## Module- 2

# Turbines and IC Engines and Pumps

A turbine is a rotary engine that extracts energy from a fluid flow. The simplest turbine will have one moving part, a rotor assembly with blades attached to it, moving fluid acts on the blades or the blades react to the flow so that they rotate and impart energy to the rotor.

**Steam turbines:**

1. Impulse turbines
2. Impulse-reaction turbines

**Impulse Steam turbine:**

- The turbine consists of a series of curved blades fixed on the circumference of a single wheel called rotor which in turn is connected to a shaft
- The high pressure and low velocity steam generated in the boiler is used as a working fluid. The working fluid contains potential energy and kinetic energy
- Before reaching the turbine the fluid's potential energy gets changed to kinetic energy by accelerating the fluid through a nozzle
- The high velocity steam leaving the nozzle is directed towards the moving blades of the turbine
- The steam flowing over the blades undergoes a change in its velocity and direction thereby resulting in change of momentum
- This resulting impulse force pushes the blade in the same direction

Example: Delaval's Turbine

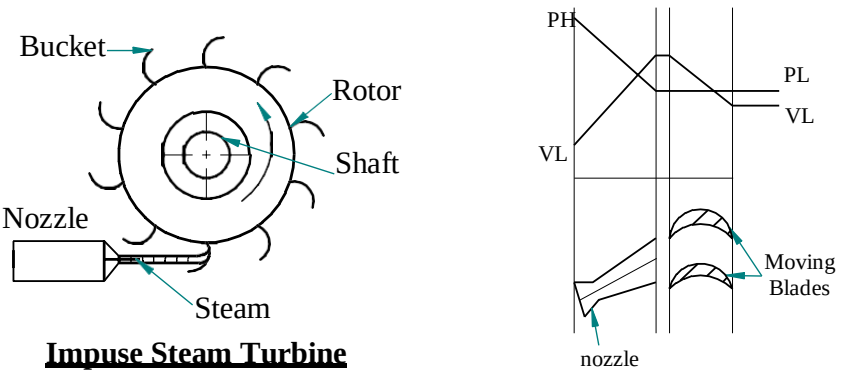



Figure 2.1 Impluse steam turbine

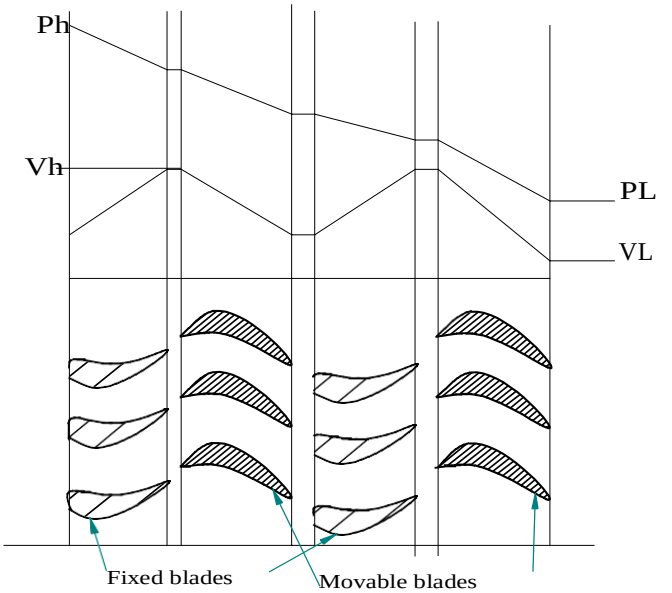


**Reaction turbine (Impulse-Reaction Turbine):**

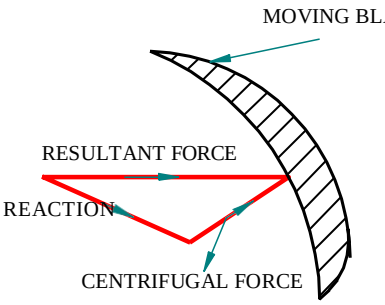
The turbine runs by the reactive force of the jet of steam rather than the direct push or impulse as in case of impulse turbine. It consists of several alternate rows of fixed and moving blades. The fixed blades are fastened to a stationary casing, while the moving blades are mounted on the periphery of a rotating wheel called rotor which in turn is connected to a shaft. In reaction turbine the shape and the cross-section of moving and fixed blades are designed such that it acts as a nozzle.

**Working**

- The high pressure, low velocity steam generated in a boiler first passes over the fixed blade
- The fixed blade acts as a nozzle where the steam gets expanded to a low pressure and high velocity and it also guides the steam onto the moving blades where it undergoes a change in its velocity and direction thereby resulting in impulse force
- The kinetic energy of the steam is converted into mechanical energy by the rotation of the rotor and when the steam leaves the moving blade, a reactive force is set up




**Reaction Turbine**




FORCE DIAGRAM FOR REACTION TURBINE

Figure 2.2 Reaction steam turbine



**Gas turbines:**

It is a thermal prime mover, which utilizes the heat energy of the burnt gases to obtain power.

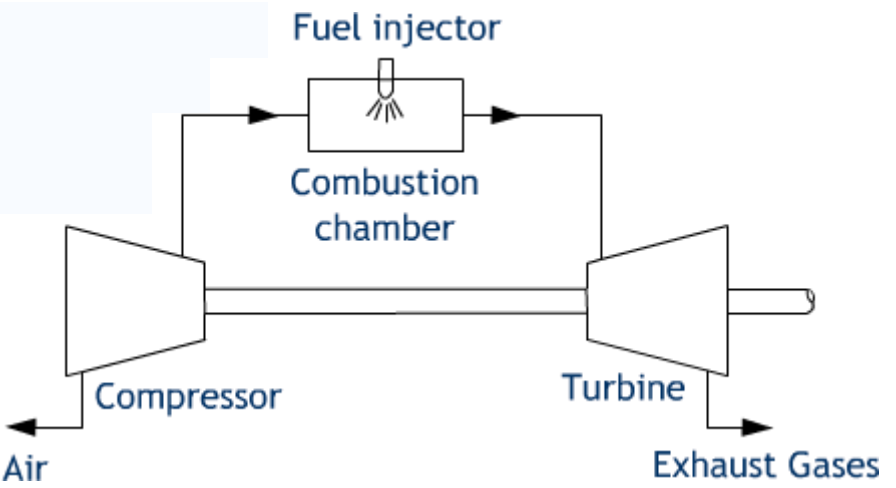
**Classification:**

a. Open cycle gas turbine
b. Closed cycle gas turbine

**Open cycle gas turbine:**

It consists of a compressor, a combustion chamber and a turbine. Both turbine and the compressor are mounted on the same shaft.

- The compressor draws air from the atmosphere and compresses it o a high pressure
- The compressed air flows into the combustion chamber where the fuel is burnt at constant pressure
- The high pressure-high temperature hot gases are then made to flow through the turbine blades where heat energy gets converted into mechanical work
- The shaft of the turbine in turn will be connected to a generator for producing electricity
- The gases coming out from the turbine are discharged to the atmosphere, hence called as open cycle gas turbine



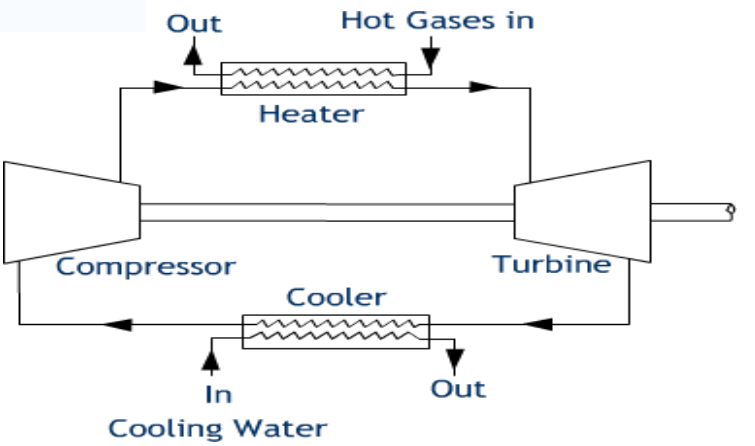

Open cycle Gas turbine

**Closed cycle gas turbine:**

It consists of a compressor, a heater, a turbine and a cooler. The compressor and turbine are mounted on the same shaft. Gases like argon, helium, nitrogen, carbon dioxide are used as working fluid for turbines.

- The working fluid is compressed in a compressor and passed on to a heater where it gets heated and the heat is transferred using an heat exchanger
- The high pressure and temperature fluid is made to flow through the turbine
- After expansion of hot gases, heat energy will get converted to mechanical work
- The fluid is then made to pass through a cooler and the low temperature and pressure fluid is made to pass to a compressor for the next cycle
- Since the working fluid is circulated again and again, hence it is called as closed cycle gas turbine





Closed cycle Gas turbine

## Water Turbines:

It is a hydraulic prime mover which converts the potential and kinetic energy of water into mechanical energy in the form of rotation of shaft.

**Classification of Water turbines:**

**1. Type of energy available at the inlet**

a. **Impulse turbine**: only kinetic energy is available at the inlet of the turbine. Example- Pelton wheel

b. **Reaction turbine**: both pressure and kinetic energy are available at the inlet of the turbine. Example- Kaplan, Francis turbine.

**2. Head at the inlet of the turbine**

a. **High head turbine**: Head of water available at the inlet of turbine. It ranges from 100 to 1000 meters. Example- Pelton wheel

b. **Medium head turbine**: Head of water available at the inlet ranges from 50 to 400 meters Example- Francis turbine.

c. **Low head turbine**: Head of water available at the inlet will be less than 50 meters Example- Kaplan turbine.

**3. Based on the direction of flow of water through the runner**

a. **Tangential flow turbine**: Water flows tangential to the runner. Example- Pelton wheel

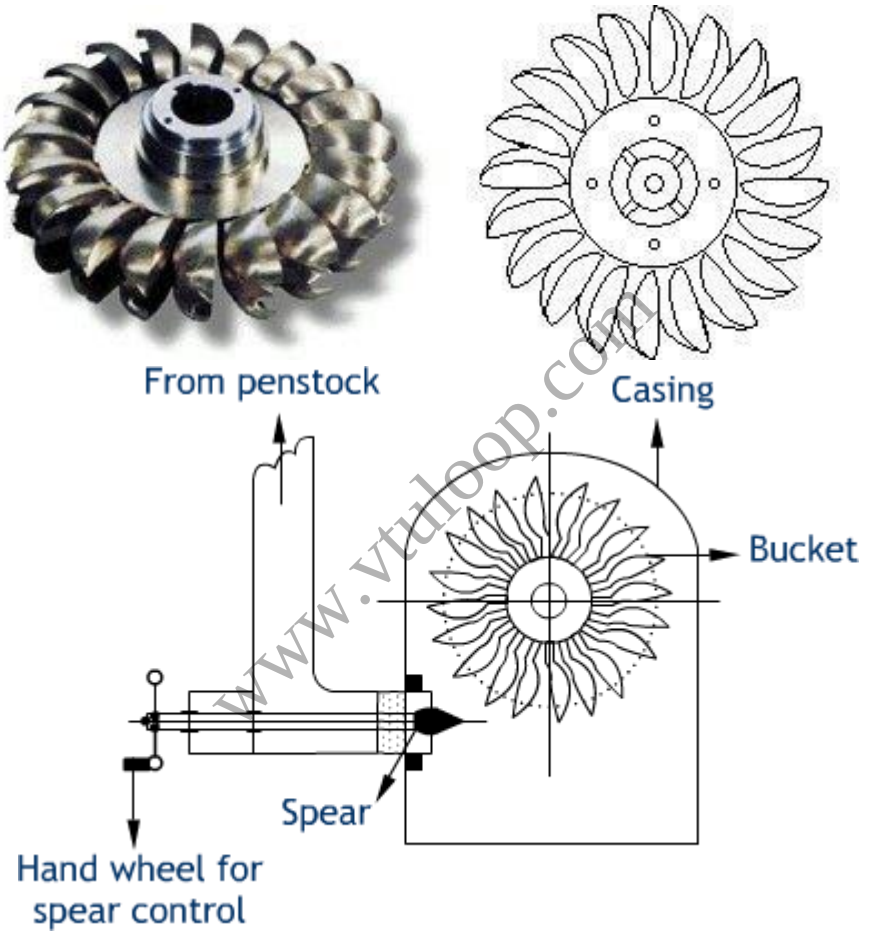
b. **Axial flow turbine**: water flows parallel to the axis of rotation of the runner. Example- Kaplan turbine.

c. **Radial flow turbine**: water flows in radial direction through the runner. Example- Thomson turbine.

**Pelton wheel:**

- It is a tangential flow impulse turbine used for high heads and small quantity water flow
- Water from the high head reservoirs is supplied to the nozzle provided with a needle which controls the quantity of water flowing out of the nozzle
- As the water flows through the nozzle the potential energy is converted to kinetic energy

- The high velocity jet of water from the nozzle is made to impinge on the curved blades known as Pelton cups fixed around the runner
- The impulsive force of the high velocity jet of water sets the runner into rotary motion and the shaft coupled to the runner also rotates



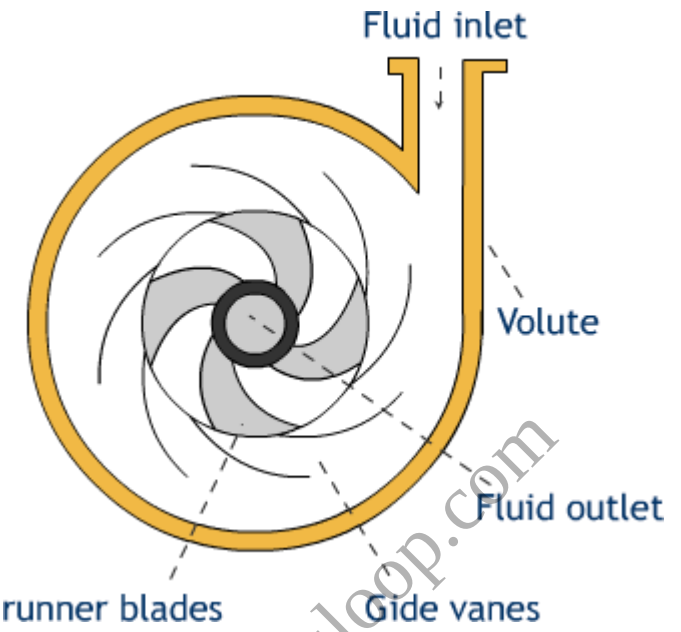

Pelton wheel turbine



**Francis Turbine**

- It is a medium head reaction turbine in which water flows radially inwards
- It consists of a spiral casing used to distribute water uniformly around the runner
- Water from the reservoir enters the spiral casing and flows radially inwards to the outer periphery of the runner through the guide blades and finally discharged to the tail race axially from the centre of the runner via a draft tube

- During its flow over the moving blades it imparts kinetic energy to the energy to the runner to set it into rotational motion. Hence the shaft connected to the runner also rotates thereby doing useful work

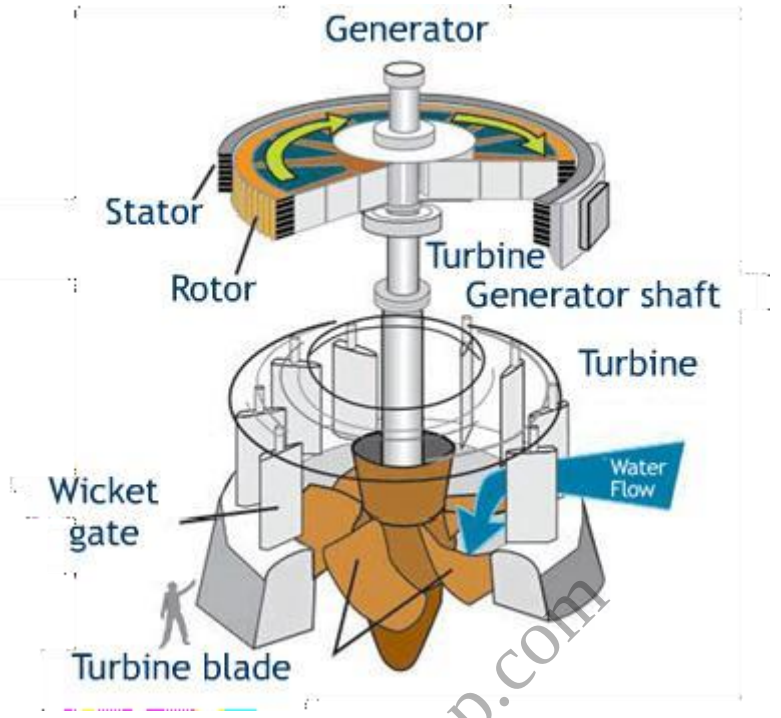



Francis Turbine



**Kaplan turbine**

- It is a low head axial flow section turbine
- The runner of the Kaplan turbine resembles with the propeller of the ship hence it is also called as propeller turbine
- Water from the reservoir flows through the spiral casing where potential energy of water gets converted to kinetic energy
- The water then moves through the guide vanes (blades) and flows axially imparting the kinetic energy to set it into rotational motion
- When the water leaves the blade at high velocity a reaction force is set up and this force rotates the runner thus potential energy of water is converted into mechanical work




Kaplan turbine



## Internal Combustion Engines

I C engines is called as internal combustion engine combustion (burning) takes inside the closed chamber. E C engine external combustion engine, burning take place outside the engine. I C engine it converts heat (thermal, chemical) energy into mechanical energy.

**Classification of I C engine:**

a) Based on thermodynamic cycle
   (1) Otto cycle (2) Diesel cycle (3) Dual combustion cycle.
b) Based on the fuel
   (1) Petrol (2) Diesel (3) Bi-fuel (4) Gas
c) Based on strokes
   (1) Two stroke (2) Four Stroke
d) Based on the Ignition
   (1) Spark Ignition (2) Compression Ignition
e) Based on number of Cylinders
   (1) Single cylinder (2) multi cylinder

f) Based on the engine placing
(1) V-engine (2) I or vertical engine (3) Horizontal engine
(4) Opposed engine (5) Radial engine

g) Based on the cooling systems
(1) Air cooled (2) Water cooled

h) Based on the application

(1) Transport (2) Locomotive (3) Marine (4) Power generation
(5) Agricultural (6) Earth moving

**Parts of I C engine:**

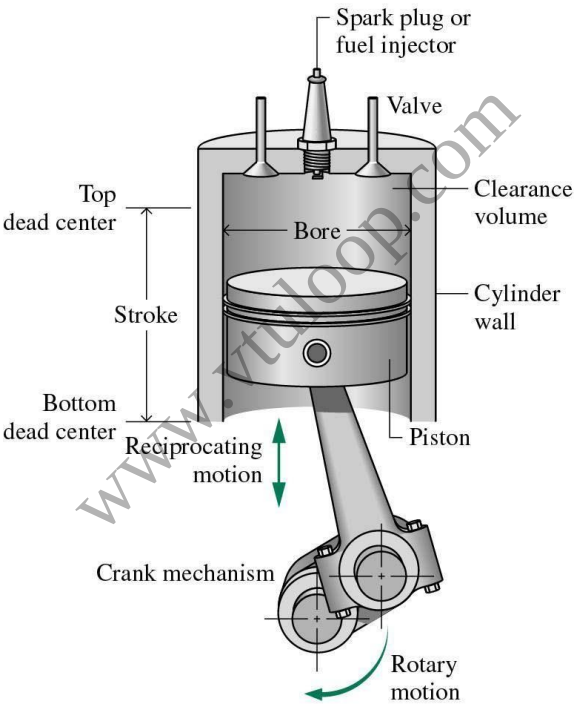



Figure :Parts of IC engine

1) Cylinder: is the heart of the engine, piston reciprocals inside the cylinder.
2) Piston : is a hallow cylinder
   It is fitted inside the cylinder
   It reciprocates inside the cylinder
   It compresses the charges and transmits the power to crank shaft.
3) Connecting Rod: it connects the piston to crank shaft. To convert reciprocating motion of the piston to rotator motioning of the crank shaft.
4) Crank shaft: it receives the rotary motion from the connection rod.
5) Valves: it controls the air/fuel to enter into the cylinder and also to discharges the exhaust gas. Inlet value air/ fuel is entering

Exhaust value Burnt gases escapes.

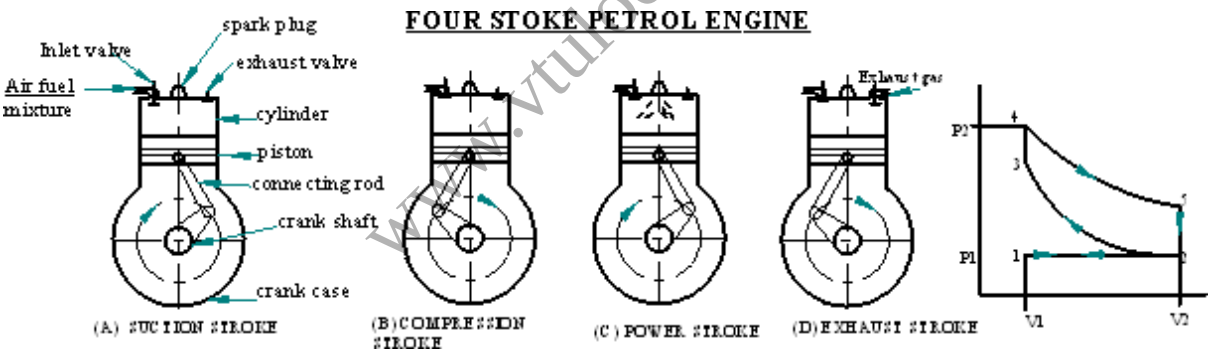
6) Fly wheel: it is fitted at end of the crank shaft.
It stores the kinetic energy and release the energy to crank shaft.

**Some of the notation:**

B.D.C: Bottom dead centre
T.D.C: Top dead centre
I.V: Inlet value
O.V: Outlet value or exhaust valve.
Stroke: The piston displacement is called as stroke (T.D.C to B.D.C or B.D.C to T.D.C)
$180^o$ revolution of the crank in 4 strokes.
Bore: Diameter of the inside cylinder.

## Four Stroke Petrol Engine (Spark Ignition):

The following are the working strokes
(A) Suction (B) Compression (C) Power (D) Exhaust stroke.




SUCTION STROKE:

1. Inlet value opens and exhaust value is closed.
2. Piston moves from top dead centre to bottom dead centre (crank rotates $0\text{-}180^o$)
3. Piston sucks the air fuel mixture in to the cylinder (constant pressure and volume increase V1 to V2)

COMPRESSION STROKE:

1. Both inlet and exhaust values closed.
2. Piston moves from bottom dead centre to top dead centre. ($180^o$ to $360^o$ crank rotation).
3. Pressure and temperature of the air fuel mixture increases. (volume decreases)
4. At the end of compression stroke volume remains constant for a small displacement , it is called constant volume cycle (compression ratio is 1:14)

POWER STROKE:

1. Both inlet and exhaust value closed.
2. High pressure and high temperature air fuel mixture catches the fire with spark plug.
3. High amount energy released and pushes piston down word direction.
4. Fly wheel stores the energy. (impact energy)

EXHAUST STROKE:

1. Exhaust value opens and inlet value closed
2. Piston moves from bottom dead centre to top dead centre.
3. The burnt gases escape from the cylinder.
4. Crank shaft completes the two revolutions and generates one power stroke.

## FOUR STROKE DIESEL ENGINE (compression ignition)



The following are the working strokes

(A) Suction (B) Compression (3) Power stroke (4) Exhaust

SUCTION STROKE:

1. Inlet value opens and exhaust value is closed.
2. Piston moves from top dead centre to bottom dead centre (rank rotates 0-180$^o$)
3. Piston sucks the fresh air into the cylinder (constant pressure and volume increases) (v1 to v2)

COMPRESSION STROKE:

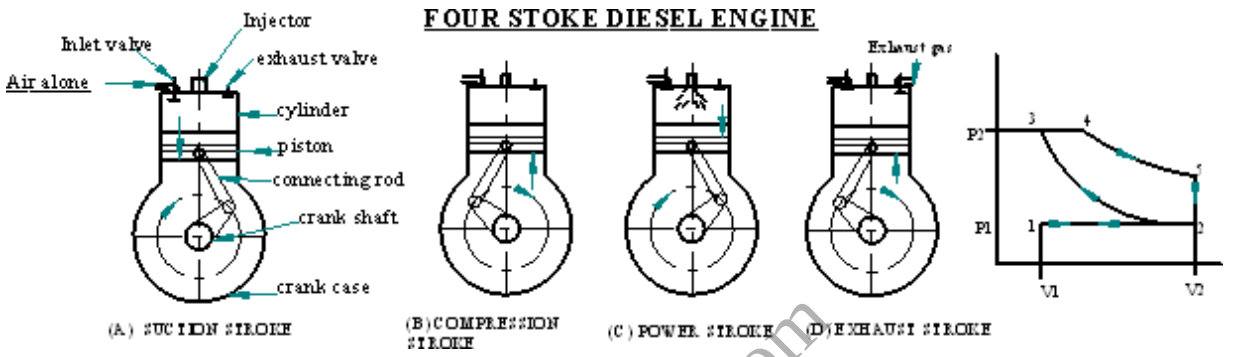
1. Both inlet and exhaust valves closed
2. Piston moves from bottom dead centre to top dead centre (180$^o$ to 360$^o$ rotation)
3. Pressure and temperature of the air increases to high
4. At the end of the compression stroke pressure remains constant for a small displacement of the piston. It is called constant pressure cycle compression (ratio is 1:20)

POWE STROKE:

(1) Both inlet and exhaust value closed.
(2) High pressure and high temperature air catches the fire with diesel is sprayed.
(3) High amount energy released and pushes piston down word direction.
(4) Fly wheel stores the energy. (impact energy)

EXHAUST STROKE:

(1) Exhaust value opens and inlet value closed
(2) Piston moves from bottom dead centre to top dead centre.
(3) The burnt gases escape from the cylinder.
(4) Crank shaft completes the two revolutions and generates one power stroke.






## Two Stroke Petrol Engine:

1. First Stroke 2. Second Stroke

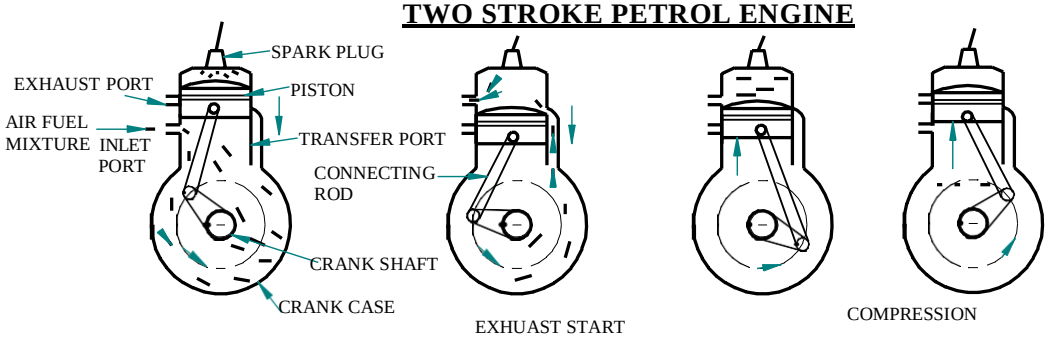
**First stroke:**

- The spark plug ignites the compressed petrol and air mixture
- The high pressure combustion gases force the piston downwards
- The piston performance the power stroke till it covers the exhaust port
- As soon as piston uncovers the transfer port, the fresh air fuel mixture flows from crankcase in to the cylinder
- This drives out of the exhaust gases by the incoming fresh charge is called scavenging
- Piston moves from top dead centre to bottom dead centre

**Second stroke:**

- In this stroke piston moves from bottom dead centre to top dead centre
- The piston covers the transfer port; air fuel mixture is cut off, suction stops
- Further movement of the piston will compress the air fuel mixture in the cylinder
- The ratio of compression is from 1:8 to 1:12
- At end of compression stroke air fuel get ignited

## TWO STROKE PETROL ENGINE




**(a) FIRST STROKE** **(b) SECOND STROKE**