NOTE

Thermal Engg-I

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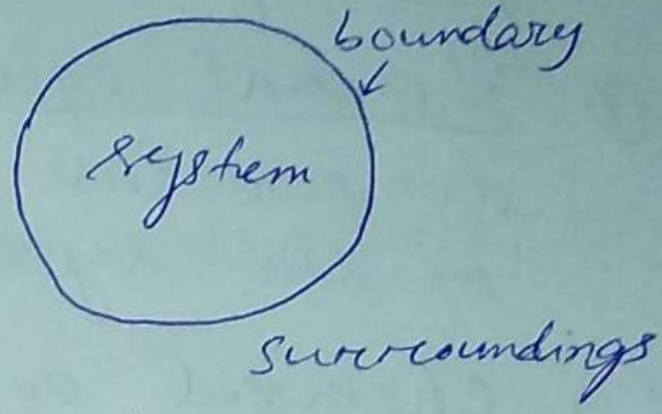
Thermodynamic Concept:-

Thermodynamic systems:-

It is the definite area where some thermodynamic process is taking place.

boundary separates systems from surroundings



classification of Thermodynamic systems:-

closed systems:- It does not permit any mass transfer across its boundary but permits energy transfer.

Open systems:- It permits transfer of both mass and energy across the boundary.

Isolated systems:- It neither permit transfer of mass nor energy.

Classification of properties:-

Extensive properties:- The properties of the system whose value for the entire system is equal to the sum of their values for the individual parts of the system.

Intensive properties:- The value for the entire system is not equal to the sum of their values for the individual parts of the system is called intensive properties.

Quasi-Static process:-

When the process is carried out in such a way that at every instant the system deviation from the thermodynamic equilibrium is infinitesimal then the process is called quasi-static process.

Thermodynamic equilibrium :-

① mechanical equilibrium :- A system is said to be in mechanical equilibrium when there is no unbalanced forces acting on any part of the system.

② Thermal equilibrium :- When there is no temperature difference between the parts of the system is called thermal equilibrium

③ chemical equilibrium :- When there is no chemical reaction within the system is called chemical equilibrium.

Energy :- It is the capacity to do work.

Types : Stored energy
Transit energy

Heat :- It is defined as the energy transfered without transfer of mass, across the boundary of a system because of the temperature difference betⁿ the system and the surroundings.

Unit - J or KJ

Specific heat :- It is the amount of heat required to raise the temperature of a unit mass of any substance through one degree.

Heat required = $mc(T_2 - T_1)$ KJ

c = sp. heat.

Work :- Work is defined as the product of force(f) and the distance moved (x) in the direction of force.

$W = f \times x$

unit is Joule.

Laws of thermodynamics :-

Zeroth law of thermodynamics :-

When two systems are each in thermal equilibrium with a third system then the two systems are also in thermal equilibrium with one anothere.

First law of thermodynamics :-

① The heat and mechanical work are mutually convertible.

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

② The energy can neither be created nor destroyed though it can be transformed from one forem to anothere.

$$\delta Q - \delta W = dE$$

Second law of thermodynamics :-

Kelvin-Plank Statement :- It is impossible to construct an engine working on a cyclic process whose sole purpose is to convert heat energy from a single thermal reservoire into an equivalent amount of work.

$$\eta_{max} = \frac{Q_1 - Q_2}{Q_1}$$

Clausius Statement :- It is impossible for a self acting machine, working in a cyclic process to transfere heat from a body at a lowere temp. to a body at a higher temperature without the aid of an external agency.

$$(COP)_R = \frac{Q_2}{Q_1 - Q_2}$$

$$(COP)_P = \frac{Q_1}{Q_1 - Q_2}$$

Application of First law of thermodynamic to a steady flow process :-

$$m\left(h_1 + \frac{V_1^2}{2} + gz_1 + q_{1-2}\right) = m\left(h_2 + \frac{V_2^2}{2} + gz_2 + W_{1-2}\right)$$

properties of perfect gases:-

Boyle's law:- The absolute pressure of a given mass of a perfect gas varies inversely as its volume when the temp. remains constant.

$$P \propto \frac{1}{V}$$

charle's law:- The volume of a given mass of a perfect gas varies directly as its absolute temperature when the absolute pressure remain constant.

$$V \propto T.$$

Gay Lussac Law:- The absolute pressure of a given mass of a perfect gas varies directly as its absolute temperature when the volume remains constant.

$$P \propto T.$$

General gas equation:-

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} = \text{.....} = \text{constant}.$$

Characteristic gas equation:-

$$PV = mRT$$

Avogadro's law:-
equal volumes of all gases at the same temperature and pressure contain equal numbers of molecules.

Specific heats of gas:- It is the amount of heat required to raise the temperature of its unit mass through one degree.

1. Specific heat at constant volume (C_v)
2. Specific heat at constant ~~temperature~~ pressure (C_p)

Relation betⁿ specific heats :-

$$C_p - C_v = R$$

$$C_p(\gamma - 1) = R$$

$$C_v = \frac{R}{\gamma - 1}$$

Enthalpy of a gas :-

It is the sum of the internal energy and product of pressure and volume

(H) Enthalpy = $U + pV$

I.C. Engine :-

Internal combustion engine are those engines in which combustion of fuel takes place inside the engine cylinder. These are petrol, diesel and gas engines.

Sequence of Operations in a cycle :-

Suction stroke
Compression stroke.
Expansion stroke.
Exhaust stroke.

The working principle of engines :-

If the engine is to work successfully then it has to follow a cycle of operations in a sequential manner. The sequence is quite rigid and cannot be changed. ~~In the fo~~ The working principle of both SI and CI engines have much in common but there are certain fundamental differences.

The spark ignition engine works on Otto cycle. The compression ignition engine works on Diesel cycle.

Petrol engine

① Petrol engine draws a mixture of petrol & air during suction stroke

② Carburattor is employed to mix air & petrol and supply to the engine during suction stroke

③ Combustion of fuel takes place at constant volume

Diesel Engine

① A diesel engine draws only ~~mixture of~~ air during suction stroke.

② Injector is employed to inject the fuel at the end of compression stroke.

③ combustion of fuel takes place at constant pressure.

Four Stroke Engine

① The thermodynamic cycle is completed in four strokes or two revolution of the crankshaft. Thus one power stroke is obtained in every two revolutions of the crankshaft.

② Power produced for same size of engine is less

③ Volumetric efficiency is more.

④ Thermal efficiency is high.

⑤ Four stroke engines have valves.

⑥ Heavy engines

Two Stroke Engine

① The thermodynamic cycle is completed in two stroke of piston or one revolution of the crankshaft. Thus one power stroke is obtained in each revolution of the crankshaft.

② Power produced for same size of engine is high.

③ volumetric efficiency is less

④ Thermal efficiency is less.

⑤ Two strokes engines have ports.

⑦ light engines.

Gas Power Cycle :-

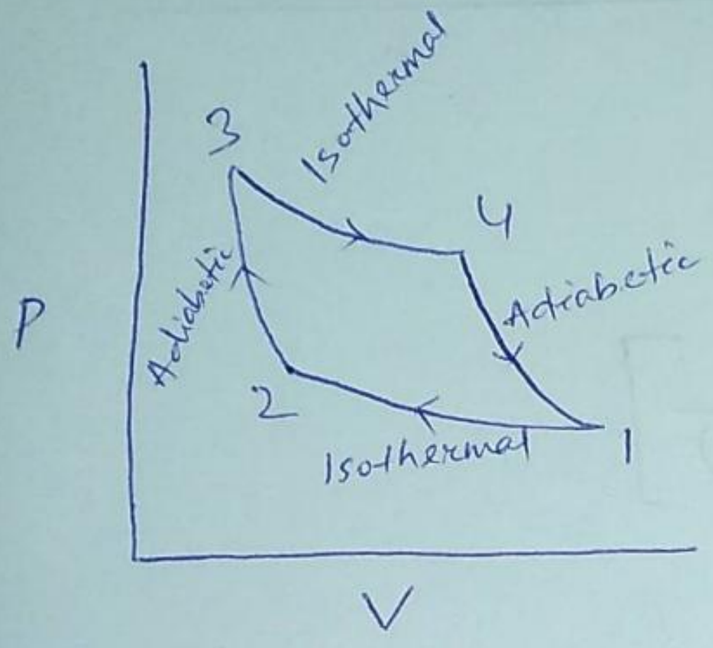
-: assumptions :-

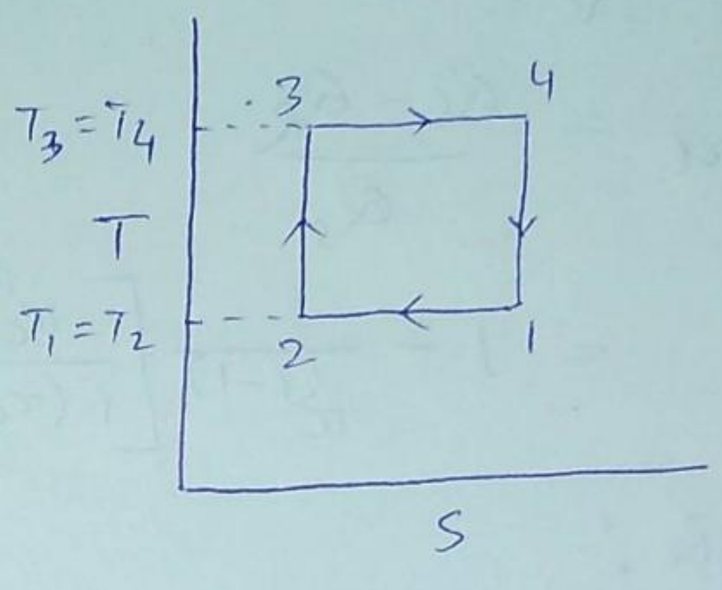
① The working medium is assumed to be a perfect gas and follow the relation $pV = mRT$

② There is no change in mass of the working medium

③ All the processes that constitute the cycle are reversible.

Carnot Cycle :-

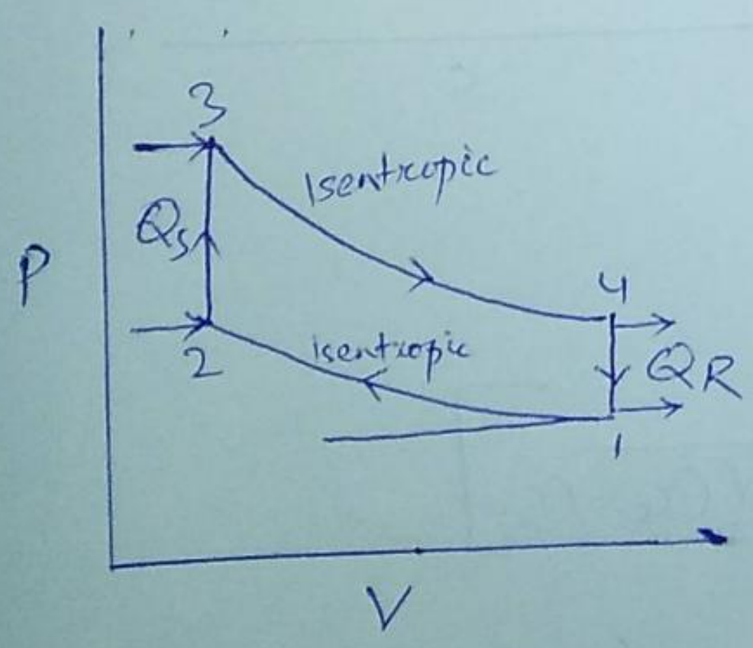


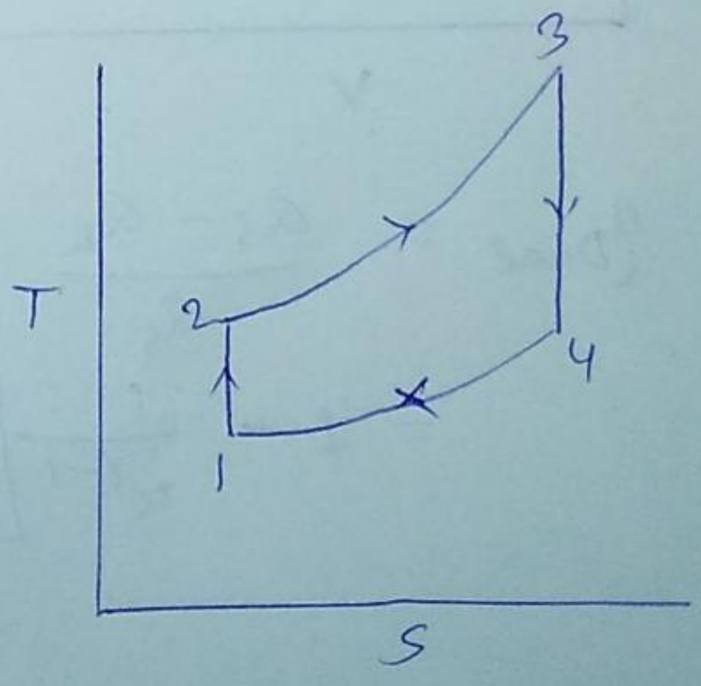


$$\eta_{carnot} = \frac{\text{Work done by the system during the cycle } (W)}{\text{Heat supplied to the system during cycle } (Q_S)}$$

$$\eta_{carnot} = \frac{T_3 - T_1}{T_3} = 1 - \frac{T_1}{T_3}$$

Otto Cycle :-



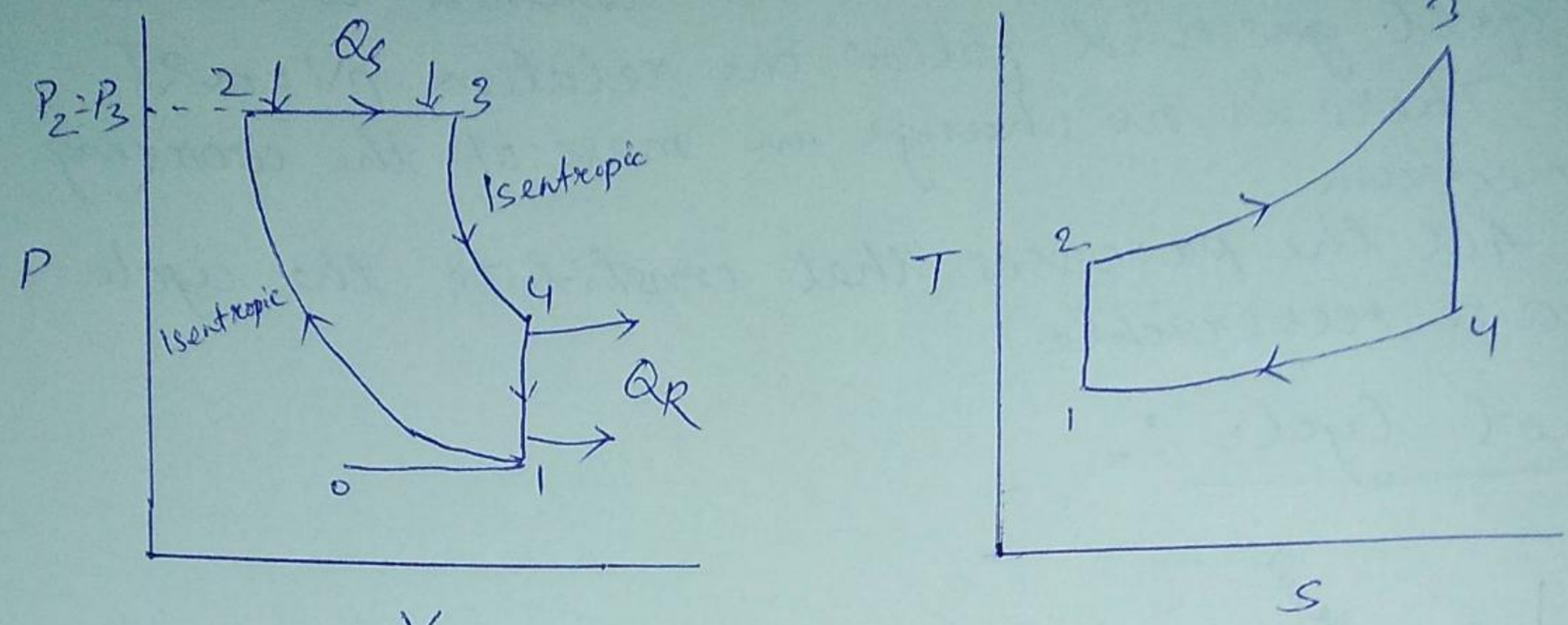


$$\eta_{otto} = \frac{Q_S - Q_R}{Q_S}$$

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

(where $r = \frac{V_1}{V_2} = \frac{V_4}{V_3}$)

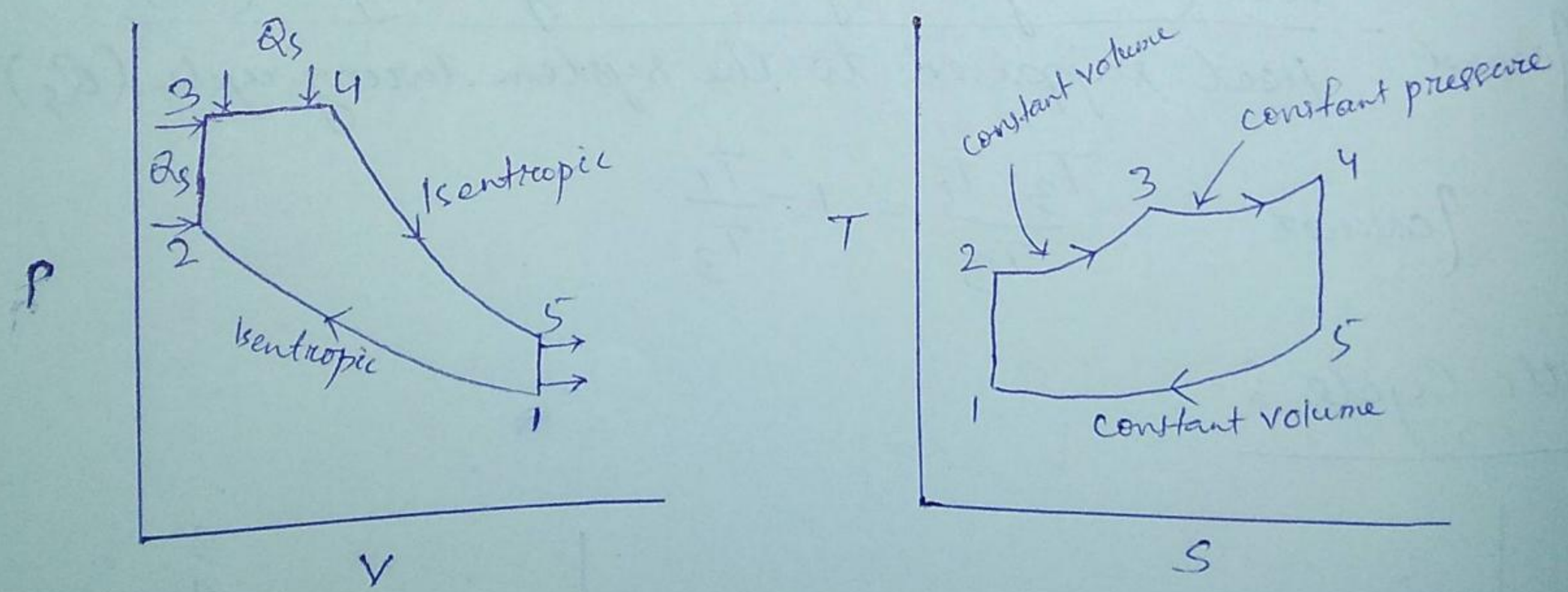
Diesel Cycle :-



$$\eta_{diesel} = \frac{Q_s - Q_R}{Q_s}$$

$$= 1 - \frac{1}{\pi_c^{(\gamma-1)}} \left[\frac{\pi_c^{\gamma} - 1}{\gamma(\pi_c - 1)} \right]$$

Dual Cycle :-



$$\eta_{Dual} = \frac{Q_s - Q_R}{Q_s}$$

$$= 1 - \frac{1}{\pi^{\gamma-1}} \left[\frac{\pi_p \pi_c^{\gamma} - 1}{(\pi_p - 1) + \pi_p \gamma (\pi_c - 1)} \right]$$

Fuels

A fuel, in general may be defined as a substance containing mostly carbon and hydrogen which on burning with oxygen in the atmospheric air, produces a large amount of heat.

Classification of fuels :-

The fuel may be classified into

i) Solid fuels
ii) Liquid fuels
iii) Gaseous fuels

Fuel also classified as

i) primary or Natural fuels - These are found in nature
ii) Secondary or Artificial fuels - These are derived from primary fuels

Characteristics of a good fuel :-

i) High calorific value.
ii) Moderate ignition temperature.
iii) Low contents of non-combustible matters.
iv) Low moisture content.
v) Free from harmful gases.
vi) Easy to transport and readily available at low cost.

Fossil fuels :-

Fossile fuels are those which have been derived from fossile remains of plant and animal life.

Advantage of solid fuels :-

1) Handling and transportation of solid fuels are easy.
2) cheap and easily available.
3) moderate ignition temperature.
4) stored conveniently without any risk.

Disadvantages of solid fuels :-

1) During burning, solid fuels produces a large amount of ash and disposal of ash is a big problem.
2) The calorific value of solid fuel is comparatively low.
3) Thermal efficiency is not so high.
4) Large space is required for storage.

Advantages of Liquid fuels :-

1) Liquid fuels do not yield any ash after burning.
2) Require comparatively less storage space.
3) Calorific value of liquid is higher than solid fuel.
4) combustion is uniform.

Disadvantages of liquid fuels :-

1) costlier than solid fuels.
2) Special types of burner are required for effective combustion.

Advantages of gaseous fuels :-

1) Gaseous fuels can be easily transported.
2) Do not produce any gas or smoke or ash.
3) High calorific value
4) High thermal efficiency

Disadvantages of gaseous fuels :-

1) Highly inflammable so more risky
2) Require large storage tank.

Uses of fuels :-

1) Wood, coals, kerosene, domestic gases, cow dung etc are used in homes for cooking.
2) petrol and diesel are used ~~for~~ in automobiles as fuels.
3) Fuels like coal and natural gas are used in industries to heat up boiler.
4) Fuels can be used to generate electricity.

Calorific Value of Fuels :-

The calorific value or heating value of a fuel may be defined as the amount of heat given out by the complete combustion of 1 kg of fuel. It is expressed in KJ/kg of fuel. The calorific value of gaseous fuels is however expressed in terms of KJ/m^3 at a specified temperature and pressure.

Octane Number :-

The knocking tendency of a fuel in S.I engine is generally expressed by its octane number. The percentage by volume, of iso-octane in a mixture of iso-octane and normal heptane, which exactly matches the knocking intensity of a given fuel, in a standard engine, under given standard operating conditions, is termed as the octane number rating of that fuel.

Cetane Number :-

The properties of ignition lag is C.I engine is generally measured in terms of cetane number. It is defined as the percentage, by volume, of cetane in a mixture of cetane and alpha-methyl-naphthalene that produces the same ignition lag as the fuel being tested in the same engine and under the same operating conditions.