

MODULE-2

Concepts of Thermodynamics

Introduction to Internal Combustion engines

Electric vehicles and Hybrid vehicles

THERMODYNAMICS

Thermodynamics is a basic science that deals with *energy*. In other words, thermodynamics may be defined as the study of energy, its forms and transformations, and its interaction with matter. Thermodynamics also deals with various properties of substances and the changes in these properties as a result of energy transformations. The principles of thermodynamics are based on our day-to-day experiences and experimental observations.

The name thermodynamics stems from the Greek words *therme* (heat) and *dunamis* (power), which terms in early days were used to describe the effort to convert heat into power. But in the present context, the name thermodynamics is used to interpret all aspects of energy and energy transformations, including power production, refrigeration, and relationships among the properties of matter.

System, Boundary and Surroundings

System. A system is a finite quantity of matter or a prescribed region of space

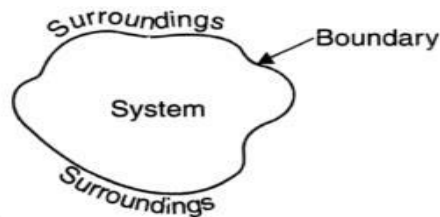


Fig. The system.

Boundary. The actual or hypothetical envelope enclosing the system is the boundary of the system. The boundary may be fixed or it may move, as and when a system containing a gas is compressed or expanded. The boundary may be *real* or *imaginary*. It is not difficult to envisage a real boundary but an example of imaginary boundary would be one drawn around a system consisting of the fresh mixture about to enter the cylinder of an I.C. engine together with the remnants of the last cylinder charge after the exhaust process

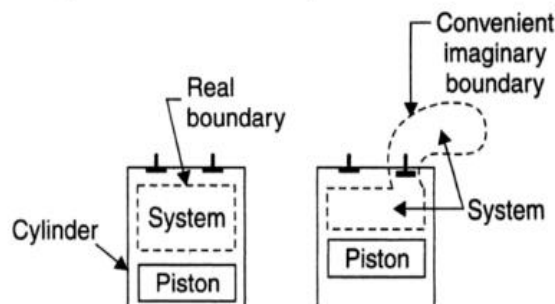


Fig. The real and imaginary boundaries.

Surroundings: Everything external to the system is called the surroundings or the environment.

Universe: system and its surroundings together is termed as universe.

$$\text{Universe} = \text{System} + \text{Surroundings}$$

CLASSIFICATION OF THERMODYNAMIC SYSTEM

The thermodynamic system can be classified into three types.

- (i) Closed system,
- (ii) Open system, and
- (iii) Isolated system.

(i) Closed System

The closed system is a system of fixed mass. In this system, energy may cross the boundary, and the total mass within the boundary is fixed. The system and its boundary may contract or expand in volume.

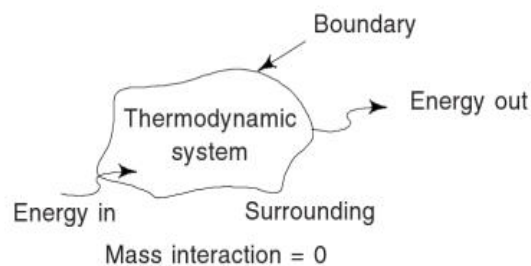
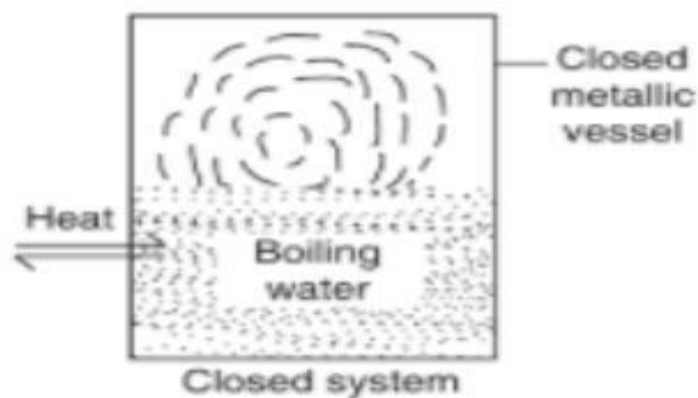


Fig. Closed System

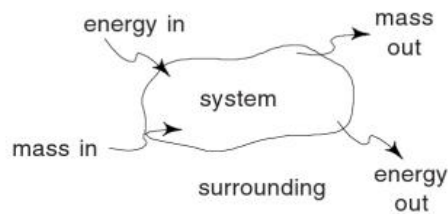
Example

- (1) Boiling water in a closed pan.



(ii) Open System

The open system is one in which matter crosses the boundary of the system. There may be energy transfer also. i.e. both energy and mass crosses the boundary of the system.



Both mass and energy interaction $\neq 0$.

Fig. Open system

Example

(1) Air compressor.

In an air compressor, air enters at low pressure and leaves at high pressure. The working substance (gas) crosses the boundary of the system. In addition to this mass transfer, heat and work interactions take place across the system boundary.

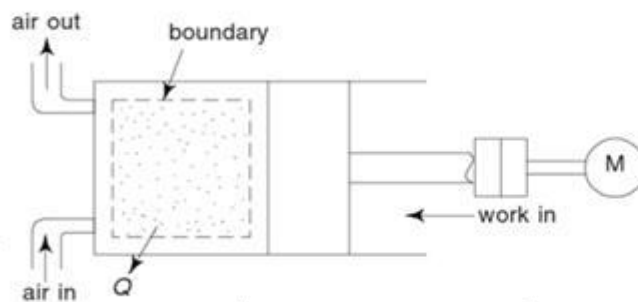


Fig: Air Compressor

(iii) Isolated System

In an isolated system, neither mass nor energy crosses the system boundary. It is of fixed mass and energy. The system is not affected by the surrounding i.e. there is no interaction between the system and surroundings.

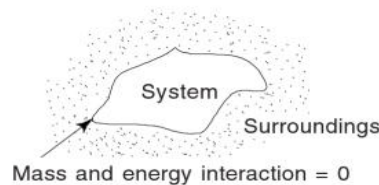


Fig Isolated system

Ex: flow through pipe.



Flow through pipe

STATE

State is the condition of the system at an instant of time as described or measured by its properties. Or each unique condition of a system is called a *state*.

THERMODYNAMIC PATH, PROCESS AND CYCLE

THERMODYNAMIC PATH

The *path* refers to the series of *state* (marked as *) through which the system passes during a process. Thus, path refers to the locii of various intermediate states passed through by a system during a process.

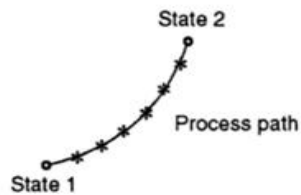


Figure Process path.

PROCESS

A process may be defined as a change of a system from one equilibrium state to another.

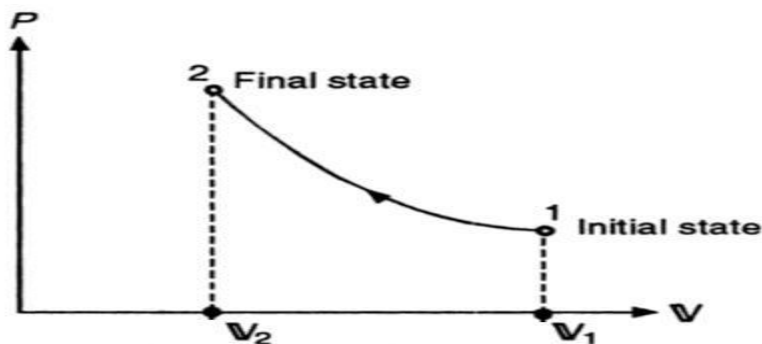


Fig. 1-2 represents a thermodynamic process.

Cycle

A system is said to have undergone a cycle if it returns to its initial state at the end of the process. That is, for a cycle the initial and the final states are identical. A typical two-process cycle is shown in Fig.

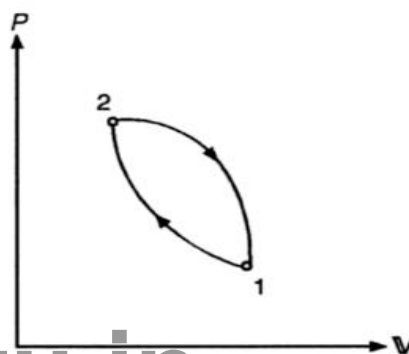


Figure A two-process cycle.

LAWS OF THERMODYNAMICS

The fundamental principles of thermodynamics are expressed by certain laws, however from the syllabus point of view, only three laws of thermodynamics are discussed as follows:

1) Zeroth law of thermodynamics

Zeroth law states that when two systems are each in thermal equilibrium with a third system, then the two systems are also in thermal equilibrium with each other.

2) First law of thermodynamics

The first law states that, when a closed system undergoes a thermodynamic cycle, the net heat transfer (Q) is equal to the net work transfer (W).

$$\text{i.e., } \oint \delta Q = \oint \delta W \quad \text{where } \oint \text{ stands for cyclic integral}$$

The first law is also known as *law of conservation of energy*, which states that *Energy can neither be created nor destroyed*. The total amount of energy and matter in the Universe remains constant, merely changing from one form to another.

According to the law of conservation of energy, we can write, total energy $\Delta E = Q - W$

3) Second law of thermodynamics

The second law of thermodynamics can be defined in two different ways according to Kelvin-Planck and Clausius as follows:

Kelvin-Planck statement

According to Kelvin-Planck, it is impossible to construct an engine working in a cyclic process, whose sole purpose is to convert heat energy from a single thermal reservoir into an equivalent amount of work. In simple words, there cannot be an engine that can work in a cyclic process converting all the heat supplied to it, into mechanical work. There is always a degradation or loss of energy in the process of producing mechanical work from the heat supplied.

Clausius statement

According to Clausius, it is impossible for a self-acting machine working in a cyclic process to transfer heat from a body at a lower temperature to a body at a higher temperature without the aid of an external agency. In simple words, heat cannot flow naturally from a cold body to a hot body without the help of work input.

WORK

Mechanics Definition of Work

In mechanics, work is defined as the product of a force and the distance in the direction of the force.

Mathematically

$$dW = F dx$$

where dW is the infinitesimal amount of work done in Joules, F is the applied force, measured in Newtons and dx is the infinitesimal displacement in metres.

Thermodynamics Definition of Work

In thermodynamics, work is defined as an interaction between a system and its surroundings, if the sole effect external to the system could be reduced to the raise of a weight.

To illustrate, let us consider the expansion of a gas inside a cylinder. As we see from Fig. , through the proper selection of linkages, we can make use of the expansion process to lift a weight. Therefore, work will be done by the gas.

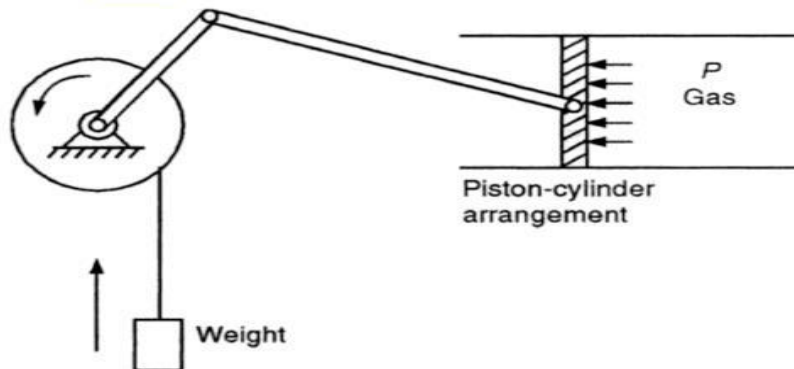


Figure : Lifting of a weight due to work done by a gas in an expansion process.

UNIT OF WORK

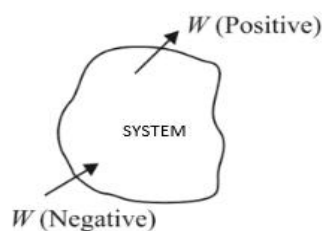
In SI system, the unit of work is newton-metre ($\text{N}\cdot\text{m}$) and this is known as joule.

A joule is defined as the work done by a force of one newton which acts for a distance of one metre along the line of force.

$$\therefore 1 \text{ J} = 1 \text{ N}\cdot\text{m}$$

The larger units of work are kilojoules or megajoules.

Sign convention :



- If the work is done by the system on the surroundings, the work is said to be *positive*.

i.e., $\text{Work done by the system} = +W$

- If the work is done on the system by the surroundings, the work is said to be *negative*.

i.e., $\text{Work done on the system} = -W$

ENERGY

The energy is basically understood as the capacity to do work. In international system, joule is used as the unit for all types of energy. As discussed in the previous sections, this unit is very small. Therefore, kilojoule (kJ) and megajoule (MJ) are recommended units in SI system for practical applications.

Forms of Energy

Energy exists in many different forms. Examples of these are: light energy, heat energy, mechanical energy, gravitational energy, electrical energy, sound energy, chemical energy, nuclear or atomic energy and so on.

1. **Kinetic Energy:** Kinetic energy (KE) is defined as the energy possessed by a moving body by virtue of its motion. The kinetic energy is expressed in the form of an equation as $K.E = \frac{1}{2}mv^2$ where, 'm' denotes the mass of the object and 'v' denotes the velocity of the object.

Ex: A moving car has kinetic energy.

2. **Potential Energy:** Potential Energy (P.E) is defined as the energy which is stored by virtue of its position. The potential energy is expressed in the form of an equation as $P.E = mgh$ where 'm' denotes the mass of the object, 'g' denotes the acceleration due to gravity and 'h' denotes the height in meters.

3. **Mechanical Energy:** Mechanical energy is defined as the energy associated with the motion and the position of the object. It can possess energy in the form of either potential energy or kinetic energy or both. Hence, mechanical energy is expressed as the sum of kinetic energy and potential energy.

$$M.E = mgh + \frac{1}{2}mv^2.$$

Ex: Car up a mountain, it has kinetic and potential energy.

4. **Chemical Energy:** Chemical Energy is defined as the energy stored within the bonds of a chemical compound, i.e., the energy is stored between the atoms and molecules of the compound. Example: electrochemical cell or battery.
5. **Nuclear energy** is energy stored in the nucleus of an atom—the energy that holds the nucleus together. Large amounts of energy can be released when the nuclei are combined or split apart. Example: Nuclear fission, nuclear fusion, and nuclear decay are examples of nuclear energy.
6. **Electrical energy:** Electrical energy is the energy carried by moving electrons in an electric conductor. It is one of the most common and useful forms of energy.
7. **Thermal Energy:** Thermal energy or heat energy reflects the temperature difference between two systems. Example: Steam has thermal energy.

HEAT

“The energy in transit is termed heat”

Heat is also a form of energy. When heat is added into the body, its temperature increases and when taken out, the temperature of the body reduces. Since heat is a form of energy, it can be converted into other forms of energy and can also be used to carry out work.

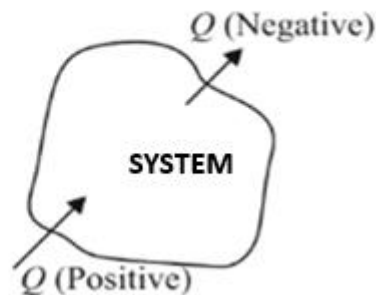
Heat denoted by the symbol Q

Units of Heat

Since heat is a form of energy, its unit is also joule in the International System. In MKS system, the unit of heat is defined as the quantity of heat required to raise the temperature of unit mass of water through one degree centigrade and named calorie which means heat energy required to raise 1 gram of water by $1^{\circ}\text{C} = 1 \text{ cal}$

and $1 \text{ cal} = 4.1868 \text{ J}$
or $1 \text{ k} \cdot \text{cal} = 4.1868 \text{ kJ}$

Sign convention :



If the heat flows *into* a system *from* the surroundings, the quantity is said to be *positive* and conversely, if heat flows *from* the system to the surroundings it is said to be *negative*.

In other words :

Heat received by the system $= + Q$

Heat rejected or given up by the system $= - Q$.

MODES OF HEAT TRANSFER

Heat transfer which is defined as the *transmission of energy from one region to another as a result of temperature gradient* takes place by the following three modes :

- (i) Conduction; (ii) Convection; (iii) Radiation.

(i) **Conduction :**

“Conduction” is the transfer of heat from one part of a substance to another part of the same substance, or from one substance to another in physical contact with it, without appreciable displacement of molecules forming the substance.

In solids, the heat is conducted by the following *two mechanisms* :

- (i) *By lattice vibration* (the faster moving molecules or atoms in the hottest part of a body transfer heat by impacts some of their energy to adjacent molecules).
- (ii) *By transport of free electrons* (Free electrons provide an energy flux in the direction of decreasing temperature — For metals, especially good electrical conductors, the electronic mechanism is responsible for the major portion of the heat flux except at low temperature).

(ii) **Convection**

When the transfer of heat takes place from one part to another part of the substance or fluid due to the actual motion of the molecules, it is called the convection mode of heat transfer. In this method, the rate of heat transfer depends mainly upon the difference in the fluid density at different temperature.

Examples of convection include:

- Boiling of water, that is molecules that are denser move at the bottom while the molecules which are less dense move upwards resulting in the circular motion of the molecules so that water gets heated.
- Warm water around the equator moves towards the poles while cooler water at the poles moves towards the equator.

Types of Convection heat transfer

- (a) **Natural convection or Free Convection:** Natural convection is induced by buoyancy forces due to density variations as a result of temperature differences.
- (b) **Forced convection:** Forced convection is the transfer of thermal energy when the flow is caused by external means, such as a fan, a pump

(iii) **Radiation:**

Radiation is the transfer of energy through electromagnetic waves. Unlike conduction and convection, it **does not require a medium** (it can travel through the vacuum of space).

Example: Heat from the Sun reaching Earth.

HEAT ENGINE

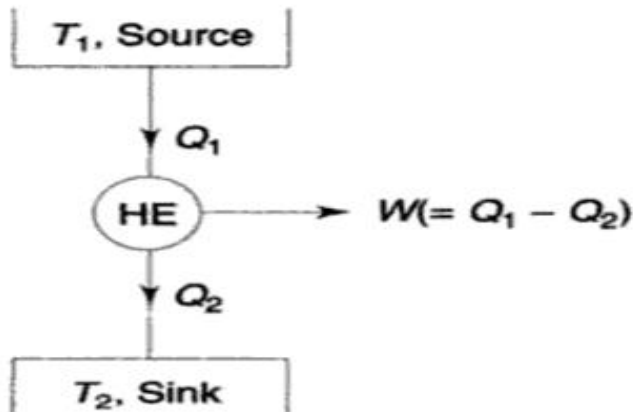


Fig. Heat engine

A heat engine is a device which operates in a cycle. It receives the heat energy from a high-temperature **reservoir**, converts some of the heat energy into work and rejects the remaining heat to a low-temperature **reservoir**.

The working of the heat engine can be illustrated as follows:

1. It receives heat Q_1 from the high-temperature **reservoir** (source) at
2. It converts the part of heat supplied into useful work as W_{net} .
3. It rejects the remaining heat Q_2 to a low-temperature **reservoir** (sink) at

For any cyclic heat engine, the net work can also be obtained from the difference between heat supplied and heat rejection.

$$W_{net} = Q_1 - Q_2$$

The **efficiency** of a heat engine or a heat engine cycle is defined as follows:

$$\eta = \frac{\text{Net work output of the cycle}}{\text{Total heat input to the cycle}} = \frac{W_{net}}{Q_1}$$

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

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

This is also known as the **thermal efficiency** of a heat engine cycle. A heat engine is very often called upon to extract as much work (net) as possible from a certain heat input, i.e. to maximize the cycle efficiency.

Heat Pump. It is a device that is used to attain and maintain a temperature higher than that of the surroundings, the aim being to heat up some space to the required high temperature. This can be achieved by transferring heat from low-temperature space to high-temperature space by applying input work on it. It is shown in Fig.

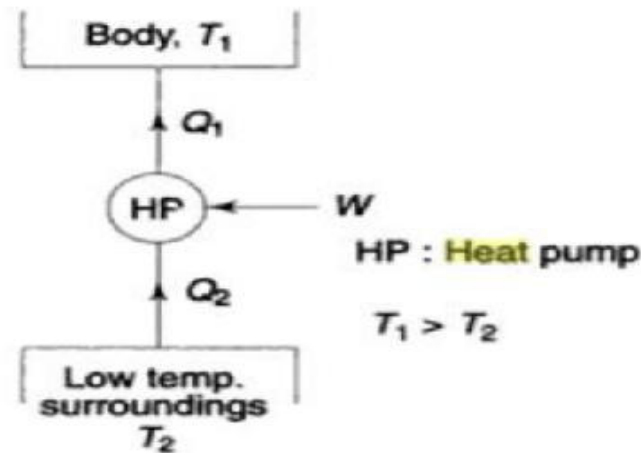


Fig. Heat pump

Heat pump picks up heat Q_2 at temperature T_2 and rejects heat Q_1 for maintaining high temperature body at temperature T_1 .

For causing this heat transfer heat pump is supplied with work W as shown.

As heat pump is not a work producing machine and also its objective is to maintain a body at higher temperature, so its performance can't be defined using efficiency as in case of heat engine. Performance of heat pump is quantified through a parameter called coefficient of performance (C.O.P). *Coefficient of performance* is defined by the ratio of desired effect and net work done for getting the desired effect.

$$\text{C.O.P.} = \frac{\text{Desired effect}}{\text{Net work done}}$$

For heat pump:

$$\text{Net work} = W$$

Desired effect = Heat transferred Q_1 to high temperature body at temperature, T_1 .

$$(\text{COP})_{\text{HP}} = \frac{Q_1}{W}$$

also

$$W = Q_1 - Q_2$$

so

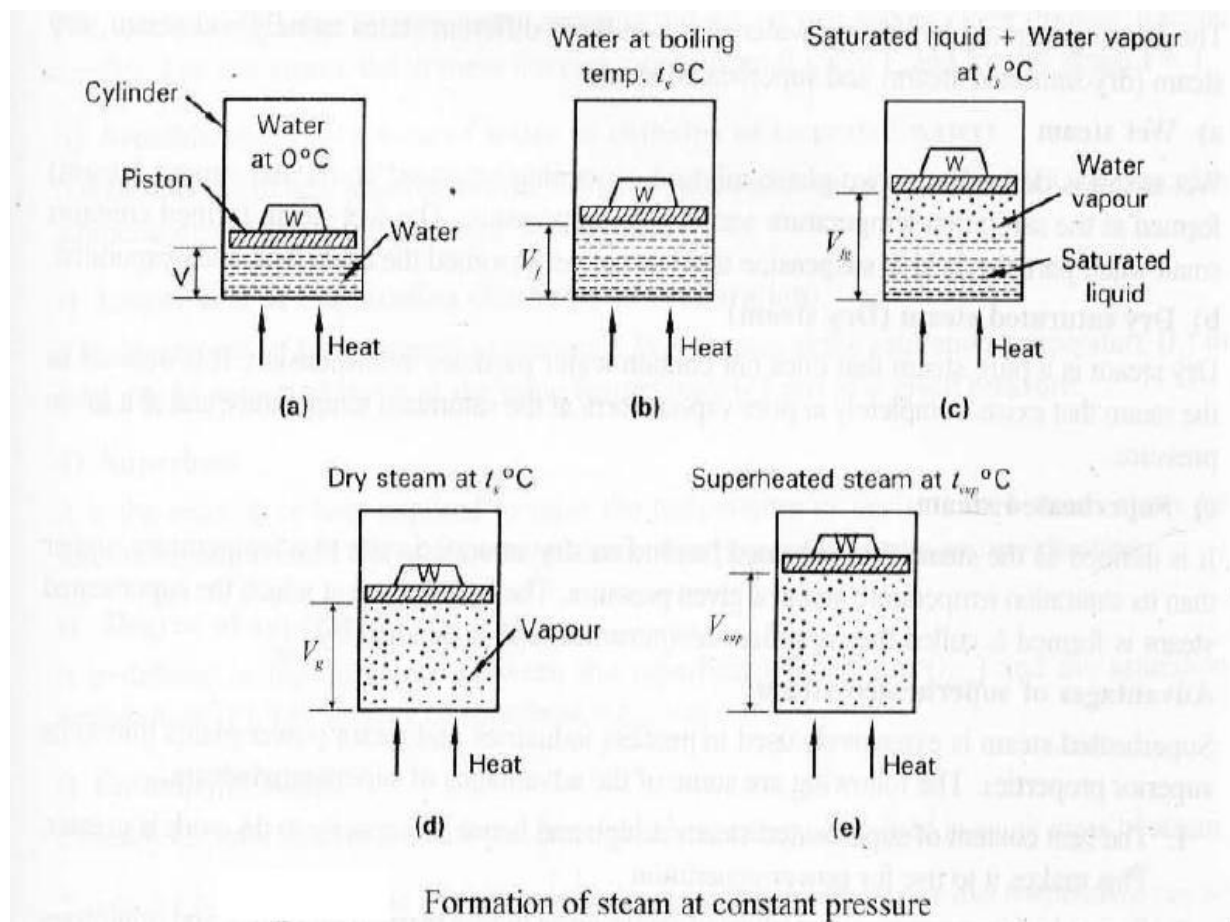
$$(\text{COP})_{\text{HP}} = \frac{Q_1}{Q_1 - Q_2}$$

STEAM FORMATION & PROPERTIES

INTRODUCTION TO STEAM

All substances under suitable conditions of temperature and pressure can exist in one of the three states, viz., solid, liquid or gas. But water is one of the pure substances that exists in all the three phases namely, in the solid phase as *ice*, liquid phase as *water*, and gaseous phase as *vapour (steam)*.

FORMATION of STEAM at CONSTANT PRESSURE



Consider 1 kg. of water at 0°C taken in a cylinder, fitted with a freely moving piston. A weight W is placed over the piston as shown in figure (a). The weight of the piston and the weight W placed over the piston exerts a constant pressure P on the water. Let V be the volume occupied by the water in the cylinder. The condition of water at 0°C is represented by a point A on the temperature enthalpy (T-H) diagram as shown in figure

When water is heated at constant pressure, it is converted to steam. The various stages involved in the process are discussed below.

- 1) On heating, the temperature of the water rises and at a certain temperature water begins to boil (evaporate). The temperature at which water starts boiling is known as *saturation temperature* and is denoted by t_s . The heating of water from 0°C to the saturation temperature (t_s) is shown by the line AB on T-H diagram. At this temperature, there is a slight increase in the volume of water (V_f) as shown in figure (b).
- 2) When water is heated beyond the saturation temperature, there will be no rise in temperature, but evaporation of water takes place. In other words, water starts converting into steam. At this stage, water exists as a two-phase mixture containing *saturated liquid* and *water vapour* occupying volume V_{fg} as shown in figure (c). The steam in this condition is called *wet steam*. Evaporation of water continues at the same saturation temperature until the whole of the water is completely converted into steam. This process is shown by the line BC on T-H diagram.
- 3) At point C , the steam formed does not contain water vapour (water particles in suspension) and hence the steam in this state is called *dry steam* or *dry saturated steam*. The volume occupied by the dry steam is shown in figure (d).
- 4) If heating is further continued at point C , the temperature of the steam increases above the saturation temperature and this temperature is called *superheat temperature* denoted by t_{sup} . The steam in this condition is called *superheated steam*. The process of heating the dry steam is called *superheating*, shown by the line CD on T-H diagram. The volume occupied by superheated steam is shown in figure (e).

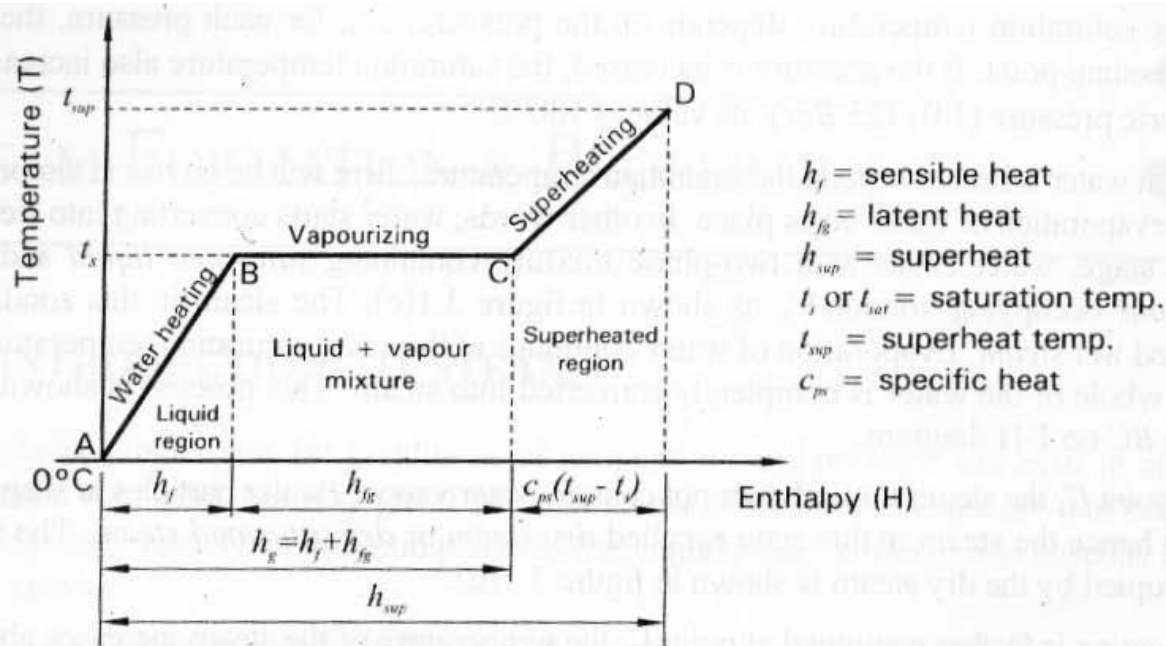


Figure Temperature-enthalpy (TH) diagram

TYPES OF STEAM / CONDITION OF STEAM

The steam generated by heating water exists in three different states namely wet steam, dry steam (dry saturated steam) and superheated steam.

a) Wet steam

Wet steam is defined as a two-phase mixture containing saturated liquid and vapour (steam) formed at the saturation temperature and at a given pressure. The wet steam formed contains small water particles held in suspension that has not yet absorbed the latent heat and evaporated.

b) Dry saturated steam (Dry steam)

Dry steam is a pure steam that does not contain water particles in suspension. It is defined as the steam that exists completely in pure vapour form at the saturation temperature and at a given pressure.

c) Superheated steam

It is defined as the steam that is heated beyond its dry saturated state to a temperature higher than its saturation temperature and at a given pressure. The temperature at which the superheated steam is formed is called the *superheat temperature*, and is denoted by t_{sup} .

Advantages of superheated steam

Superheated steam is extensively used in process industries and steam power plants due to its superior properties. The following are some of the advantages of superheated steam.

1. The heat content of superheated steam is high and hence its capacity to do work is greater. This makes it to use for power generation.
2. Due to high temperature, superheated steam gives higher thermal efficiency and minimizes the specific consumption of steam when used in turbines.

3. As there is no moisture content in superheated steam, erosion/corrosion of turbine blades are minimized.
4. Superheating is done in a superheater, that obtains heat from waste burnt gases. This improves efficiency of the boiler.

STEAM PROPERTIES

The various properties of steam are briefed as follows.

a) Dryness fraction

It is defined as the ratio of mass of dry steam present in a known quantity of wet steam to the total mass of wet steam. The dryness fraction refers to the quality of steam, or an indication of the extent of dryness of steam. It is denoted by x .

$$\text{Dryness fraction } (x) = \frac{\text{mass of dry steam present in wet steam}}{\text{mass of wet steam}} = \frac{m_g}{m_f + m_g}$$

where m_g = mass of dry steam and m_f = mass of suspended water particles.

For example, if 1 kg. of wet steam contains 0.9 kg. of dry vapour, then dryness fraction $x = 0.9$. For wet steam, the dryness fraction ranges from $0 < x < 1$, and for dry steam $x = 1$.

b) Sensible heat (Total heat of water or enthalpy of saturated water)

It is the amount of heat required to raise the temperature of 1 kg. of water from 0°C to saturation temperature (t_s) at a given pressure. It is denoted by h_f .

c) Latent heat of evaporation (Enthalpy of evaporation)

It is the amount of heat required to convert 1 kg. of water at the saturation temperature (t_s) to 1 kg. of dry saturated steam at the same temperature (t_s) and at a given pressure.

d) Superheat

It is the amount of heat required to raise the temperature of dry saturated steam above its saturation temperature and at a given pressure. The process is known as *superheating*.

e) Degree of superheat

It is defined as the difference between the superheat temperature (t_{sup}) and the saturation temperature (t_s), i.e., Degree of superheat = $t_{\text{sup}} - t_s$.

f) Enthalpy of steam

Enthalpy (or total heat) of steam is the amount of heat energy contained in a unit mass of steam.

Enthalpy is defined as the sum of internal energy (U) and the product of pressure (P) and volume (V). It is denoted by h and expressed in kJ/kg .

$$\text{Enthalpy } h = U + PV$$

- **Enthalpy of wet steam**

Enthalpy of wet steam is defined as the amount of heat required at a given pressure to convert 1 kg . of water at 0°C to 1 kg . of wet steam at a given dryness fraction. It is denoted by h_w and is given by $h_w = h_f + x.h_{fg}$ kJ/kg .

where h_f = sensible heat, x = dryness fraction.

h_{fg} = latent heat or latent heat of evaporation

- **Enthalpy of dry saturated steam**

It is defined as the amount of heat required at a given pressure to convert 1 kg . of water at 0°C to 1 kg . of dry saturated steam at the saturation temperature. It is denoted by h_g and is given by $h_g = h_f + h_{fg}$.

Note We know that $h_w = h_f + xh_{fg}$. Dry steam exists completely in pure vapour form. Hence, dryness fraction $x = 1$. Therefore, $h_g = h_f + h_{fg}$.

- **Enthalpy of superheated steam**

It is defined as the amount of heat required at a given pressure to convert 1 kg . of water at 0°C to 1 kg . of superheated steam at the given superheat temperature. It is denoted by h_{sup} and is given by the equation $h_{\text{sup}} = h_g + C_{ps} (t_{\text{sup}} - t_s)$

where h_g = enthalpy of dry steam t_{sup} = superheat temperature,

t_s = saturation temperature, & C_{ps} = Specific heat* of superheated steam

g) Specific volume of steam

Specific volume of steam is defined as the volume occupied by a unit mass of steam at a given temperature and pressure. It is expressed in m^3/kg .

- **Specific volume of saturated water**

It is defined as the volume occupied by 1 kg . of water at the saturation temperature and at a given pressure. It is denoted by V_f .

- **Specific volume of wet steam**

Wet steam contains a two-phase mixture of saturated water and vapour (steam). Hence specific volume of wet steam is defined as the volume occupied by the saturated water and vapour at a given pressure. It is denoted by V_w and is given by : $V_w = x.V_g$.

where x = dryness fraction of steam V_g = specific volume of dry steam

- **Specific volume of dry saturated steam**

It is defined as the volume occupied by 1 kg. of dry saturated steam at the saturation temperature and at a given pressure. It is denoted by V_g .

- **Specific volume of superheated steam**

It is defined as the volume occupied by 1 kg. of superheated steam at the superheat temperature (t_{sup}) and at a given pressure. It is denoted by V_{sup} .

Superheated steam behaves like a perfect gas. Therefore, according to Charles law, we

have $\frac{V_{sup}}{t_{sup}} = \frac{V_g}{t_s} \quad \therefore V_{sup} = \frac{V_g \cdot t_{sup}}{t_s}$ where t_{sup} and t_s are in Kelvin.

h) Density of steam

It is the mass of steam per unit volume of steam at the given pressure and temperature. It is the reciprocal of specific volume.

$\therefore$ Density of wet steam $= \rho_w = \frac{1}{xV_g}$ and for dry steam $= \rho_g = \frac{1}{V_g}$ ($\because x = 1$ for dry steam).

i) External work of evaporation

When water at the saturation temperature is heated at constant pressure, it gets converted into steam by absorbing the latent heat. A part of this latent heat is used to move the piston due to the increase in volume of steam during evaporation. Refer Figure 1.7. The work done, due to change in volume of steam from V_f to V_g is called *external work of evaporation*.

External work of evaporation $= W = 100.P (V_g - V_f)$ where P = pressure in bar.

At low pressure, V_f is very small and hence can be neglected. Hence $W = 100.P.V_g$

- For *wet steam* of dryness fraction x , $W_w = 100.P.x.V_g$
- For *dry steam* $W_g = 100.P.V_g$
- For *superheated steam*, $W_{sup} = 100.P.V_{sup}$

j) Internal energy

Every substance has definite amount of heat energy stored in it. The actual heat energy stored in the steam is known as *internal energy of steam*, and can be obtained by subtracting the external work of evaporation from enthalpy of steam.

Internal energy (U) = Enthalpy of steam – external work of evaporation

- For wet steam, internal energy $U_w = h_f + x.h_{fg} - 100..P.x.V_g$ kJ/kg.
- For dry steam $U_g = h_g - 100.P.V_g$ kJ/kg.
- For superheated steam, $U_{sup} = h_{sup} - 100.P.V_{sup}$
 $= [h_g + C_{ps} (t_{sup} - t_s)] - 100.P.V_{sup}$ kJ/kg.

NUMERICAL PROBLEMS

Problem 1 Determine the dryness fraction of steam, which has 1.5 kg of water in suspension with 50 kg of steam.

Solution :

Step 1 Data

Mass of water particles $m_f = 1.5$ kg Mass of dry steam $m_g = 50$ kg

Step 2 To find dryness fraction x

$$\text{w.k.t. dryness fraction} = x = \frac{m_g}{m_f + m_g} = \frac{50}{1.5 + 50} = 0.97$$

$$\therefore \text{dryness fraction} = x = 0.97$$

Problem 2 8 kg of wet steam contains 1.56 kg of water particles in suspension. What is the dryness fraction of steam.

Solution :

Step 1 Data

Mass of wet steam = 8 kg Mass of water particles $m_f = 1.56$ kg

$\therefore$ Mass of dry steam present $m_g = 8 - 1.56 = 6.44$ kg

Step 2 To find dryness fraction x

$$\text{w.k.t. dryness fraction} = x = \frac{m_g}{m_f + m_g} = \frac{6.44}{1.56 + 6.44} = 0.805$$

$$\therefore \text{dryness fraction} = 0.805$$

Problem 3 Calculate the enthalpy of steam at a pressure of 30 bar if its dryness fraction is 0.75.

Solution :

Step 1 Data

$$\text{Pressure } p = 30 \text{ bar} \quad \text{Dryness fraction } x = 0.75$$

Step 2 To find enthalpy of steam (h).

Since $x = 0.75$ is less than 1, the given steam is wet.

$$\text{w.k.t. enthalpy of wet steam} = h_w = h_f + x h_{fg} \quad \text{---- [1]}$$

Note Since pressure (P) is given in the problem, the properties (h_f & h_{fg}) from steam tables has to read on pressure basis.

From steam tables for pressure, $P = 30 \text{ bar}$, we have, $h_f = 1008.3 \text{ kJ/kg}$ and $h_{fg} = 1794 \text{ kJ/kg}$

$$\therefore \text{equation (1) reduces to, } h_w = 1008.3 + [0.75 \times 1794] = 2353.8$$

$$\therefore \text{enthalpy of wet steam } h_w = 2353.8 \text{ kJ/kg}$$

Problem 4 Find the enthalpy of 1 kg of steam at 12 bar when steam is (i) dry saturated (ii) 22% wet, and (iii) superheated to 250°C . Assume specific heat of the superheated steam as 2.25 kJ/kg K .

Solution :

Step 1 Data

$$\text{Mass of steam} = m = 1 \text{ kg} \quad \text{Pressure } P = 12 \text{ bar}$$

From steam tables, corresponding to a pressure of 12 bar, we have

$$t_{sat} = t_s = 188^\circ\text{C}, \quad h_f = 798.4 \text{ kJ/kg}, \quad h_{fg} = 1984.3 \text{ kJ/kg}, \quad \text{and } h_g = 2782.7 \text{ kJ/kg}$$

Step 2 To find enthalpy of dry saturated steam (h_g)

$$\text{w.k.t. for dry saturated steam, enthalpy} = h_g = h_f + h_{fg} = 798.4 + 1984.3 = 2782.7$$

$$\therefore h_g = 2782.7 \text{ kJ/kg of steam}$$

Step 3 To find enthalpy (h) when steam is 22% wet

$$\text{w.k.t. enthalpy of wet steam} = h_w = h_f + x h_{fg} \quad \text{---- [1]}$$

$$\text{but } x = ?$$

If steam is 22% wet, then it is $100 - 22 = 78\%$ dry.

$$\text{i.e., } x = 0.78$$

$$\therefore \text{equation (1) reduces to, } h_w = 798.4 + [0.78 \times 1984.3] = 2346.15$$

$$h_w = 2346.15 \text{ kJ/kg}$$

Step 4 To find enthalpy when steam is superheated to 250°C .

$$\text{w.k.t. enthalpy of superheated steam} = h_{sup} = h_g + C_{ps} (t_{sup} - t_{sat})$$

$$\text{where } C_{ps} = 2.25 \text{ kJ/kg K, and } t_{sup} = 250^\circ\text{C}$$

$$\therefore h_{sup} = 2782.7 + 2.25 (250 - 188) = 2922.2$$

$$h_{sup} = 2922.2 \text{ kJ/kg of steam}$$

Problem 5 Find the enthalpy of 0.5 kg of steam at a pressure of 10 bar absolute for the following

conditions. (i) it is 1.5% wet, (ii) it is dry saturated, (iii) it is at a temperature of 200°C . Assume specific heat as 2.3 kJ/kg K .

Solution :

Step 1 Data

Mass of steam $m = 0.5 \text{ kg}$ Pressure $P = 10 \text{ bar}$

From steam tables, corresponding to $P = 10 \text{ bar}$, we have

$t_{\text{sat}} = 179.9^{\circ}\text{C}$, $h_f = 762.6 \text{ kJ/kg}$, $h_{fg} = 2013.6 \text{ kJ/kg}$ and $h_g = 2776.2 \text{ kJ/kg}$

Step 2 To find enthalpy when steam is 1.5% wet.

w.k.t. for wet steam, $h_w = h_f + x h_{fg}$ ----- [1]

but $x = ?$

If steam is 1.5% wet, then it will be $100 - 1.5 = 98.5\%$ dry

$\therefore$ dryness fraction $= x = 0.985$

equation (1) reduces to, $h_w = 762.6 + (0.985 \times 2013.6) = 2746 \text{ kJ/kg}$

$\therefore$ for 0.5 kg of steam $h_w = 0.5 \times 2746$

$h_w = 1373 \text{ kJ}$

Step 3 To find enthalpy of dry steam

w.k.t. for dry saturated steam, enthalpy $h_g = h_f + h_{fg} = 762.6 + 2013.6 = 2776.2$

$h_g = 2776.2 \text{ kJ/kg}$ of steam

$\therefore$ for 0.5 kg of steam, $h_g = 0.5 \times 2776.2 = 1388.1$

$h_g = 1388.1$

Step 4 To find enthalpy of superheated steam at 200°C .

w.k.t. for superheated steam, $h_{\text{sup}} = h_g + C_{ps} (t_{\text{sup}} - t_{\text{sat}})$ where $t_{\text{sup}} = 200^{\circ}\text{C}$

$h_{\text{sup}} = 2776.2 + 2.3 (200 - 179.9) = 2822.43 \text{ kJ/kg}$ of steam

$\therefore$ for 0.5 kg of steam, $h_{\text{sup}} = 0.5 \times 2822.43 = 1411.21$

$h_{\text{sup}} = 1411.21 \text{ kJ}$

INTRODUCTION TO I C ENGINE

INTRODUCTION TO I C ENGINE

HEAT ENGINES

Any type of engine or machine which derives heat energy from the combustion of fuel or any other source and converts this energy into mechanical work is termed as a **heat engine**.

Heat engines may be classified into two main classes as follows :

1. External Combustion Engines.
2. Internal Combustion Engines.
1. **External Combustion Engines (E.C. Engines)**

In this case, combustion of fuel takes place outside the cylinder as in case of steam engines where the heat of combustion is employed to generate steam which is used to move a piston in a cylinder. Other examples of external combustion engines are hot air engines, steam turbine and closed cycle gas turbine. These engines are generally used for driving locomotives, ships, generation of electric power etc.

2. **Internal Combustion Engines (I.C. Engines)**

In this case, combustion of the fuel with oxygen of the air occurs within the cylinder of the engine. The internal combustion engines group includes engines employing mixtures of combustible gases and air, known as gas engines, those using lighter liquid fuel or spirit known as petrol engines and those using heavier liquid fuels, known as oil compression ignition or diesel engines.

CLASSIFICATION OF I.C. ENGINES

Internal combustion engines may be classified as given below :

1. According to cycle of operation :

- (i) Two-stroke cycle engines
- (ii) Four-stroke cycle engines.

2. According to cycle of combustion :

- (i) Otto cycle engine (combustion at constant volume)
- (ii) Diesel cycle engine (combustion at constant pressure)
- (iii) Dual-combustion or Semi-Diesel cycle engine (combustion partly at constant volume and partly at constant pressure).

3. According to arrangement of cylinder :

- (i) Horizontal engine
- (ii) Vertical engine
- (iii) V-type engine
- (iv) Radial engine etc.

4. According to their uses :

- (i) Stationary engine
- (ii) Portable engine
- (iii) Marine engine
- (iv) Automobile engine
- (v) Aero engine etc.

5. According to the fuel employed and the method of fuel supply to the engine cylinder :

- (i) Oil engine
- (ii) Petrol engine
- (iii) Gas engine
- (iv) Kerosene engine
- (v) Carburettor, hot bulb, solid injection and air injection engine.

6. According to the speed of the engine :

- (i) Low speed engine
- (ii) Medium speed engine
- (iii) High speed engine.

7. According to method of ignition :

- (i) Spark ignition (S.I.) engine
- (ii) Compression ignition (C.I.) engine.

8. According to method of cooling the cylinder :

- (i) Air-cooled engine
- (ii) Water-cooled engine.

9. According to method of Governing :

- (i) Hit and miss governed engine
- (ii) Quality governed engine
- (iii) Quantity governed engine.

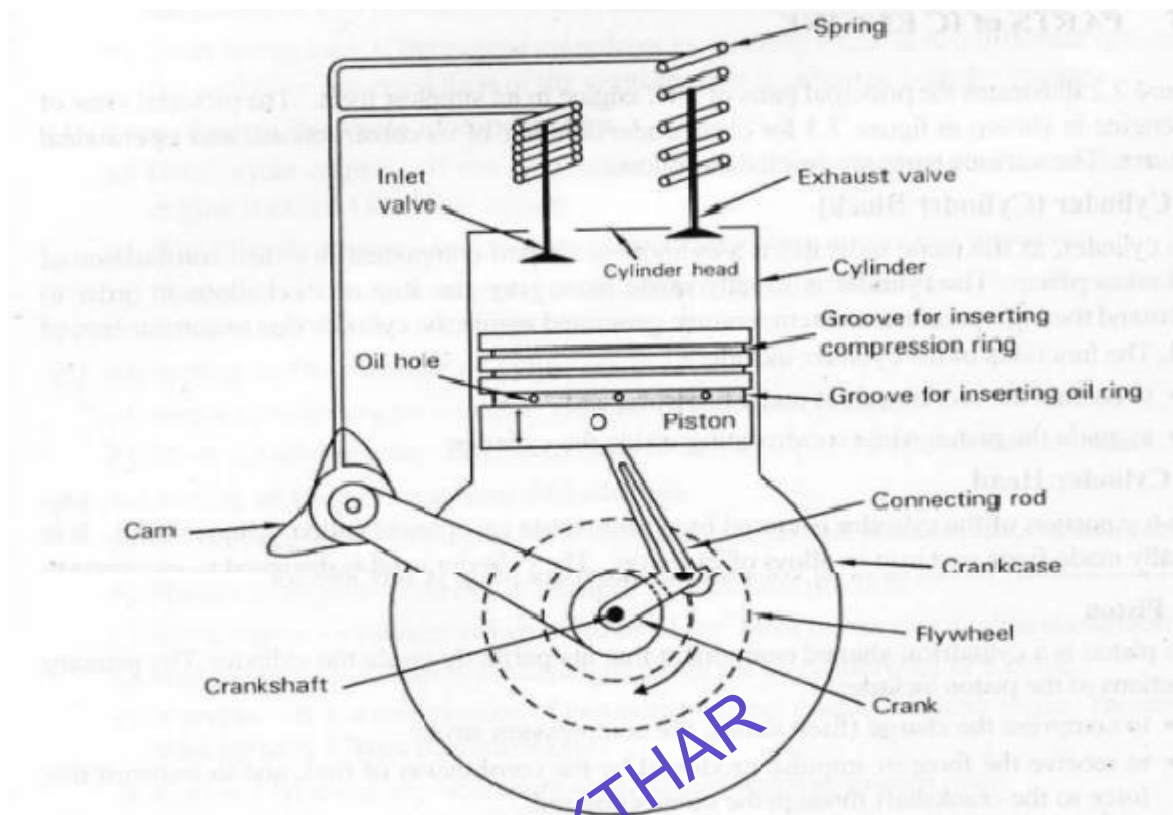
10. According to valve arrangement :

- (i) Overhead valve engine
- (ii) L-head type engine
- (iii) T-head type engine
- (iv) F-head type engine.

11. According to number of cylinders :

- (i) Single cylinder engine
- (ii) Multi-cylinder engine.

PARTS OF IC ENGINE



a) Cylinder (Cylinder Block)

The cylinder, as the name indicates is a cylindrical shaped component in which combustion of fuel takes place. The cylinder is usually made from gray cast iron or steel alloys in order to withstand the high pressure and temperature generated inside the cylinder due to combustion of fuel. The functions of the cylinder include:

- to contain the working fluid under pressure, and
- to guide the piston while reciprocating inside the cylinder.

b) Cylinder Head

The top portion of the cylinder is closed by a removable component called cylinder head. It is usually made from cast iron or alloys of cast iron. The cylinder head is designed to incorporate inlet and exhaust valves, or other components like spark plug, or fuel injector.

c) Piston

The piston is a cylindrical shaped component that fits perfectly inside the cylinder. The primary functions of the piston include:

- to compress the charge (fuel) during the compression stroke
- to receive the force or impulse produced by the combustion of fuel, and to transmit this force to the crankshaft through the connecting rod.
- Act as a guide (supporting member) for the upper end of the connecting rod.
- Serve as a carrier for the piston rings that are used to seal the combustion chamber from the crankcase.

Pistons are usually made from cast iron, or aluminum alloy for lightness.

d) Piston Rings

Towards the top of the piston, a few grooves are provided to accommodate the piston rings. The piston rings are of two types: *compression ring* and *oil ring*.

e) Connecting Rod

The connecting rod forms a link between the piston and the crankshaft as shown in figure. The upper end of the connecting rod is connected to the piston by means of a *piston pin or gudgeon pin*, while its lower end is connected to the crankshaft through the crank. The function of the connecting rod is to convert the reciprocating motion of the piston into rotary motion of the crankshaft.

f) Crank

The crank is a lever, with one of its end connected to the lower end of the connecting rod, while the other end connected to the crankshaft.

g) Crankshaft

The crankshaft transmits the power developed by the engine through the flywheel, clutch, transmission and differential to drive (move) the vehicle. The crankshaft is forged or cast from an alloy of steel and nickel.

h) Crankcase

The crankcase is the lower part of the cylinder block that encloses the crankshaft and provides a reservoir for the lubricating oil.

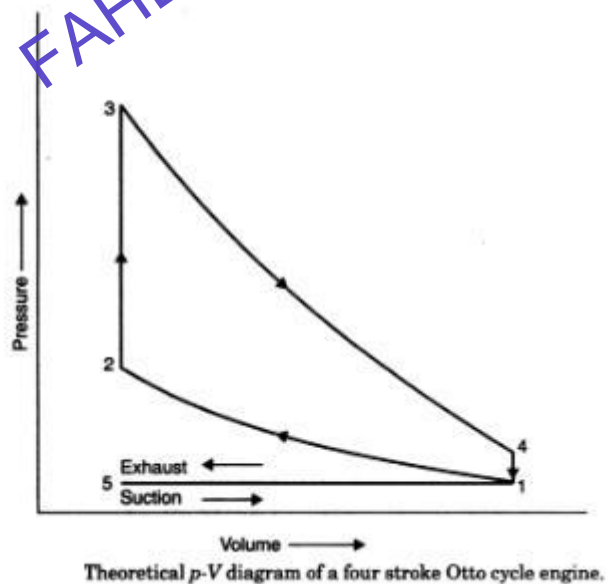
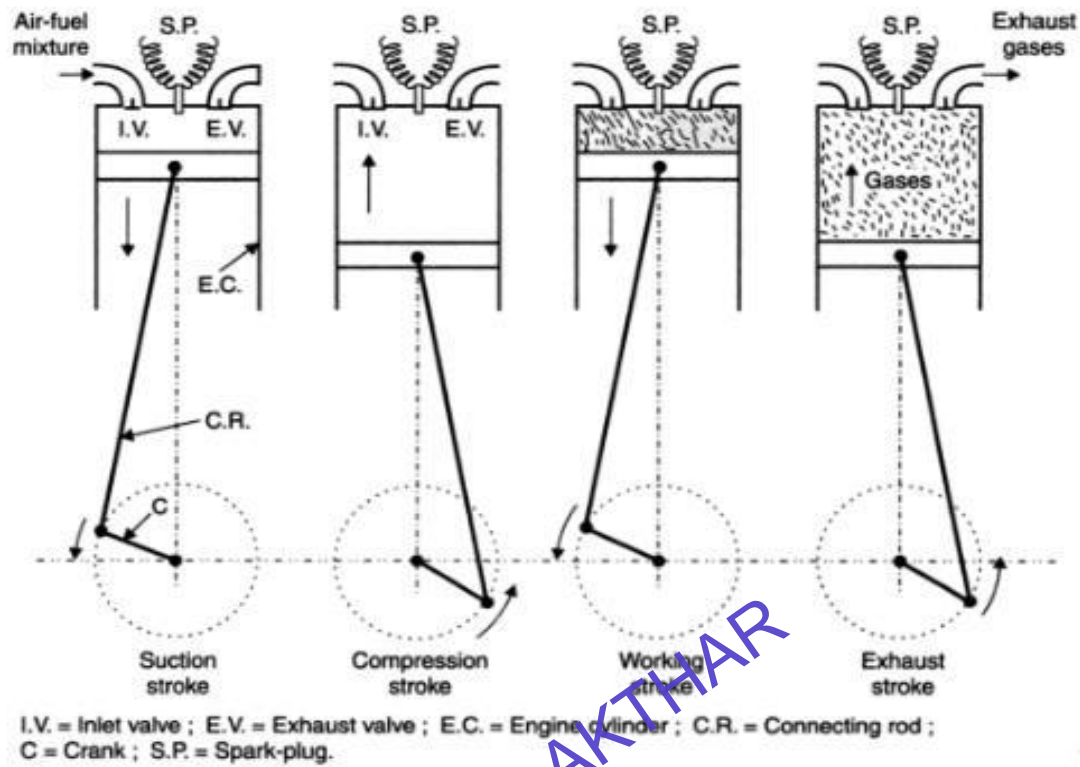
i) Flywheel

The flywheel is a large disc or a wheel mounted on the crankshaft, forming an inertial mass that stores rotational energy and supplies the same for the piston to reciprocate during subsequent strokes.

j) Valves

There are two valves for each cylinder: *inlet valve and exhaust valve*. Fresh air and/or fuel mixture enters the engine cylinder through the inlet valve, while the burnt gases are discharged outside the cylinder through the exhaust valve. Both the valves are opened and closed by means of cams driven by the camshaft through a timing gear or chain so that the charge enters or discharges the cylinder at the right time.

4-S PETROL ENGINE (SI ENGINE)



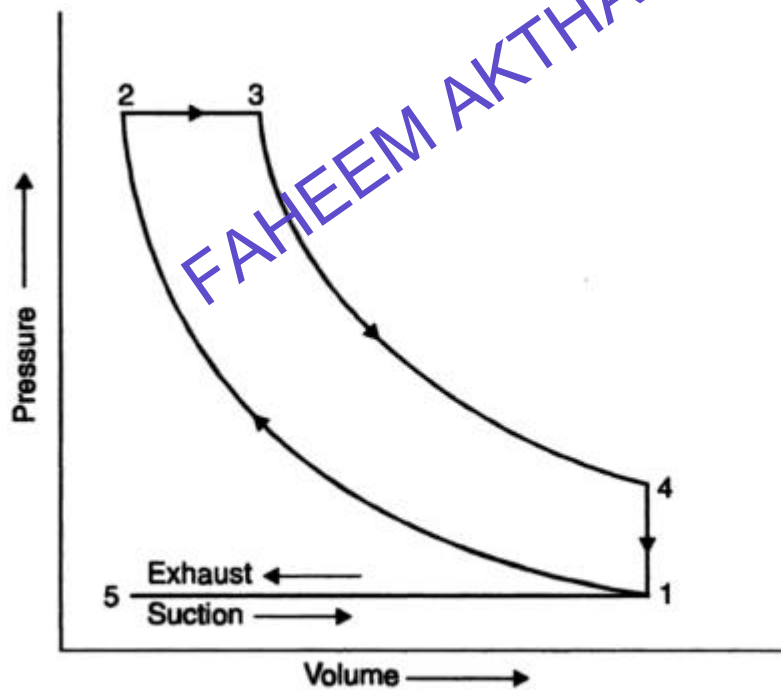
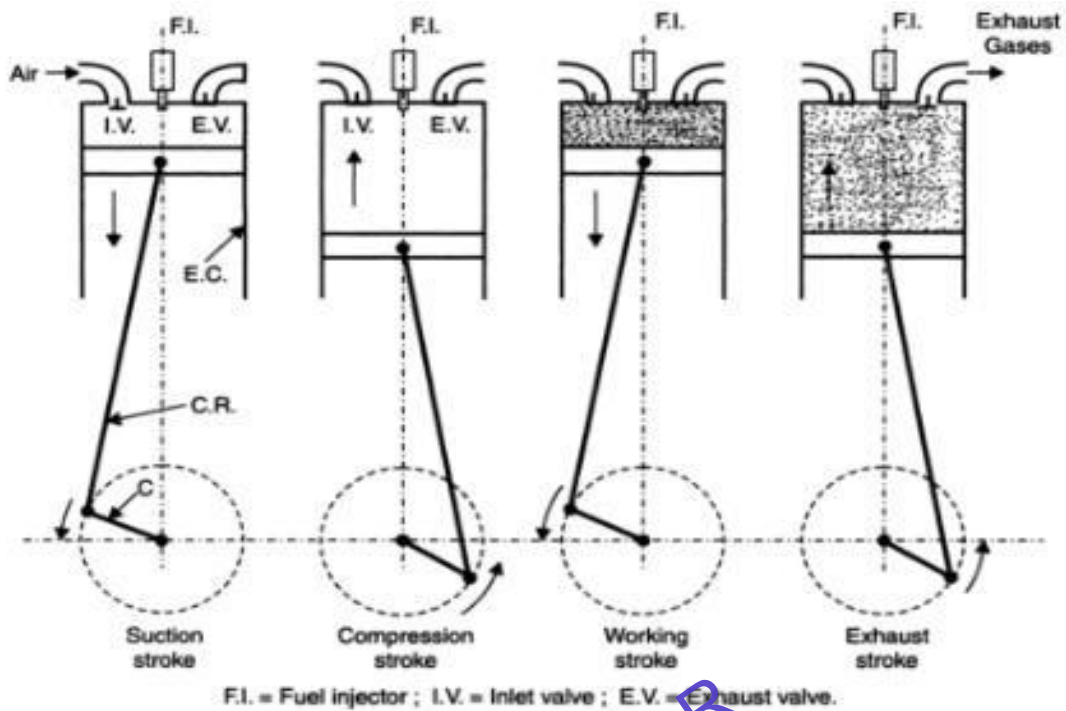
1. **Suction stroke.** During this stroke (also known as *induction stroke*) the piston moves from Top Dead Centre (T.D.C.) to Bottom Dead Centre (B.D.C.) ; the inlet valve opens and proportionate air-fuel mixture is sucked in the engine cylinder. This operation is represented by the line 5-1
The exhaust valve remains closed throughout the stroke.

2. **Compression stroke.** In this stroke, the piston moves (1-2) towards T.D.C. and compresses the enclosed air-fuel mixture drawn in the engine cylinder during suction stroke. The pressure of the mixture rises in the cylinder to a value of about 8 bar. Just before the end of this stroke the spark-plug initiates a spark which ignites the mixture and combustion takes place at constant volume (line 2-3) Both the inlet and exhaust valves remain closed during the stroke.

3. **Expansion or working stroke.** When the mixture is ignited by the spark-plug the hot gases are produced which drive or throw the piston from T.D.C. to B.D.C. and thus the work is obtained in this stroke. It is during this stroke when we get work from the engine ; the other three strokes namely suction, compression and exhaust being idle. *The flywheel mounted on the engine shaft stores energy during this stroke and supplies it during the idle strokes.* The expansion of the gases is shown by 3-4 Both the valves remain closed during the start of this stroke but when the piston just reaches the B.D.C. the exhaust valve opens.

4. **Exhaust stroke.** This is the last stroke of the cycle. Here the gases from which the work has been collected become useless after the completion of the expansion stroke and are made to escape through exhaust valve to the atmosphere. This removal of gas is accomplished during this stroke. The piston moves from B.D.C. to T.D.C. and the exhaust gases are driven out of the engine cylinder ; this is also called *scavenging*. This operation is represented by the line (1-5)

4-S DIESEL ENGINE (CI ENGINE)



Theoretical p - V diagram of a four stroke Diesel cycle.

1. **Suction stroke.** With the movement of the piston from T.D.C. to B.D.C. during this stroke, the inlet valve opens and the air at atmospheric pressure is drawn inside the engine cylinder ; the exhaust valve however remains closed. This operation is represented by the line 5-1

2. **Compression stroke.** The air drawn at atmospheric pressure during the suction stroke is compressed to high pressure and temperature (to the value of 35 bar and 600°C respectively) as the piston moves from B.D.C. to T.D.C. This operation is represented by 1-2 Both the inlet and exhaust valves do not open during any part of this stroke.

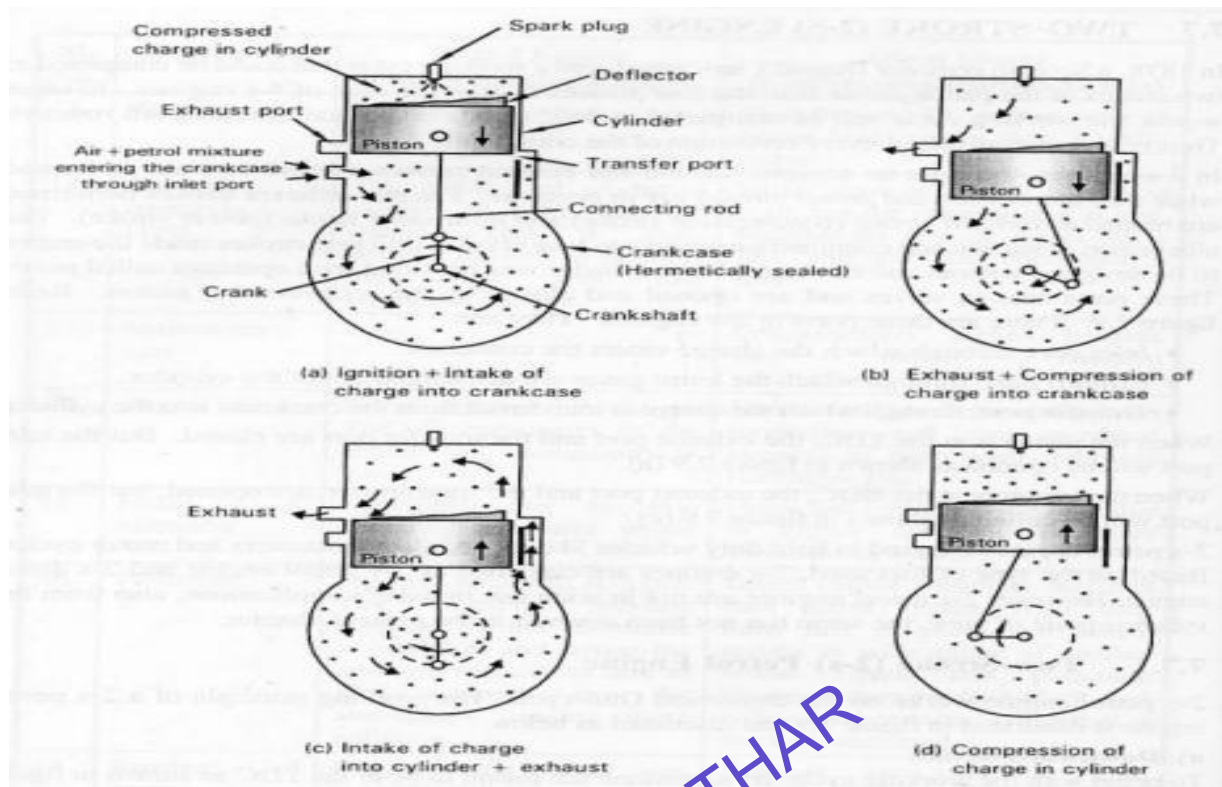
3. **Expansion or working stroke.** As the piston starts moving from T.D.C. a metered quantity of fuel is injected into the hot compressed air in fine sprays by the fuel injector and it (fuel) starts burning at constant pressure shown by the line 2-3. At the point 3 *fuel supply is cut off*. The fuel is injected at the end of compression stroke but in actual practice the ignition of the fuel starts before the end of the compression stroke. The hot gases of the cylinder expand adiabatically to point 4, thus doing work on the piston. The expansion is shown by 3-4

4. **Exhaust stroke.** The piston moves from the B.D.C. to T.D.C. and the exhaust gases escape to the atmosphere through the exhaust valve. When the piston reaches the T.D.C. the exhaust valve closes and the cycle is completed. This stroke is represented by the line 1-5

FAHEEM AKTHAR

BY
FAHEEM AKTHAR
NIT-R

2-S PETROL ENGINE



a) Downward stroke

To begin with the working cycle, let us assume the piston to be at the TDC as shown in figure

(a). At this position, the air + petrol mixture that has entered the cylinder in the previous cycle is compressed to high pressure and temperature. In the mean time, the inlet port will be opened, and as a result fresh charge of air + petrol mixture enters the crankcase as shown in figure (a). The exhaust port and transfer port will be closed as shown in the figure.

The compressed charge in the cylinder (above the piston head) is ignited by means of an electric spark generated by the spark plug. As the combustion of fuel takes place, the burnt gases expand and exert a large force on the piston causing it to move rapidly from the TDC to BDC. This force (or power) is transmitted to the crankshaft through the connecting rod. As a result, the crankshaft rotates at high speeds. The crankshaft then transmits the power through clutches, gears, and other transmission elements to turn the wheels of the vehicle and cause it to move.

b) Upward stroke

During the upward stroke, the piston moves from BDC to TDC. As the piston moves upwards, it covers the transfer port thereby stopping the flow of fresh charge from the crankcase into the cylinder. Refer figure (d). Further movement of the piston covers the exhaust port and thereafter the actual compression of the charge begins. In the meantime, the inlet port opens and the upward moving piston creates suction (partial vacuum) in the crankcase due to which fresh charge from the carburetor is drawn into the crankcase through the inlet port. Thus the intake of fresh charge takes place while the compression stroke is in progress. Refer figure

(a). When the piston reaches the TDC, the upward stroke is completed and with this, the crankshaft completes 360° or one-revolution. Thus one cycle is completed.

In the next cycle, the compressed charge in the cylinder is ignited by the spark plug and the process continues.

PETROL v/s DIESEL ENGINE

Table shows a brief comparison between petrol and diesel engine.

Sl. No.	Description	Petrol Engine (Spark Ignition Engine)	Diesel Engine (Compression Ignition Engine)
1.	Cycle of operation	Works on Otto cycle or constant volume combustion cycle.	Works on Diesel cycle or constant pressure combustion cycle
2.	Fuel used	Petrol or Gasoline.	Diesel
3.	Admission of charge	Mixture of air and petrol enters the cylinder during the suction stroke.	Only air enters the cylinder during suction stroke. Diesel is injected at the end of compression stroke.
4.	Compression ratio	Compression ratio ranges from 6:1 to 10:1	Compression ratio is comparatively high and is in the range of 16:1 to 22:1.
5.	Ignition of fuel	Fuel is ignited by a spark generated by the spark plug.	The heat of compression of air ignites the fuel.
6.	Power developed	Power developed is low due to low compression ratios.	Comparatively higher due to high compression ratios.
7.	Thermal efficiency	Thermal efficiency is low due to low compression ratios.	Comparatively higher due to high compression ratios.
8.	Fuel consumption	More	Comparatively less
9.	Weight/space occupied	Lighter in weight and also occupies less space.	In order to withstand high temperatures and pressures during compression, the engine is designed to be somewhat heavier and stronger. Also occupies more space.
10.	Speed	Due to light weight, they run at high speeds.	Due to heavy weight, they run at low/medium speeds.
11.	Uses	Used in scooters, motor bikes, cars, large boats, etc.	Used in buses, trucks, tractors, bulldozers, marine, and industrial applications.

FOUR STROKE v/s 2-STROKE ENGINE

Table shows a brief comparison between 4-s and 2-s engine.

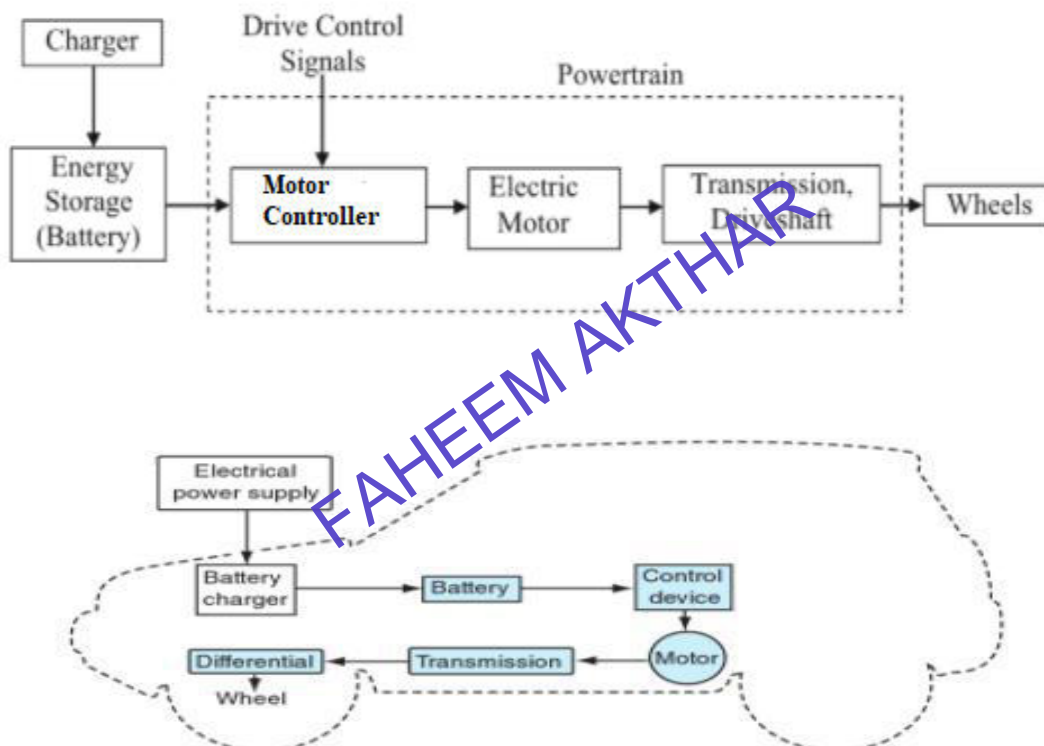
Sl. No.	Description	4-S Engine	2-S Engine
1.	Working cycle	Requires 4 different strokes of the piston or 2 revolutions of the crankshaft to complete one working cycle of operation.	Requires only 2 strokes of the piston or 1 revolution of the crankshaft to complete one working cycle.
2.	Valves	Consists of valves, which are opened and closed by valve mechanisms.	Consists of ports (openings) instead of valves. The ports are opened and closed by the reciprocating piston.
3.	Admission of charge	Charge directly enters the engine cylinder.	The charge first enters the crankcase and is then discharged into the cylinder.
4.	Discharge of gases	The burnt gases are pushed outside the cylinder by the piston.	The incoming fresh charge from the crankcase pushes the burnt gases outside the cylinder.
5.	Suction and Exhaust	Suction and exhaust process take place in separate strokes of piston.	Suction and exhaust takes place while compression and power strokes are in progress.
6.	Power developed	Power is developed for every 2 revolutions of the crankshaft.	Power is developed for each revolution of the crankshaft thereby giving significant power boost to the vehicle.
7.	Fuel consumption	Low fuel consumption, because the fresh charge never mixes with the exhaust gas.	More fuel consumption, because the fresh charge mixes with the exhaust gas during scavenging.
8.	Mechanical efficiency	Low, due to increased number of strokes per cycle, and also due to valve mechanisms which consumes power.	Comparatively higher, due to 2 strokes per cycle, and also absence of valves.
9.	Uses	4-s engines are used in bikes, cars, buses, trucks, aircraft, power plants, etc.	Used in mopeds, motor cycle, jet skis, chain saws, lawn movers, marine engines, etc.

INSIGHT INTO FUTURE MOBILITY

ELECTRIC VEHICLE

A vehicle is propelled with electric motors and draw power from onboard electric source is an electric vehicle. For storing the electric energy, most common storage device used in Electric vehicle is battery. It can store large amount of energy in a small volume and weight.

WORKING PRINCIPLE



The figure shows the simple construction of electric vehicle. It consists of battery, motor controller, motor which is connected to the transmission system. Here, battery is the energy source which is charged by taking electric current from the grid (In Solar power electric vehicle, Battery is charged with the use of solar PV panel which is attached on the roof of the vehicle). These batteries are rechargeable. After that controller control the flow of energy from energy source to the motor. Motor transmit the power to the wheels of the vehicle by the use of transmission system.

COMPONENTS OF ELECTRIC VEHICLE (EV)

There are three important components in electric vehicle namely,

1. Motor
2. Motor Controller
3. Battery

MOTOR The main function of motor is to convert supplied electric energy current in to mechanical energy. It has only two basic main parts Rotor and stator. The rotor is rotating parts which carry permanent magnet and stator is stationary part and containing stator winding.

MOTOR CONTORLLER: the electric vehicle which uses brushless DC motor has to use motor controller which helps to control various properties of motor to take sufficient current and voltage applied to motor. When accelerating pedal is press, this linked variable resistor type controller gives signal to the motor controller to adjust speed as per our needs.

BATTERY The main function of battery is to store electric energy. Most Hybrid and electric vehicle used lithium ion batteries. Due to advancing technologies, most of automobile manufacturer uses rechargeable batteries.

ADVANTAGES OF ELECTRIC VEHICLE (EV)

1. No fuel, No pollution.
2. It required less maintenance.
3. Total operation is noise free.
4. It generates high starting torque.
5. We can charge at home.
6. Less Running cost than gasoline powered vehicle.
7. It helps to save fossil fuels.

DISADVANTAGES OF ELECTRIC VEHICLE (EV)

1. It is quite expensive.
2. Not for long range travelling because availability of less number of electric charging power station.
3. It requires more time for recharging the battery

The Hybrid Electric Vehicle (HEV)

The term hybrid vehicle refers to a vehicle with at least two sources of power. A hybrid-electric vehicle indicates that one source of power is provided by an electric motor. The other source of motive power can come from a number of different technologies, but is typically provided by an internal combustion engine designed to run on either gasoline or diesel fuel.

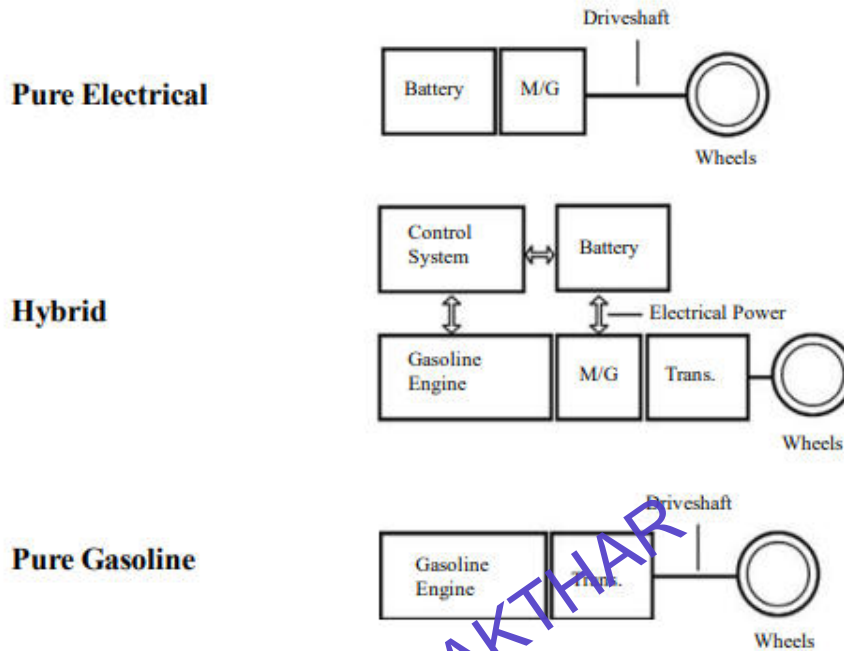
Based on this general definition, there are many types of HEVs, such as:

- The gasoline ICE and battery
- Diesel ICE and battery
- Battery and FC
- Battery and capacitor
- Battery and flywheel
- Battery and battery hybrids.

Most commonly, the propulsion force in HEV is provided by a combination of electric motor and an ICE. The electric motor is used to improve the energy efficiency (improves fuel consumption) and vehicular emissions while the ICE provides extended range capability.

Hybrid electric vehicle (HEV)

Consistent with the definition of hybrid above, the hybrid electric vehicle combines a gasoline engine with an electric motor. An alternate arrangement is a diesel engine and an electric motor.



HYBRID VEHICLE COMPONENTS

Components used in hybrid electric vehicles are given below:

- **Gasoline engine**

The hybrid car has a gasoline engine much like the one you will find on most cars. However, the engine on a hybrid will be smaller and lighter, and is more efficient than the engine in a conventional vehicle.

- **Fuel tank**

The fuel tank in a hybrid is the energy storage device for the gasoline engine.

- **Electric motor**

Electric motor used in hybrid cars are usually dc series motor since it's versatile and ease with which a variety of speed-torque characteristics can be obtained, and wide range of speed control is also possible in this.

- **Generator**

The generator is similar to an electric motor, but it acts only to produce electrical power. It is used mostly on series hybrids.

- **Batteries**

The batteries in a hybrid car are the energy storage device for the electric motor. Unlike the gasoline in the fuel tank, which can only power the gasoline engine, the electric motor on a hybrid car can put energy into the batteries as well as draw energy from them.

- **Transmission**

The transmission on a hybrid car performs the same basic function as the transmission on a conventional car.

HYBRID VEHICLE CONFIGURATION.

The hybrid drive train concept can be implemented by different configurations as follows:

- Series configuration
- Parallel configuration
- Series-parallel configuration

Series Hybrid System: In case of series hybrid system the mechanical output is first converted into electricity using a generator. The converted electricity either charges the battery or can bypass the battery to propel the wheels via the motor and mechanical transmission.

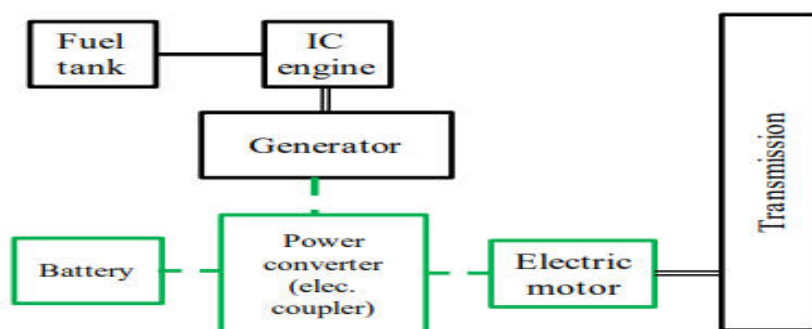


Figure Series hybrid

Parallel Hybrid System: The parallel HEV allows both ICE and electric motor (EM) to deliver power to drive the wheels. Since both the ICE and EM are coupled to the drive shaft of the wheels via two clutches, the propulsion power may be supplied by ICE alone, by EM only or by both ICE and EM. The EM can be used as a generator to charge the battery by regenerative braking or absorbing power from the ICE when its output is greater than that required to drive the wheels.

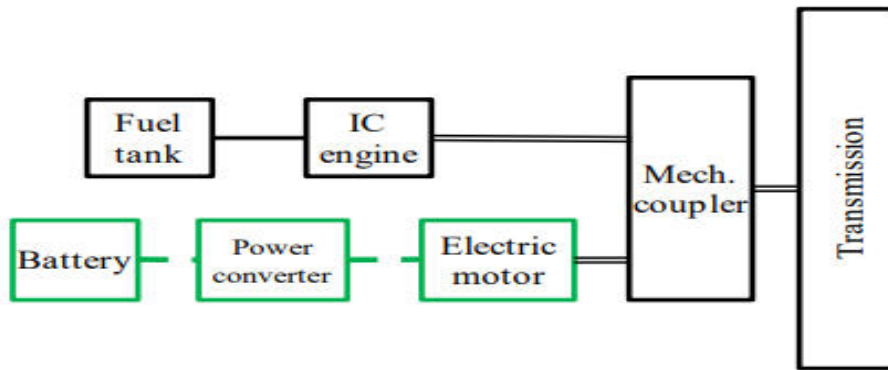


Figure Parallel hybrid

Series-Parallel System In the series parallel hybrid the configuration incorporates the features of both the series and parallel HEVs. However, this configuration needs an additional electric machine and a planetary gear unit making the control complex.

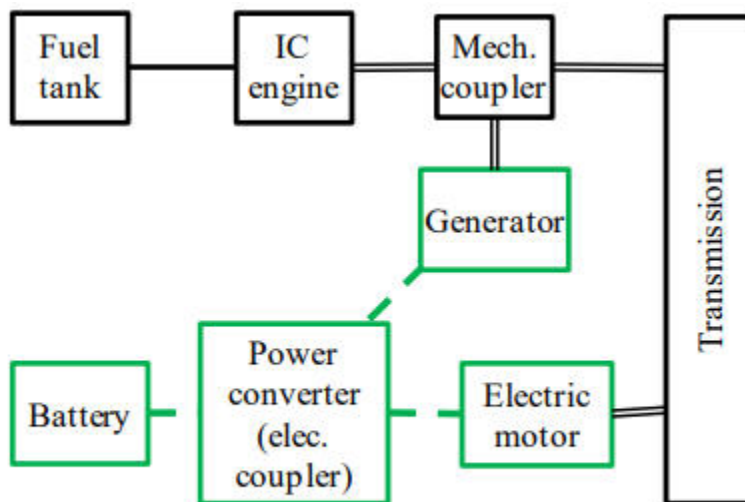


Figure Series-Parallel hybrid

ADVANTAGES OF HYBRID VEHICLE

Eco-friendly: Since hybrids house an electric motor as well as a gasoline engine, they need less fossil fuel, resulting in less CO₂ emissions. On top of that, they have more efficient gas mileage than conventional cars.

Financial benefits: Many governments around the world have introduced tax credits and incentives for buyers and owners of hybrids. They are also exempt from environmental charges.

Higher resale value: As more and more people are getting tired of gasoline price fluctuations and care about our planet, they are becoming more willing to make the switch to hybrids. As a result, the resale value of such vehicles keeps increasing.

Lighter cars: Hybrids are manufactured with lightweight materials, which allow vehicles to run on less energy. Their smaller sized and lightly built engines also contribute to conserving energy.

Regenerative braking: Hybrids use the system called “regenerative braking,” in which the battery recharges a little whenever the driver brakes. The mechanism allows the driver more time between manual recharges.

DISADVANTAGES OF HYBRID VEHICLE

Less power: Hybrids combine both an electric motor and a gasoline engine, with their gasoline engine primarily operated as the power source. Therefore, neither the gasoline engine nor the electric motor works as strongly as they do in conventional gasoline or electric cars.

Pricey to buy: The initial cost of hybrids is more expensive than conventional vehicles’ in most cases.

Higher running costs: Due to their engine and continuous development in technology, it may not be easy to find a mechanic with the required expertise. And they would likely charge you a little more for maintenance and repairs. Moreover, the highest running cost occurs when replacing the battery.

Poor handling: Hybrids have more machinery than conventional cars, which adds extra weight and reduces fuel efficiency. So, hybrid car manufacturers have had to make smaller engines and batteries to cut down on weight. But this results in reduced power for the vehicle and support in the body and suspension.