Unit 1 Energy Science PART-1

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Units and Scales of energy use :- The basic unit of energy is joule, the calorie has been defined in terms of the joule. The equivalence between the calorie and joule is historically known as the mechanical equivalent to heat.

1. Calorie :-

1 calorie is the amount of energuy neefed to raise the temperature od 1 gram water by 1 degree celcius

1 Calorie = 4.184 joule
1 cal = 4.184 joule
1 Kcal = 4184 joule

Energy is defined as the capability of doing work .
SI Unit of energy is Joule and can also be measured in calorie , KWh

2. Kilowatt Hour :- The kilowatt hour is standard unit of electricity production and consumption.

different types of energy are-
mechanical energy
thermal energy
nuclear energy
heat energy
light energy
electrical energy
gravitational energy
electromagnetic energy

1 Kilowatt = 1000 Watt

1 Kilowatt hour = 3600 × 1000
$= 3.6 \times 10^6$ joule

1 Kilowatt hour = $\frac{3.6 \times 10^6}{1055.00}$
= 3412 Btu

characteristics of energy -
1. it is available in different forms.
2. it can neither be creatd nor be destroyed
3. it can be transported from one place to another
4. it can be transformed from one form to another

3. British Thermal unit :- This is the english system analog of the calorie.

1 BTU is the amount of engy required to raise the temperature of 1 pound of water by 1 degree farenheit .
1 BTU = 252 CALORIE

1 Btu = 252 calorie
1 Btu = 252 × 4.184 joule
= 1054.08 Joule

Electric potential is the amount of work done in moving 1 coulimb of charge .SI unit is V (volt).
1V= J/C

4. Large scale units :- To define ~~natinal~~ national or Global energy budgets, it is common practice to use large-scale units based upon the joule, Btu and kWh.

A. Exajoule :- $1\ EJ = 10^{18}\ J$

B. Quadrillion Btu :- $1\ quad = 10^{15}\ Btu.$

$= 1.055\ EJ$

C. Terawatt-year :-

$$1\ TWYr = 10^{12} \times 365 \times 24$$
$$= 8760 \times 10^{12}\ Wh$$
$$= 8.76 \times 10^{12}\ KWh$$

Basic SI UNITS -
1. mass - kg
2. length - meter
3. time - second
4 . Electric current - Ampere
5. temperature - kelvin

Chemical energy is the energy stored in form of bonds between atoms and molecules.

Nuclear Energy is the energy stored in the nucleus of an atom

$$1\ TWYr = 8.76 \times 10^{12} \times 3.6 \times 10^{6}\ joule$$
$$= 31.54 \times 10^{18}\ joule$$
$$= 31.54\ EJ$$

$$1\ TWYr = 31.54 \times \frac{1}{1.055}\ quad$$
$$= 29.89\ quad.$$

World energy usage is about 300 quad/year, US is about 100 quad/year in 1996.

Mechanical Energy and Transport :- Mechanical energy is the sum of kinetic energy and potential energy. It is macroscopic energy associated with the system. The conservation of mechanical energy an isolated system is constant only for conservative force.

$$\text{Mechanical Energy} = \text{Kinetic energy} + \text{Potential energy}$$

(i) **Kinetic Energy** :- The kinetic energy depends on the speed of an object and is the ability of a moving object to do work on other objects when it collides with them.

the energy stored in a body when it is in motion .

$$\text{Kinetic energy} = \frac{1}{2} m v^2$$

(ii) **Potential Energy** :- The energy stored in an object due to its position and height is known as potential energy.

$$\text{Potential energy} = mgh.$$

The potential energy depends on the position of an object subjected to conservative force. It is defined as the object's ability to do work and is increased as the object is moved in opposite direction of the direction of the force.

$$\text{Potential energy} = -\int_{x_1}^{x_2} F \, dx$$

Mechanical energy can be transport into heat energy by heat energy into mechanical energy by first law of thermodynamics

$$\frac{W}{Q} = J = \text{Constant.}$$

Many devices are used to convert mechanical energy to other forms of energy. Electric motors converts electrical energy to mechanical energy, electric generator converts mechanical energy to electrical energy and heat engine converts heat energy to mechanical energy.

Heat Energy :- According to first law of thermodynamics it is expresses in term equivalence between mechanical work and heat energy.

" When a mechanical work is spent in producing heat, a definite quantity of heat is produced for every unit of work spent and conversely, when heat is employed to do work, the same definite quantity of heat disappears for every unit of work obtained". If W is the amount of work, then amount of heat Q that can be produced by it.

$$W = JQ$$

where $J = 4.184$ Joule / calories $= 4.184 \times 10^3$ Joule/calories and J is called the mechanical equivalent to heat.

Electromagnetic Energy :- Electromagnetic energy is a form of energy that is reflected or emitted from objects in the form of electric and magnetic waves that can travel through space. such as Radio waves, Radar waves, ultraviolet light, microwaves, Gamma Rays and x- Rays.

Sunlight is also a form of electromagnetic energy. Electromagnetic radiation is created from ~~objects in the~~ when an atomic particle, such as an electron is accelerated by an electric field, causing it to move.

The movement produces oscillating electric and magnetic fields, which travels at right angles to each other in a bundle of light energy called a photon.

Photons travel in harmonic waves at the fastest speed possible in the universe. Electromagnetic energy is given by.

$$U = \frac{1}{2}\epsilon_0 E^2 + \frac{1}{2}\mu_0 H^2$$

$$U = \frac{1}{2}\epsilon_0 E^2 + \frac{B^2}{2\mu_0}$$

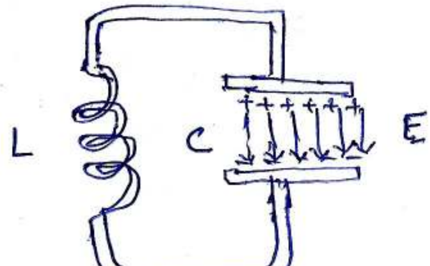
The transfer of energy by an electromagnetic wave is at right angles to both electric and magnetic components of the wave vibration and its rate is proportional to the vector product of their amplitudes as per poynting theorem.

$$S = E \times H$$

it is called poynting vector, and represent electromagnetic energy transported per unit area per unit time.

Electromagnetic Energy storange in L.C. circuit:-

LC circuits are circuits that contain inductors and capacitors, the energy stored with in an LC circuits oscillates back and force between the electric field of the capacitor and the magnetic field of the indicator. This oscillation is known as electro-magnetic oscillation.



The energy stored on a capacitor

$$U = \frac{1}{2}\frac{q^2}{C}$$

$$U = \frac{1}{2}CV^2 \quad (\because q = CV)$$

This energy is stored in the electric field.

The energy stored on a capacitor is in the form of energy density in an electric field is given by.

$$\eta_E = \frac{\text{Energy}}{\text{Volume}} = \frac{1}{2}\epsilon E^2$$

This can be shown to be consistent with the energy stored in a charged parallel plate capacitor.

$$\text{Energy} = \eta_E \cdot V$$
$$= \frac{1}{2}\epsilon E^2 \times Ad$$
$$= \frac{1}{2}\epsilon \frac{V^2}{d^2} \cdot Ad$$
$$= \frac{1}{2}\frac{\epsilon A}{d} V^2$$
$$= \frac{1}{2} C V^2$$

Energy in an Inductor, when a electric current is flowing in an inductors, there is energy stored in the magnetic field. The instantaneous Power which must be supplied to initiate the current in the inductor is

$$P = VI$$
$$= LI\frac{dI}{dt}$$

The energy ~~stored~~ input build to a final current I is given by the integral

$$\text{Energy Storage} = \int_0^t P\,dt$$
$$= \int_0^{I} LI'\,dI'$$

$$= \frac{1}{2} LI^2$$

Introduction to the quantum energy :- The free electrons in the atoms can only be found in certain discrete energy states. one of the implications of these quantized energy states is that only certain photon energies are allowed when electron jump down from higher energy levels to lower energy levels, producing the hydrogen atom spectrum - Quantum mechanics is an important tool to understand at the theortical level the electronic structure of chemical compounds and mechanism, thermodynamics and kinetics of chemical reactions.

The quantization of energy refers to the fact that at subatomic levels, energy is best thought of as occuring in discrete "packets" called photons, Each photons contains a unique amount of discrete energy

$$E = h\nu$$

Wave Particle Duality :- According to Plank's quantum theory, the energy of light is concentrated in small bundle called photon. Hence, light behaves as a wave and as a particle, this nature of light is called dual nature, while this property of light is known as wave particle duality.

Wave function and its significance :-

The quantity whose variation builds up matter waves is called wave function ψ. The probability of finding the particle at a given point is proportional to $|\psi|^2$ at that point and the probability of finding the particle ~~whin~~ within an element of volume $d\tau = dx\,dy\,dz$ is $|\psi|^2 d\tau$.

Since the particle is necessarily somewhere in space the integral over the whole space must be unity, that is

$$\int_{-\infty}^{\infty} |\psi|^2 d\tau = 1$$

A wave function ψ satisfying the above relation is called normalized wave function. Every acceptable wave function must be normalized.

Condition for wave function to be acceptable

(i) Normalised wave function must be singlevalued

(ii) It must be finite everywhere.

(iii) ψ must be continuous throughout the entire space of the system and have a continuous first derivative.

Schrodinger wave equation :-

Schrodinger wave equation is a fundamental equation in quantum mechanics and describes the variation of wave function ψ in space and time

$$-\frac{\hbar^2}{2m}\nabla^2\psi + V\psi = i\hbar\frac{\partial\psi}{\partial t} \quad \text{--- (1)}$$

Schrodinger time independent wave equation.

$$\nabla^2\psi + \frac{2m}{\hbar^2}(E-V)\psi = 0 \quad \text{--- (2)}$$

The solution of equation (1) becomes

$$\psi = f(x,y,z)\, e^{-iEt/\hbar} \quad \text{--- (3)}$$

The values of energy for which steady state equations can be solved, are called eigen values and the corresponding wave functions are called eigen functions.

The eigen values of energy.

$$E_n = \frac{n^2 h^2}{8mL^2} \quad \text{--- (4)}$$

It is ~~called~~ clear that particle can have only certain discrete energy corresponding to $n = 1, 2, 3, \ldots$ and corresponding eigen function:

$$\psi_n = \sqrt{\frac{2}{2}}\sin\frac{n\pi x}{L} \quad \text{--- (5)}$$

Particle in a box :- (i) The energy of a particle is quantized

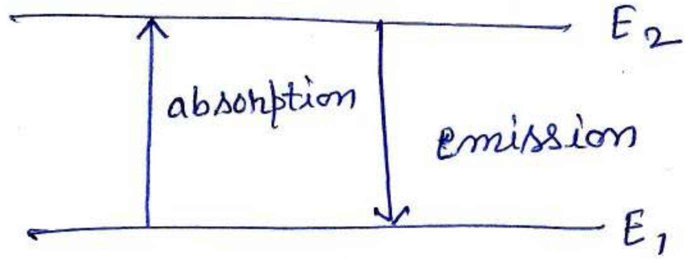
(ii) The lowest possible energy for a particle is not zero. This means that particle always has some kinetic energy.

(iii) The square of the wave function is related to the probability of finding the particle in a specific position for a given energy level.

Energy Quantization:- An atom or molecule can only have certain ~~fixed fixed~~ energies, energy is quantized and an atom and molecules can exist only in certain discrete levels.

The minimum energy is $\frac{1}{2}h\nu$, the molecule is always vibrating. It is never at rest. It has zero point energy, which must be allowed for many applications.

$$E_n = (n + \tfrac{1}{2}) h\nu$$



The Bohr-Einstein condition is

$$\Delta E = E_2 - E_1$$
$$\Delta E = h\nu$$

where h is Planck constant and ν is the frequency of light absorbed / emitted. $h\nu$ is called quanta of energy.

Energy in chemical Process and System :-

Energy plays a key role in chemical process. According to modern view in chemical reaction bonds between atoms in the reactant must be broken and atoms of piece of molecules are reassembled into product by forming new bond.

* chemical reaction often involves changes in energy due to the breaking and formation of bonds.

* In chemical reaction, heat energy released then it is called exothermic reaction while heat energy that take (absorb) is called endothermic reaction.

Exothermic Reaction :- In a chemical reaction that release heat energy surrounding its

for example :- combustion reaction reaction are usually exothermic.

$$\text{Reactant} \longrightarrow \text{Product} + \text{Heat}$$

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{Heat}$$

$$C + O_2 \longrightarrow CO_2 + \text{Heat}$$

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Heat}.$$

Endothermic Reaction :- In a chemical reaction that absorb heat energy from its surrounding is called endothermic reactions.

$$\text{Rectant} + \text{Heat} \longrightarrow \text{Product}.$$

$$N_2 + O_2 + \text{Heat} \longrightarrow 2NO$$

$$CaCO_3 \xrightarrow{\text{Heat}} CaO + CO_2$$

The energy change in chemical reaction is due to the difference in the amount of stored chemical energy between the product and reactant. this stored chemical energy or heat content of its system is known as enthalply (ΔH)

In exothermic reaction enthalpy is negative, and in endothermic reaction enthalpy is possitive.

$$\Delta H = H_{Products} - H_{reactant} < 0$$

$$\Delta H = H_{Products} - H_{reactant} > 0$$

~~Flow~~ of CO_2 :- carbon cycle is the process where carbon compounds are interchanged among the biosphere, geosphere, pedosphere, hydrosphere and atmosphere of the earth.

VVIP

Process of CO_2 cycle :- 1. carbon present in the atmosphere is absorbed by plants for photosynthesis (chemical process).

2. these plants are then consumed by animals and carbon get bioaccumulated in their bodies.

3. These animals and plants eventually die, and with time upon decomposing, carbon is released back into the atmosphere.

4. Some carbon that is not realised back into the atmosphere eventually becomes fossil fuels.

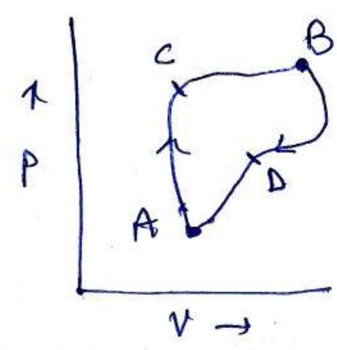
5. These fossil fuels are then used for human activities, which pumps more carbon back into the atmosphere.

Entropy :- The concept of entropy was first introduced by clausius, it is a very important thermodynamic quantity and very useful in the study of behaviour of heat engine. Entropy is the measure of a system thermal energy per unit temperature that is unavailable for doing useful work. Because work is obtained from orderd molecular motion, the amount of entropy is also a measure of the molecular disorder or randomness of a system.

$$S = K \log_e W$$

The available energy of universe tends to zero and decrease in available energy is equal to increase in entropy.

Entropy and Temperature :- Entropy of a system is a function of the thermodynamical coordinates defining the state of the system viz, the pressure temperature, volume or internal energy, and its change between two states is equal to the integral of the quantity dQ/T between the states along any reversible path joining them. The change in entropy.

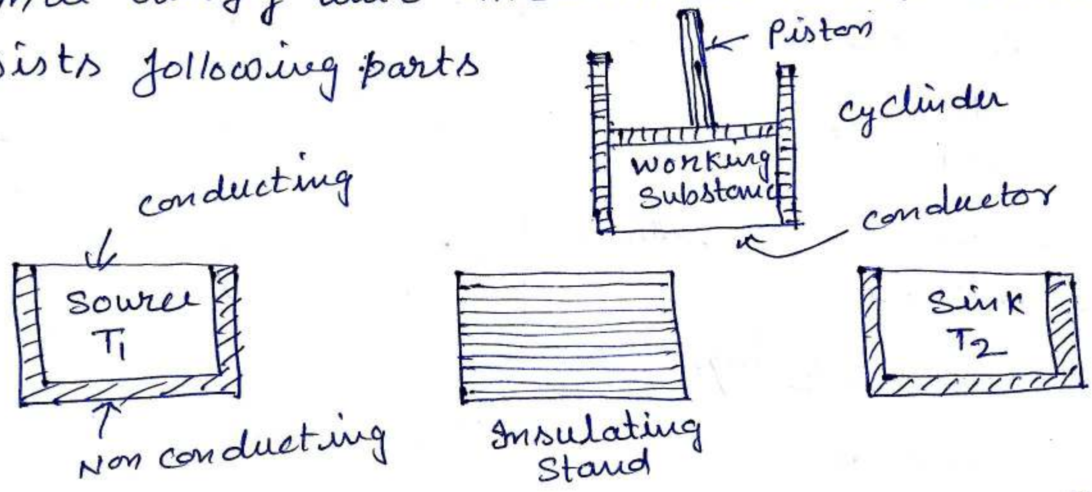


$$S_B - S_A = \int_A^B \frac{dQ}{T}$$

The entropy of a adiabatic reversible process is constant and in irreversible process is increase.

$\Delta S > 0$

Carnot Engine and carnot cycle :- It is theortical thermodynamics cycle proposed by Sadi carnot. It can be show that it is most efficient cycle for converting a given amount of thermal energy into mechanical work. Carnot engine consists following parts



(i) A cylinder with perfectly non-conducting walls but perfectly conducting base, containing air as the working substance and fitted with a perfectly isulating and frictionless piston.

(ii) A hot body of infinitely large heat capacity maintained at a constant high temp. T_1 absolute serving as the source of heat.

(iii) A cold body of infinitely large heat capacity. maintained at a lower constant temp T_2 absolute serving as the sink.

(iv) A perfectly insulating platform serving as a stand for the ~~pis~~ cylinder.

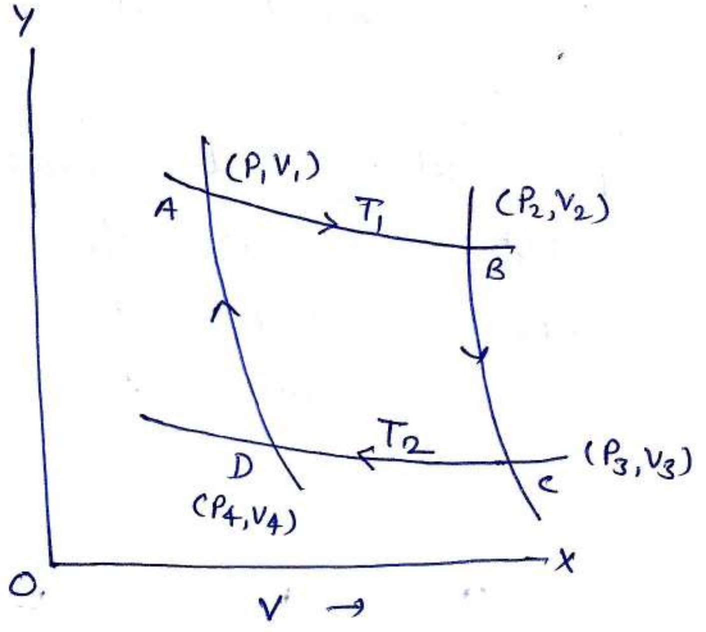
The working substance is subjected to a cycle of four operations, two isothermal and two adiabatic operations. Such cycle is known as carnot cycle and is represented on the P-V diagram.

(i) The work done in isothermal process $A \rightarrow B$

$$W_1 = Q_1 = RT_1 \log_e \frac{V_2}{V_1} \quad \text{---(1)}$$

(ii) The work done in adiabatic process $B \rightarrow C$

$$W_2 = \frac{R}{1-\gamma}\left[T_2 - T_1\right] \quad \text{---(2)}$$



(iii) The work done in isothermal process $C \rightarrow D$

$$W_3 = Q_3 = RT_2 \log_e \frac{V_4}{V_3} \quad \text{---(3)}$$

(iv) The work done in adiabatic process $D \rightarrow A$

$$W_4 = \frac{R}{1-\gamma}\left[T_1 - T_2\right] \quad \text{---(4)}$$

The total work done in carnot cycle.

$$W = W_1 + W_2 + W_3 + W_4$$

$$W = RT_1 \log_e \frac{V_2}{V_1} + \frac{R}{1-\gamma}\left[T_2 - T_1\right] + RT_2 \log_e \frac{V_4}{V_3} + \frac{R}{1-\gamma}\left[T_1 - T_2\right]$$

$$W = RT_1 \log_e \frac{V_2}{V_1} - RT_2 \log_e \frac{V_3}{V_4} \quad \text{---(5)}$$

The point A, D and B, C are same adiabatic curve.

$$T_1 V_1^{\gamma-1} = T_2 V_4^{\gamma-1}, \qquad T_1 V_2^{\gamma-1} = T_2 V_3^{\gamma-1}$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_4}\right)^{\gamma-1} \qquad \frac{T_2}{T_1} = \left(\frac{V_2}{V_3}\right)^{\gamma-1}$$

then $\left(\frac{V_1}{V_4}\right)^{\gamma-1} = \left(\frac{V_2}{V_3}\right)^{\gamma-1}$

$$\frac{V_2}{V_1} = \frac{V_3}{V_4}$$

The work done in carnot cycle

$$W = RT_1 \log \frac{V_2}{V_1} - RT_2 \log \frac{V_2}{V_1}$$

$$= R \log \frac{V_2}{V_1}\left[T_1 - T_2\right]$$

$$= R(T_1 - T_2) \log \frac{V_2}{V_1}$$

The efficiency of carnot engine

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

$$= \frac{R(T_1 - T_2)\log_e \frac{V_2}{V_1}}{RT_1 \log_e \frac{V_2}{V_1}}$$

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

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

Stirling Engine :- It is a device that converts heat energy to mechanical work by alternately compressing and expanding a fixed quantity of working fluid at different temperatures. fluid gas remains inside the system and it is displaced from the hot side to the cool side and vice versa when the engine is operating. There is no exhaustion like normal petrol engine, the engine works very quietly. The compressible gas can be air, hydrogen, helium, nitrogen or even vapour depending on the design of the engine. Any source of heat can power the engine, from solid coal to oil and solar energy, only the heat source must be adjusted to the engine.

This engine offers the possibility for having high efficiency with less exhaust emission in comparison with the internal combustion engine. The Striling engine has high performance in many applications.

The cycle of a striling engine has four phases.

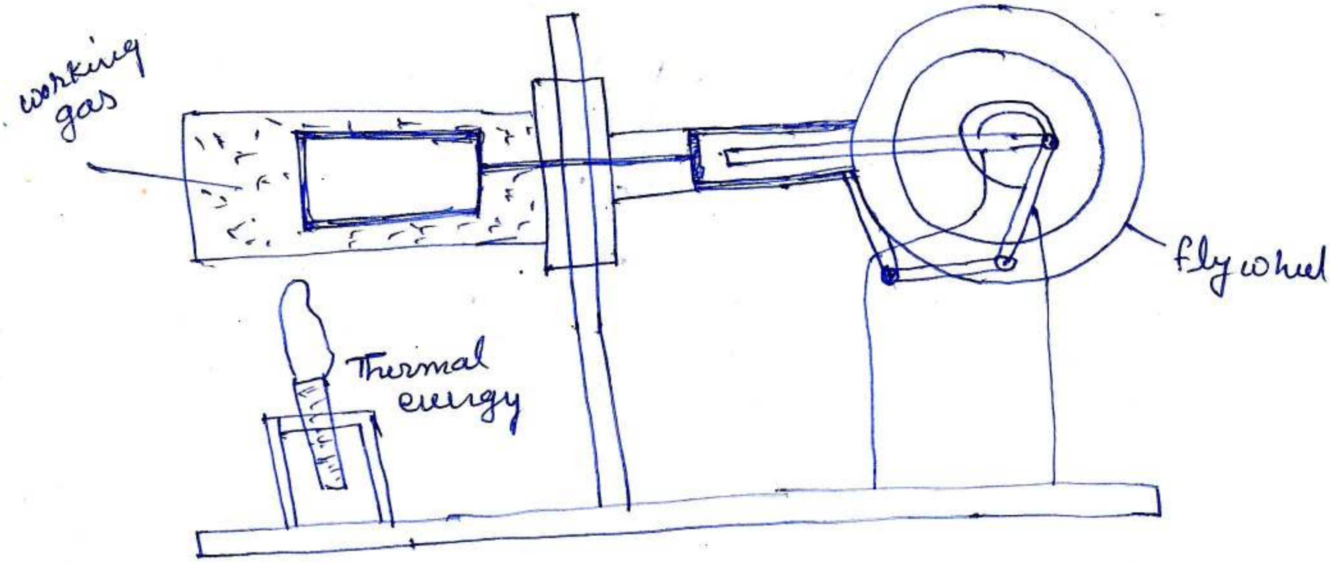
(i) Heating :- Heat source provides energy to the engine so that it raises pressure and temp. of gas

(ii) Expansion :- In this process the volume increases, but pressure and temp decreases, mechanical energy is produced from heat energy.

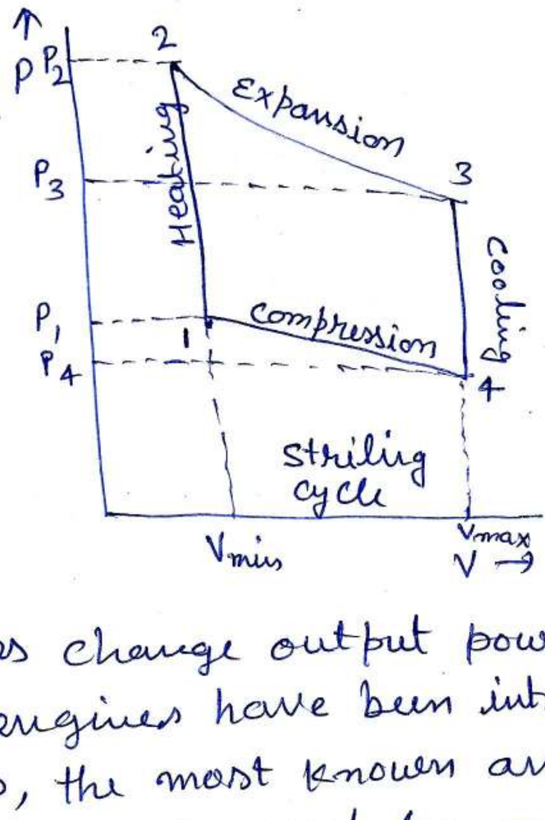
(iii) Cooling :- The gas is ~~coo~~ cooled then pressure and temp. decrease, so the gas is prepared to be compressed during this process.

(iv) Compression :- The pressure of gas increases whereas its volume decrease, a part of produced mechanical energy is used for processing of this cycle-

Diagram of striling engine is given



The P-V diagram of striling engine is given by.



The striling cycle energy is

$$E = PV$$
$$E = nRT = \text{constant}$$

The striling cycle energy depends on pressure and volume, so any change in these two main parameters change output power of engine. The striling engines have been introduced for different purposes, the most known and practical models are Alpha, Beta and Gamma. the working mechanism of all the three is the same, but each type has individual designation.

Phase change Energy conversion :- The amount of heat energy observed by a unit mass of substance in change of its phase (such as from solid to liquid or from liquid to gas) at a constant temperature is called latent heat. The latent heat is given by

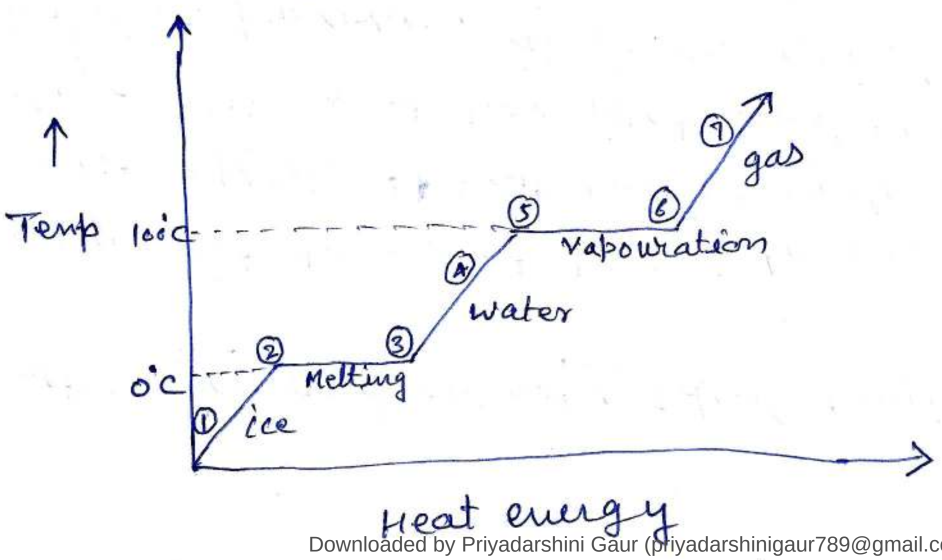
$$dQ = mL$$

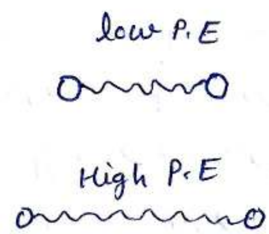
When a substance changes its phase from solid to liquid or liquid to gas at constant pressure its volume increase. Hence a part of heat energy observed is used up in increasing against the external pressure and rest of the heat energy is used in increasing its internal potential energy. There is no change in internal kinetic energy of the substance since temperature remains constant. The work done in increasing it's volume.

$$dW = P\,dV$$

The clausius clapeyron equation of phase change

$$\frac{dP}{dT} = \frac{L}{T(V_2 - V_1)}$$





Internal Combustion Engine :- The engine in which the combustion takes place inside the engine or within the cylinder are known as internal combustion engine. I C engines are two types -

(1) **Otto Engine** :- absorbed heat at constant volume.

(2) **Diesel Engine** :- absorbed heat at constant pressure.

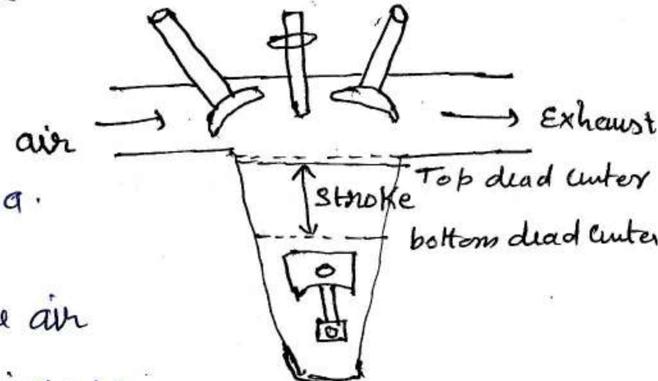
(1) **Otto Engine** :- An Ideal thermodynamic cycle which makes your gasoline fuelled Car to move and speed up by performing a four piston strokes of the the car's engine.

(i) cylinder :- The space to which the piston travels up and down.

(ii) Top dead Center :- Farthest point when the piston's ~~downward~~ upward travel.

(iii) Bottom dead Center :- Farthest point when the piston's downward travel.

(iv) Stroke :- The point when the piston travels from bottom dead center to top dead center or vice-versa.



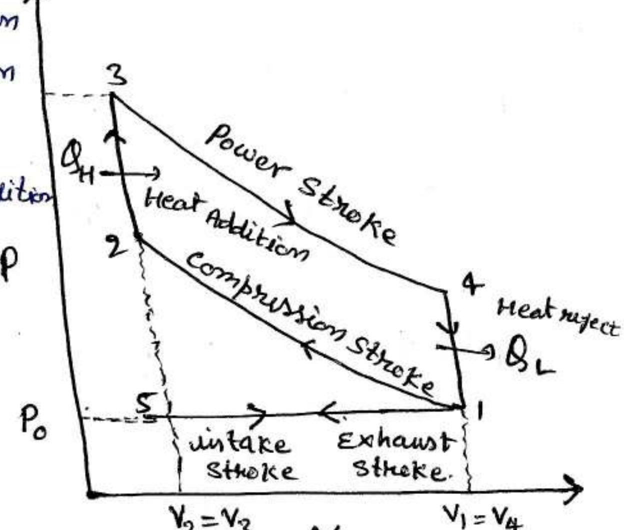
(v) Intake valve :- Introduces the air and gasoline mixture into the cylinder.

(vi) Exhaust Valve :- evacuates the unburned gasses from the Cylinder.

cycle of otto engine :- The otto cycle is a set of process used by spark ignition internal combustion engine

Process → 1 → 2] adiabatic compression
3 → 4] adiabatic Expansion

Process → 2 → 3 Isochoric Heat Addition
4 → 1 Isochoric heat release



Efficiency of otto engine :-

Ideal otto cycle

$$\eta = 1 - \frac{Q_L}{Q_H} = 1 - \frac{m c_v (T_4 - T_1)}{m c_v (T_3 - T_2)} = 1 - \frac{T_4 - T_1}{T_3 - T_2}$$

we know that Process 3 → 4 is adibatic ~~compression~~ expansion then -

$$T_3 V_2^{\gamma - 1} = T_4 V_1^{\gamma - 1} \quad \text{—— (A)}$$

Process 1 → 2 is adiabatic compression.

$$T_1 V_1^{\gamma - 1} = T_2 V_2^{\gamma - 1} \quad \text{—— (B)}$$

$$(T_4 - T_1) V_1^{\gamma - 1} = (T_3 - T_2) V_2^{\gamma - 1}$$

$$\frac{T_4 - T_1}{T_3 - T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma - 1} = \left(\frac{1}{\rho}\right)^{\gamma - 1}$$

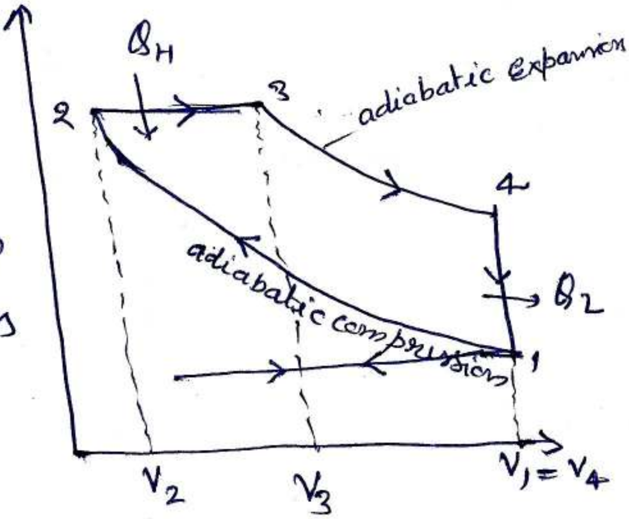
where $\rho = \frac{V_1}{V_2}$ is called compression ratio.

$$\eta = 1 - \left(\frac{1}{\rho}\right)^{\gamma - 1}$$

Diesel cycle :- Diesel cycle is a compression ignition (rather than spark ignition) engine. fuel is sprayed into the cylinder at P_2 (pressure high). When the compression is complete, and there is ignition without a spark. An idealized Diesel cycle is shown.

Process → 1 → 2, 3 → 4] Isentropic Process

Process → 2 → 3 Isobaric Process P
4 → 1 Isochoric Process



Efficiency of Diesel cycle :- Heat added at constant pressure is given by.

$$Q_H = m c_p (T_3 - T_2)$$

Heat rejected at constant volume is given by,

$$Q_L = m c_v (T_4 - T_1)$$

Work done in expansion is given by,

$$W = Q_H - Q_L$$

$$W = m c_p (T_3 - T_2) - m c_v (T_4 - T_1)$$

Efficiency of Diesel cycle.

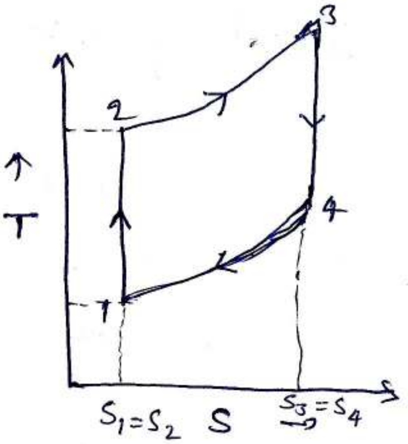
$$\eta = \frac{W}{Q_H}$$

$$\eta = 1 - \frac{Q_L}{Q_H} = 1 - \frac{m c_v (T_4 - T_1)}{m c_p (T_3 - T_2)}$$

$$\eta = 1 - \frac{(T_4 - T_1)}{\gamma (T_3 - T_2)}$$

For Process 1→2 Isentropic compression.

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$



$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = \rho^{\gamma-1}$$

$$T_2 = T_1 \rho_c^{\gamma-1} \quad \text{—— (1)}$$

where ρ_c is called compression ratio.

For Process 2→3 constant pressure heat addition.

$$\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3}$$

$$\frac{T_3}{T_2} = \frac{V_3}{V_2} = \rho_e$$

$$T_3 = \rho_e T_2 \quad \text{—— (2)}$$

Where ρ_e is called expansion ratio (fuel cut off ratio)

$$T_3 = \rho_e \rho_c^{\gamma-1} T_1 \quad \text{—— (3)}$$

For Process 3→4 Isentropic process.

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = \left(\frac{P_3}{P_4}\right)^{\gamma-1/\gamma}$$

$$= \left(\frac{V_1}{V_3}\right)^{\gamma-1}$$

$$= \left(\frac{V_1}{V_2} \times \frac{V_2}{V_3}\right)^{\gamma-1} = \left(\rho_c \frac{1}{\rho_e}\right)^{\gamma-1}$$

$$T_4 = \frac{T_3}{\left(\frac{\rho_c}{\rho_e}\right)^{\gamma-1}} = \frac{\rho_e T_2}{\left(\frac{\rho_c}{\rho_e}\right)^{\gamma-1}} = \frac{\rho_e \rho_c^{\gamma-1} T_1}{\left(\frac{\rho_c}{\rho_e}\right)^{\gamma-1}}$$

$$T_4 = \rho_e^{\gamma} T_1$$

$$\eta_{Diesel} = 1 - \frac{1}{\gamma}\left(\frac{T_1 \rho_e^{\gamma} - T_1}{T_1 \rho_c^{\gamma-1}\rho_e - T_1 \rho_c^{\gamma-1}}\right)$$

$$= 1 - \frac{(\rho_e^{\gamma} - 1)}{\gamma(\rho_c^{\gamma-1}\rho_e - \rho_c^{\gamma-1})}$$

$$= 1 - \frac{1}{\gamma \rho_c^{\gamma-1}}\left[\frac{\rho_e^{\gamma} - 1}{\rho_e - 1}\right]$$

$$\eta_{Diesel} = 1 - \frac{1}{\gamma \rho_c^{\gamma-1}}\left[\frac{\rho_e^{\gamma} - 1}{\rho_e - 1}\right]$$

<u>Closed and Open cycle</u> :- In every cycle a fresh working fluid is used & used one is exhausted out. is called open cycle, In open cycle fuel is high quality and working fluid is low grade and light weighted.

~~In every cycle a used~~ Same working fluid recirculated every cycle is called closed cycle, In closed cycle working fluid are high quality and fuel low calorific value.

<u>Cold air Assumptions</u> :- (i) Air is treated as a ideal gas i.e C_p, C_v values do not vary w.r.to temp.

(ii) Radiation effects are negligible.

(iii) Negligible pressure losses of air during flow through the pipes of heat exchanger.