

heat capacity = $\boxed{C = \frac{\Delta Q}{\Delta T}}$

UNIT

$J K^{-1}$

SPECIFIC HEAT CAPACITY

The amount of heat required to raise the temperature of a unit mass of a substance through unit degree is called specific heat capacity

MATHEMATICALLY

$$\Delta Q \propto \Delta T \quad \text{—— (1)}$$

$$\Delta Q \propto m \quad \text{—— (2)}$$

combining eq (1) and (2)

$$\Delta Q \propto \Delta T m$$

$$\Delta Q = c \Delta T m$$

$$c = \frac{\Delta Q}{\ldots}$$

UNIT

$J\,Kg^{-1} K^{-1}$

MOLAR SPECIFIC HEAT CAPACITY

The quantity of heat required to raise the tempe of **one mole** of a gas by **1K** is called mola specific heat.

MATHEMATICALLY

$$\Delta Q \propto \Delta T \quad \text{— (1)}$$

$$\Delta Q \propto n \quad \text{— (2)}$$

combining eq (1) and (2)

$$\Delta Q \propto \Delta T n$$

$$\Delta Q = C_M n \Delta T$$

$$\boxed{C_M = \frac{\Delta Q}{n \Delta T}}$$

C_m = molar specific heat capacity

UNIT = Joule mole^{-1} K^{-1}

MOLAR SPECIFIC HEAT AT CONSTANT VOLUME

The amount of heat required to raise the temperature of one mole of gas by **1K** while keeping its **volume constant**

$$\boxed{\Delta Q_V = n C_V \Delta T}$$

MOLAR SPECEFIC HE AT CONSTANT PRES

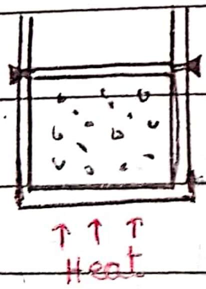
The amount of heat required to the temperature of one mole gas by **1K** while **keeping its pressure constant**

$$\boxed{\Delta Q_P = n C_P \Delta T}$$

Why $C_p > C_v$

AT CONSTANT VOLUME

When gas is heated at constant volume, its internal energy increases only but no work is done by the gas.



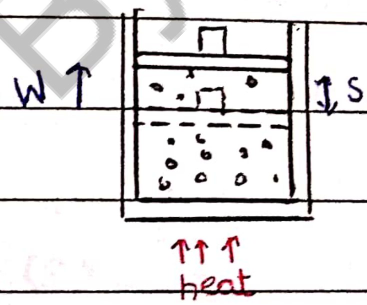
$$Q_v = \Delta Q_v$$

$$\Delta U = \Delta Q_v$$

$$\Delta U = C_v \Delta T$$

AT CONSTANT PRESSURE

When gas is heated at constant pressure, work is done with increase in internal energy. So more heat is required to get particular temperature.



$$Q_p = \Delta Q_v + W$$

$$\Delta U = \Delta Q_v$$

$$\Delta U = C_v \Delta T$$

At Constant Volume

If ΔQ_v is the amount of heat supplied and ΔT is the rise in temperature,

$$\Delta Q_v = nC_v\Delta T \quad \text{—— (1)}$$

According to 1st law of thermo-dynamics

$$\Delta Q_v = \Delta U + \Delta W_v$$

$$\Delta W_v = 0$$

$$\Delta Q_v = \Delta U + 0$$

$$\Delta Q_v = \Delta U \quad \text{—— (2)}$$

comparing eq (1) & (2)

$$\Delta U = nC_v\Delta T \quad \text{—— (3)}$$

At Constant Pressure

If ΔQ_p is the amount heat supplied and ΔT is rise in temperature,

$$\Delta Q_p = nC_p\Delta T$$

According to 1st law of thermodynamics

$$\Delta Q_p = \Delta U + \Delta W_p$$

$$\Delta W_p = P\Delta V = nR\Delta T$$

$$\Delta Q_p = \Delta U + nR\Delta T$$

$$nC_p\Delta T = nC_v\Delta T + nR\Delta T$$

Dividing both sides by $n\Delta T$

$$\frac{nC_p\Delta T}{n\Delta T} = \frac{nC_v\Delta T}{n\Delta T} + \frac{nR\Delta T}{n\Delta T}$$

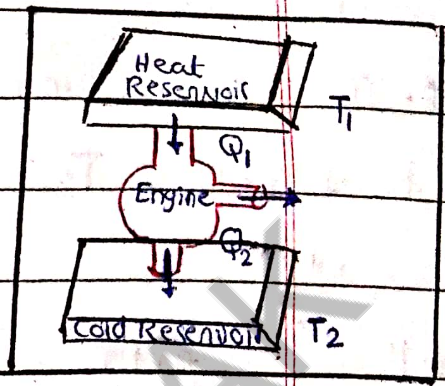
$$C_p = C_v + R$$

$$\boxed{C_p - C_v = R}$$

R = universal gas constant = 8.315 $J\,mol^{-1}K^{-1}$

تاریخ ______

HEAT ENGINE



DEFINITION A device that converts heat energy into mechanical work

Heat Energy → mechanical work

CONSTRUCTION

Heat Source or heat reservoir (HTR)

It is a source of heat energy and it is at high temperature T_1. Its temperature remains constant during transfer of heat in or out.

Heat Sink or cold reservoir (LTR)

It is a body at low temperature T_2. Its temperature remains constant.

Working Substance

Gas is used as working substance which is taken through cyclic process.

WORKING

1. Heat engine work b/w hot and cold body
2. Engine gains heat energy Q from HTM at temperature T_1

3. It converts part of heat energy into mechani[cal]
work
4. The remaining part Q_2 is rejected to LTR at
temperature T_2

→ Heat engine is made to operate in cyclic proc[ess]
to get continous steady mechanical energy

MATHEMATICALLY

In cyclic process
$\Delta U = 0$

According to 1st law of thermodynamics

$$\Delta Q = \Delta U + \Delta W$$
$$\Delta Q = 0 + \Delta W$$
$$\Delta Q = \Delta W$$
$$Q_1 - Q_2 = \Delta W$$

Q_1 = heat energy absorbed by heat engine to HT[R]
Q_2 = heat energy rejected by heat engine to LTR

EFFICIENCY OF HEAT ENGINE

The ratio of net work done to the heat absorbed by the engine

MATHEMATICALLY

$$\text{Efficiency} = \frac{\text{Work done by the engine}}{\text{Heat absorbed by the engine}}$$

$$\eta = \frac{\Delta W}{Q_1}$$

$$\eta = \frac{Q_1 - Q_2}{Q_1}$$

$$\eta = \frac{Q_1}{Q_1} - \frac{Q_2}{Q_1}$$

$$\eta = 1 - \frac{Q_2}{Q_1}$$

IDEAL CASE

If no heat exhausted by engine so that all the heat Q_1 absorbed were converted to work $(Q_2 = 0)$

$$\eta = 1 - \frac{0}{Q_1}$$

$$\eta = 1 - 0$$

$$\eta = 1$$

$$\eta = 1 \times 100$$

$$\eta = 100\%$$

2nd LAW OF THERMODYNAMICS

* 2nd law of thermodynamics gives the verificat
of 1st law of thermodynamics.
* specifies direction to flow of heat
* gives method for conversion of heat into work
* Based on natural law.

LORD KELVIN STATEMENT

"It is impossible to construct a heat engine, operating continu in a cycle which takes heat from heat sourc at higher temperature and performs an equiva amount of work without rejecting any hea to heat sink at low temperature."

RUDOLF CLAUSIUS STATEMENT

"It is impossible to cause heat to flow from a cold body to hot body without the expendiure of work"

work performed < heat absorbed

CARNOT HEAT ENGINE

In 1824 sadi carnot introduced a theoretical engine to improve efficiency of heat engine

CONSTRUCTION

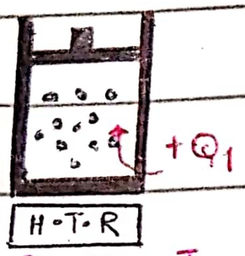
1. cylinder that contains gas with movable piston
2. Insulated piston and walls
3. conducting base.

CARNOT CYCLE

carnot engine operates in a cycle known as carnot cycle. It consists of 4 steps:

1. Isothermal Expansion
2. Adiabatic Expansion
3. Isothermal Compression
4. Adiabatic compression

ISOTHERMAL EXPANSION



$P_2, \frac{V_2}{2}, T_1$

1. The working system is at pressure P_1 volume V_1, temperature T_1

2. The gas is placed on H.T.R at T_1 absorbing heat +Q keeping temperature constant

3. By expanding the gas, pressure decreases from P_1 to P_2

4. Volume increases from V_1 to V_2

5. Temperature remain T_1

ADIABATIC EXPANSION

P_3, V_3, T_2

1. The working system is at pr
P_2 volume , temperature T_1

2. The gas cylinder is placed o
an insulating stand. No hea
enters or leaves the system

3. By expanding gas, pressure decreases from P_2 to P_3

4. Volume increases from V_2 to V_3

5. In this case work is done by the system so internal energy decrease and temp falls from T_1 t

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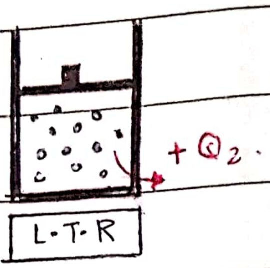
ISOTHERMAL COMPRESSION



P_4, V_4, T_2

...e working system is at
...re P_3, volume V_3 temp T_2

... gas cylinder is placed at
...R at T_2, rejecting heat
...gy $-Q$ keeping temp constant

... the gas compress, press-
... increases from P_3 to P_4

...olume reduces from
... to V_4

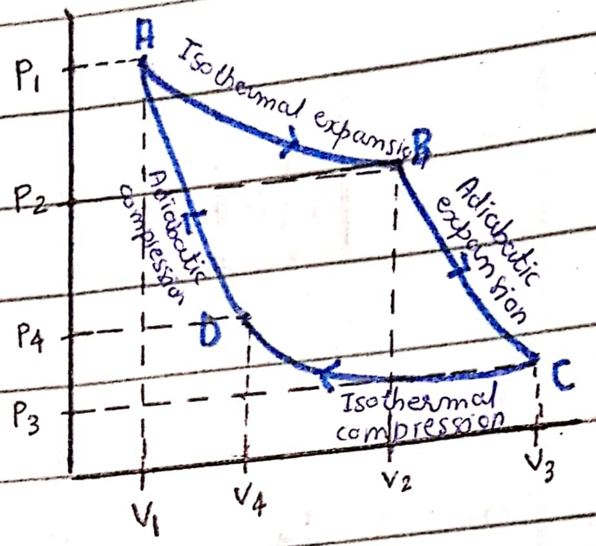
...emperature remain
...T_2

ADIABATIC COMPRESSION

P_1, V_1, T_1

1. The working system is at pressure P_4 volume V_4 tempe T_1
2. The gas cylinder is placed at insulating stand so no heat can enter or leave system
3. let the gas compress, pressure increases from P_4 to P_1 (return to its initial state)
4. volume reduces from V_4 to V_1
5. work is done on the system so internal energy increases due to which temp increases from T_2 to T_1

GRAPHICAL REPRESENTATION



EFFICIENCY

Q_1 = heat absorbed during isothermal expansion

Q_2 = heat rejected during isothermal compression

$$\Delta W = Q_1 - Q_2$$

Area ABCD = represent the work done by engine in one cycle.

$$\eta = \frac{\text{work obtained}}{\text{heat supplied}}$$

$$\eta = \frac{\Delta W}{Q_1}$$

$$\eta = \frac{Q_1 - Q_2}{Q_1}$$

$$\eta = \frac{Q_1}{Q_1} - \frac{Q_2}{Q_1}$$

$$\eta = 1 - \frac{Q_2}{Q_1}$$

$$\because \frac{Q_2}{Q_1} = \frac{T_2}{T_1}$$

$$\eta = 1 - \frac{T_2}{T_1}$$

- If ratio is small then efficiency will be greater
- If ratio is bigger then efficiency will be less

CARNOT THEOREM

STATEMENT-1

No heat engine is more efficient than carnot engine working b/w 2 same temperature.

STATEMENT-2

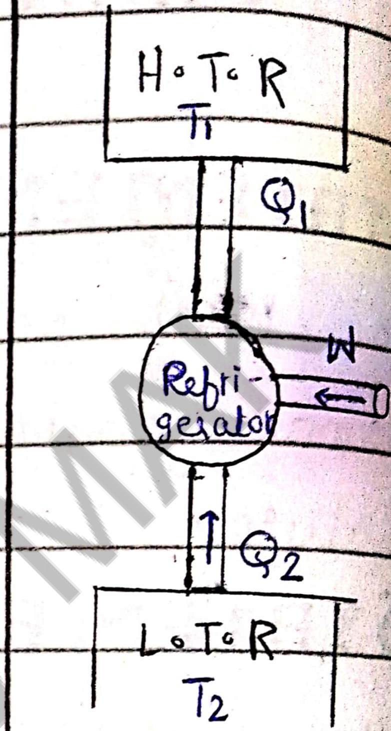
All carnot and reversible engine have same efficiency when they are working b/w 2 same temperature.

REFRIGERATOR

"The device which will either cool or ~~maintai~~ maintain a body temperature below that of surrounding is called refrigerating machine"

1. The working substance performs cycle in a direction opposite to that of a heat engine.
2. It takes heat from L.T.R and ejects it to H.T.R with expenditure of work.

WORKING



1. The amount of heat Q_2 is removed from L.T.R at temperature T_2

2. A work W is performed by the compressor of the refrigerator on the refrigenant

3. The quantity of heat Q_1 is rejected to H.T.R at temperature T_1

$$Q_1 = W + Q_2$$

4. $$Q_1 - Q_2 = W$$

CO-EFFICIENT OF PERFORMANCE

The ratio of amount of heat removed from the heat sink to the work required to do so.

COOLING ENERGY RATIO	HEATING ENERGY RATIO
$\eta_{cooling} = \frac{Q_2}{W}$	$\eta_{heating} = \frac{Q_1}{W}$
$\eta_{cooling} = \frac{Q_2}{Q_1 - Q_2}$	$\eta_{heating} = \frac{Q_1}{Q_2 - Q_1}$
$\eta_{cooling} = \frac{T_2}{T_1 - T_2}$	$\eta_{heating} = \frac{T_1}{T_2 - T_1}$

ENTROPY

DEFINITION

"The measure of randomness or disorderness of the system is called entropy."

Randomness $\propto$ Entropy

EXAMPLE

consider a container having gas molecules. When heat is given, the random motion of molecules will increase, disorderness will increase, which mean entropy will increase.

MATHEMATICALLY

$$\Delta S = \frac{\Delta Q}{T} = \frac{J}{K} = JK^{-1}$$

ΔQ = Amount of heat which system absorb or reject.

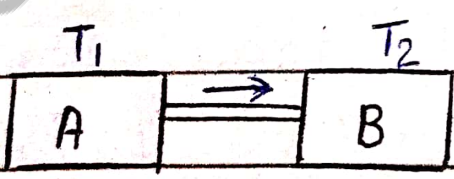
SIGN CONVENTION

- If heat is added = $+\Delta Q$ = Entropy ($+\Delta S$) increas
- If heat is rejected = $-\Delta Q$ = Entropy ($-\Delta S$) decrea

STATE FUNCTION

- Entropy is state function, independent of path followed
- Depends only on initial and final state of system $\Delta S = S_f - S_i$

EXAMPLE



consider 2 systems **A** and **B** having temperature T_1 and T_2 respectively. which are connected throug conducting rod. Heat flows from system A at temperature T_1 to system B at Temperature T_2. $T_1 > T_2$ so system A loses the heat and system B gains the heat.

$$S_1 = \frac{Q}{T_1} \qquad S_2 = \frac{Q}{T_2}$$

$$\Delta S = S_2 - S_1$$

$$\Delta S = \frac{Q}{T_2} - \frac{Q}{T_1} \qquad \frac{Q}{T_2} > \frac{Q}{T_1}$$

ΔS = positive (entropy increases)

natural process, the entropy will ways increase of the universe

$$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surrounding}$$

d LAW OF THERMODYNAMICS IN ERMS OF ENTROPY

If a system undergoes a natural process, t will go in the direction that causes e entropy of system plus the environment to increase"

REVERSIBLE PROCESS	**IRREVERSIBLE PROCESS**
Entropy = constant $\Delta S = 0$	Entropy increases

DEGRADATION OF ENERGY

In all natural processes, energy tends to pass from a more useful form to a less useful form. This is called "degradation of energy."

ADIABATIC EQUATION

According to 1st law of thermodynamics

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

$$0 = \Delta U + \Delta W$$

$$0 = \Delta U + P\Delta V$$

$$0 = nC_v \Delta T + P\Delta V$$

$$nC_v(\Delta T) = -P\Delta V$$

$$nC_v\left[\frac{\Delta PV}{nR}\right] = -P\Delta V$$

$W = F \cdot d$
$W = (PA)\Delta y$
$W = P\Delta V$

$PV = nRT$
$\Delta PV = nR\Delta T$
$\frac{\Delta PV}{nR} = \Delta T$

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$$C_v \frac{\Delta PV}{R} = -P\Delta V$$

$$C_v \frac{\Delta P}{P} = \frac{-\Delta V}{V} R$$

$$C_v \frac{\Delta P}{P} = -\frac{\Delta V}{V} (C_p - C_v) \qquad (\because C_p - C_v = R)$$

$$\frac{\Delta P}{P} = -\frac{\Delta V}{V} \left(\frac{C_p - C_v}{C_v} \right)$$

$$\frac{\Delta P}{P} = \frac{-\Delta V}{V} \left(\frac{C_p}{C_v} - \frac{C_v}{C_v} \right)$$

$$\frac{\Delta P}{P} = \frac{-\Delta V}{V} (\gamma - 1) \qquad \left(\because \frac{C_p}{C_v} = \gamma\right)$$

$$\frac{\Delta P}{P} = \frac{-\Delta V}{V}\gamma + \cancel{\frac{\Delta V}{V}} \rightarrow 0 \qquad \left[\frac{\Delta V}{V} \approx 0\right]$$

$$\frac{\Delta P}{P} = \frac{-\Delta V}{V}\gamma$$

Applying integration

$$\int \frac{\Delta P}{P} = -\gamma \int \frac{\Delta V}{V}$$

$$\ln P = -\gamma \ln V + \ln C$$

$$\ln P = -\ln V^{\gamma} + \ln C$$

$$\ln P + \ln V^{\gamma} = \ln C$$

$$\ln PV^{\gamma} = \ln C$$

$(\because \log A + \log B = \log A \times B)$

$PV^{\gamma} = C$

$PV^{\gamma} = \text{constant.}$