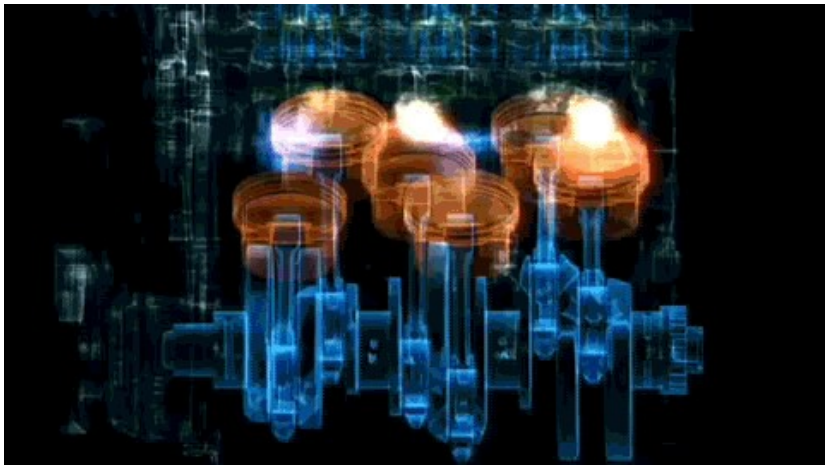
IIT Kanpur
Kanpur, India (208016)

Energy Systems-1



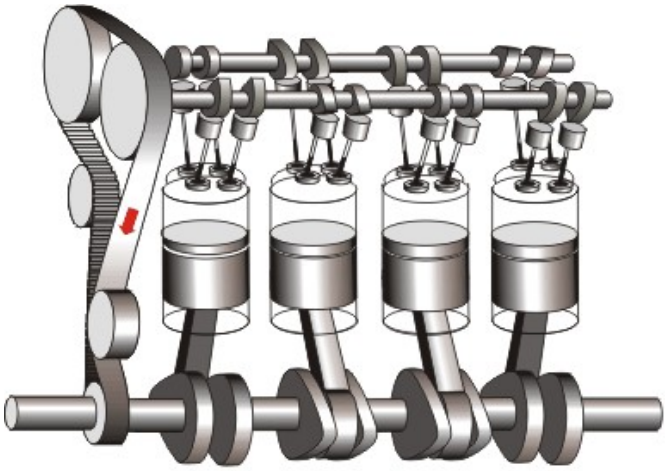
Lecture-9

Introduction of IC Engine

Date- 25/8/2017, Friday

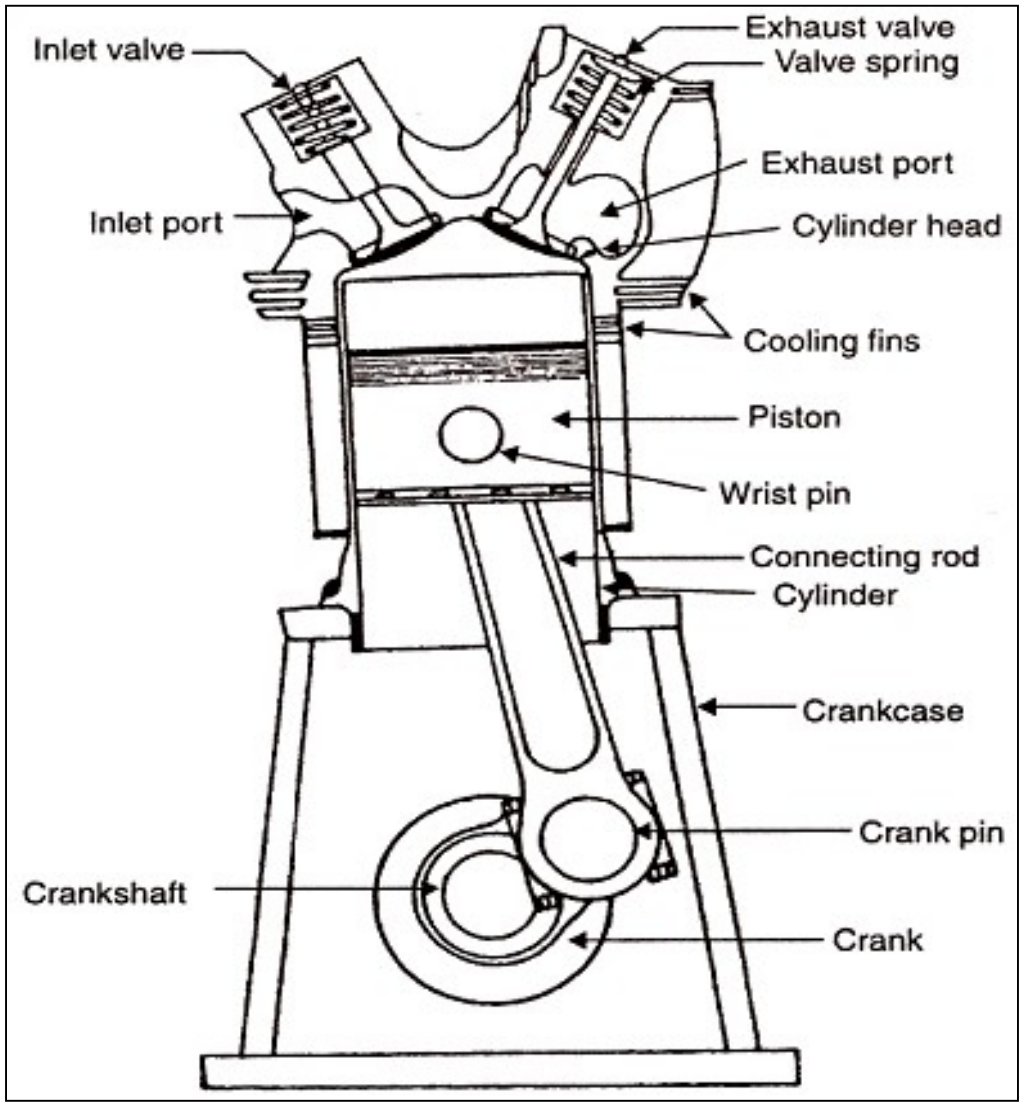
ME 301

Introduction



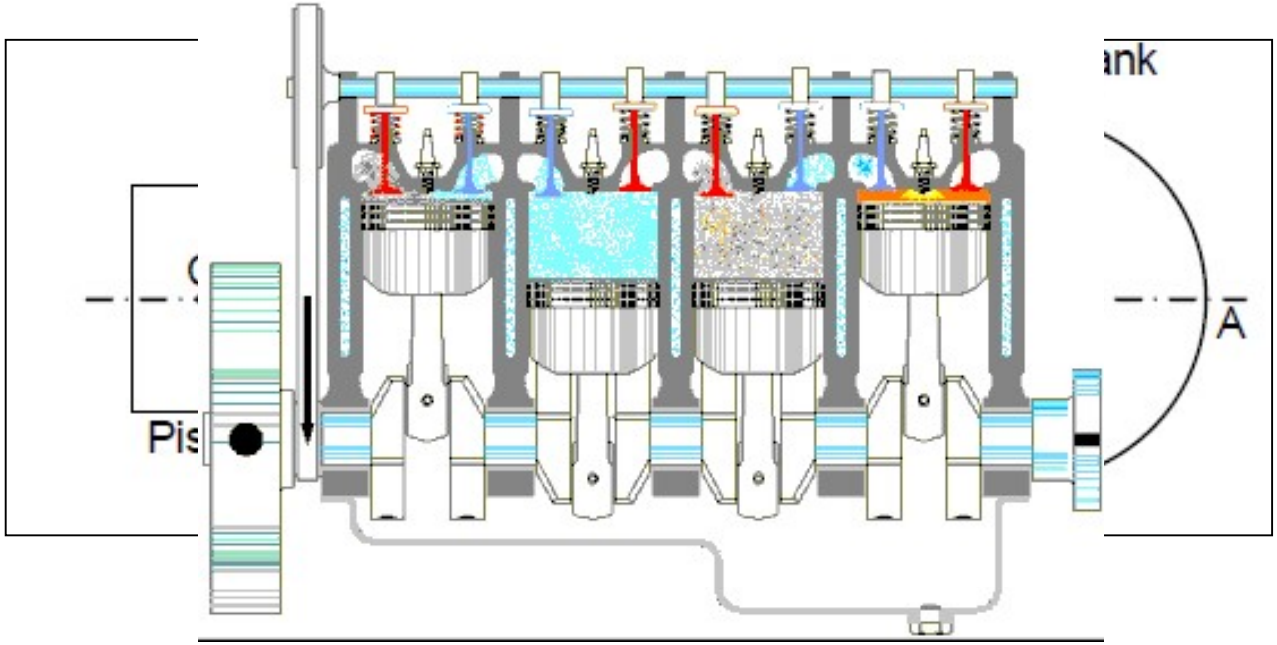
- There are two types of engines:
  - Internal combustion
    - -- Combustion occurs in the working fluid
    - -- Open cycle – the working fluid is replenished in each cycle
    - -- Exhaust gas is dumped into the atmosphere
  - External combustion
    - -- Use of heat exchanger to transfer energy to the working fluid
    - --Open or closed cycle
    - -- Example: steam engine, sterling engine
- The purpose of internal combustion engines is the production of mechanical power from the chemical energy contained in the fuel.
- In internal combustion engines, energy is released by burning or oxidizing the fuel inside the engine.
- Main two types of IC engines are :
  - -- Spark ignition (SI) engine (also called Otto engine or gasoline or petrol engines)
  - -- Compression ignition (CI) engine (also called Diesel engine)
- These two types of engine have found wide application in transportation (land, sea and air) and power generation.

Engine Terminology and Basic Working Principle



Different Engine Parts

Engine Terminology and Basic Working Principle



- A reciprocating engine contains following main parts;

  Cylinder, Piston , Connecting rod , Crank

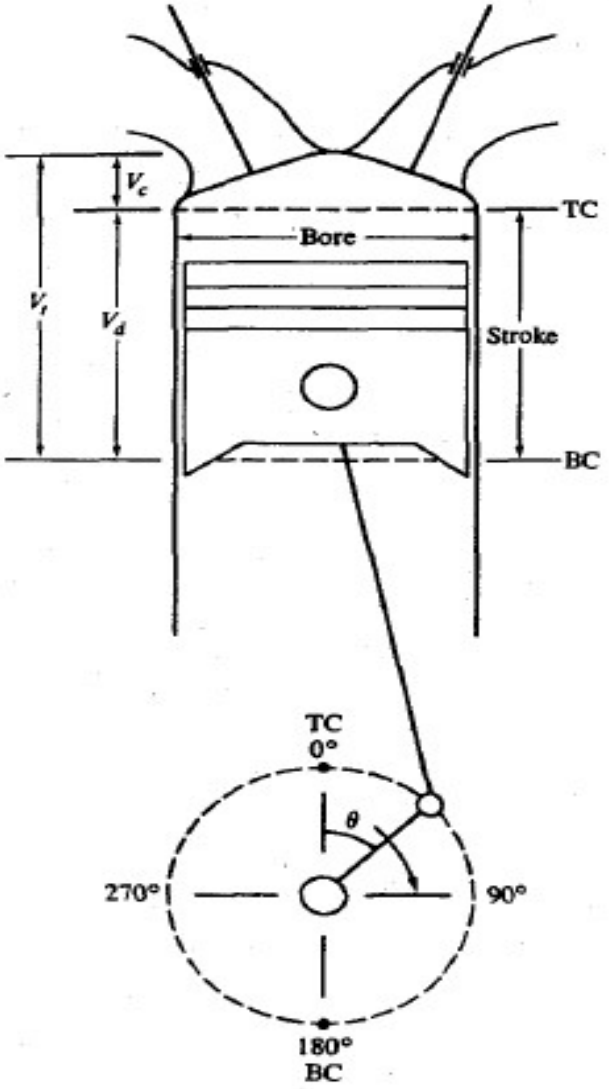
- The piston is pushed to right in the cylinder. The connecting rod is then pushed and in turn it causes the crank to rotate about its centre O.
- The engine shaft (perpendicular to plane of paper) rotates and provide power.
- The piston reciprocates between two extreme points C1 and C2, called dead centre. C1 is top dead centre (TDC or TC) and C2 is bottom dead centre (BDC or BC).

Engine Terminology and Basic Working Principle

- When piston is at TC, there is clearance between the piston and head of the cylinder. The volume of this space is called clearance volume (V_c).
- The volume between TC and BC is called swept volume or stroke volume (V_d).
- The linear distance between TC and BC is known as stroke and apparently stroke is two times the radius of the crank.
- The ratio of maximum volume to minimum volume is the compression ratio (r_c).

$$r_c = \frac{V_S + V_c}{V_c}$$

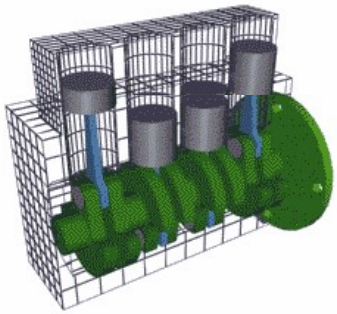
- Typical values of r_c, are 8 to 12 for SI engines and 12 to 24 for CI engines.

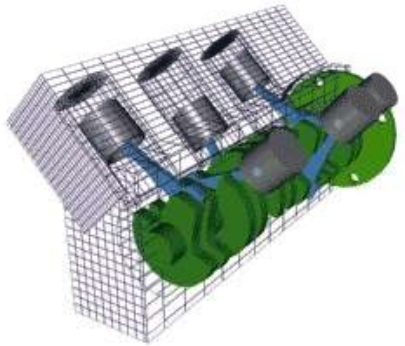


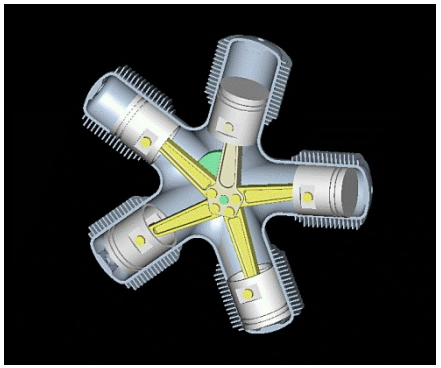
TDC Positions

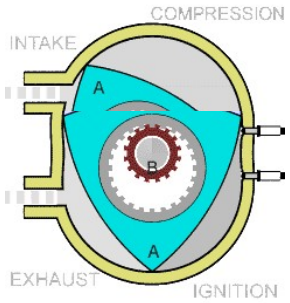
Classification of IC Engine

- **Based on Method of Ignition**
  - Spark ignition engine: Ignition is done by spark.
  - Compression ignition engine: Ignition is done by compressive pressure.
- **Based on Design**
  - Reciprocating engine: Subdivided by arrangement of cylinders: e.g., in-line, V, radial, opposed.
  - Rotary engine: Wankel and other geometries.









- **Based on Working Cycle**
  - Four-stroke cycle: Naturally aspirated (admitting atmospheric air), supercharged (admitting pre-compressed fresh mixture), and turbocharged (admitting fresh mixture compressed in a compressor driven by an exhaust turbine).
  - Two-stroke cycle: Crankcase scavenged, supercharged, and turbocharged.

Classification of IC engine

- **Based on Combustion Chamber Design**
  - Open Chamber: Many designs: e.g., disc, wedge, hemisphere, bowl-in-piston.
  - Divided Chamber: Small and large auxiliary chambers; many designs: e.g., swirl chambers, pre-chambers.
- **Based on Method of Cooling**
  - Water Cooled: Water is used for cooling the engine.
  - Air Cooled: Air is used for cooling the engine.
- **Based on Valve or Port Design and Location**
  - Overhead (or I-head) Valves
  - Underhead (or L-head) Valves
  - Rotary Valves
  - Cross-Scavenged Porting: Inlet and exhaust ports on opposite sides of cylinder.
  - Loop-Scavenged Porting: Inlet and exhaust ports on same side of cylinder.
  - Through- or Uniflow-Scavenged: Inlet and exhaust ports or valves at different ends of cylinder.

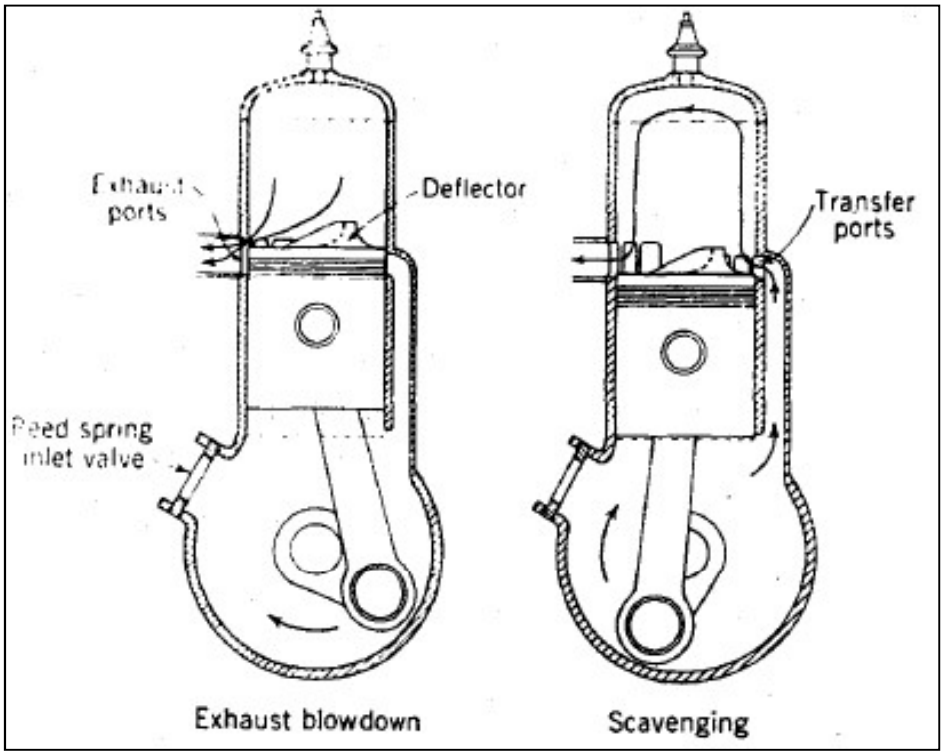
Classification of IC engine

- **Based on fuel**
  - Petrol
  - Diesel
  - Natural gas
  - Liquid petroleum gas
  - Alcohols (methanol, ethanol)
  - Hydrogen
  - Dual fuel

- **Based on method of load control**
  - Throttling of fuel and air flow together
  - Control of fuel flow alone
  - A combination of these two

- In most of the discussion working cycle and method of ignition has been selected as the primary classifying feature.

Introduction to Two Stroke Cycle



Two Stroke Engine Cycle

- In two stroke cycle one power stroke requires one revolution of crankshaft.
- To obtain a higher power output from a given engine size, and a simpler valve design, the two-stroke cycle was developed.
- Ports in the cylinder liner, opened and closed by the piston motion, control the exhaust and inlet flows while the piston is close to BC.

Introduction to Two Stroke Cycle

- The two stroke cycle is applicable to both SI and CI engines.
- The two strokes are Compression stroke and power or expansion stroke

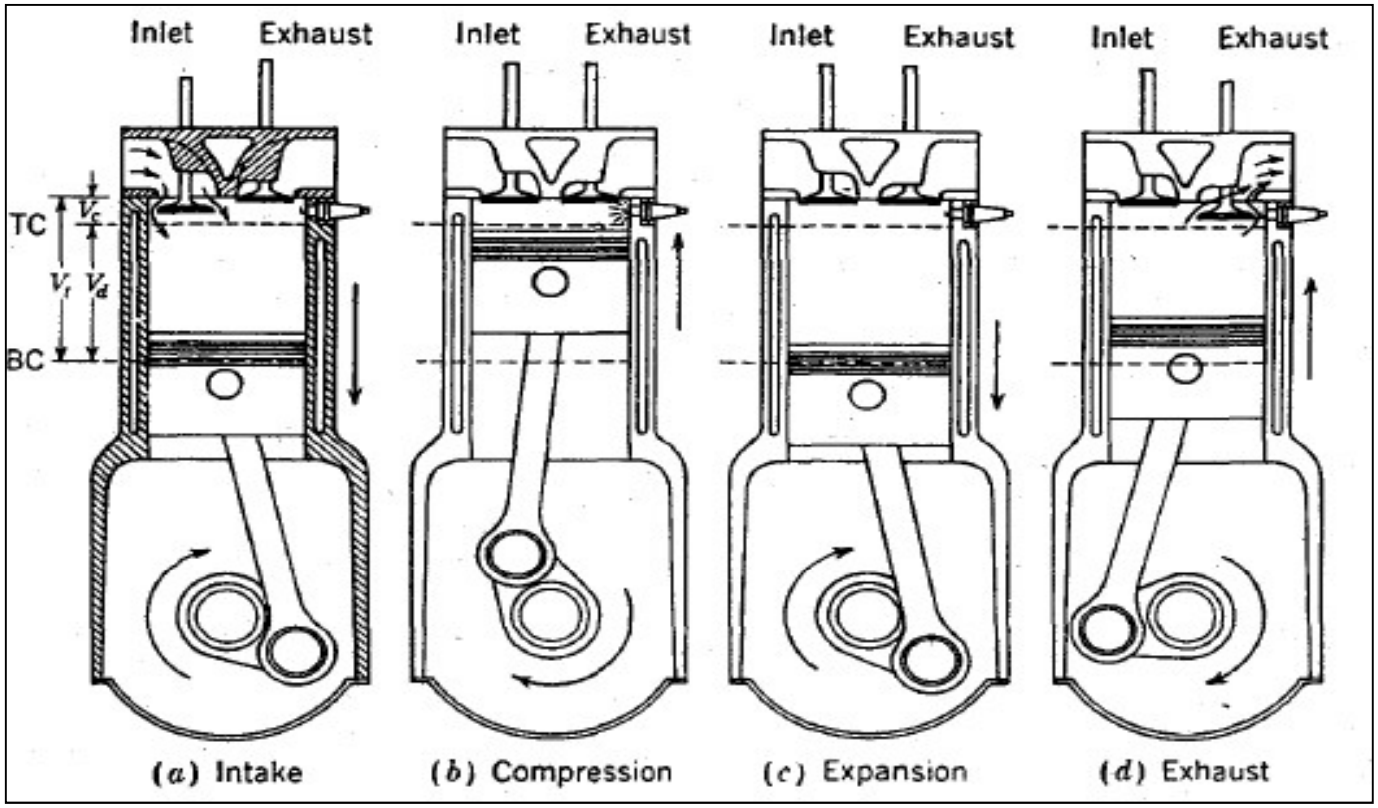
Compression stroke

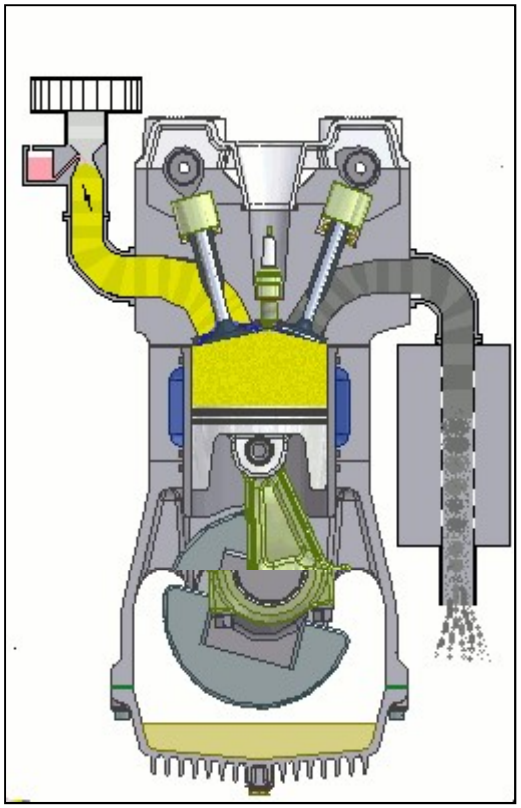
- Starts by closing the inlet and exhaust ports,
- Then compresses the cylinder contents and draws fresh charge into the crankcase,
- As the piston approaches TC, combustion is initiated.

Power or expansion stroke

- starts with the piston at TC and ends at BC,
- First the exhaust ports and then the intake ports are uncovered,
- Most of the burnt gases exit the cylinder in an exhaust blow down process.
- When the inlet ports are uncovered, the fresh charge which has been compressed in the crankcase flows into the cylinder.
- The piston and the ports are generally shaped to deflect the incoming charge from flowing directly into the exhaust ports and to achieve effective scavenging of the residual gases.

Introduction to Four Stroke Cycle





4 Stroke Engine Cycle

- The majority of reciprocating engines operate on what is known as the four-stroke cycle.
- In four stroke cycle one power stroke requires one revolution of crankshaft.
- The four stroke cycle is applicable to both SI and CI engines.
- The four stokes are intake stroke, compression stroke, power stroke and exhaust stroke.

Introduction to four stroke cycle

- **Intake stroke**
  - Starts with the piston at TC and ends with the piston at BC, which draws fresh mixture into the cylinder.
  - To increase the mass inducted, the inlet valve opens shortly before the stroke starts and closes after it ends.
- **Compression stroke**
  - When both valves are closed and the mixture inside the cylinder is compressed to a small fraction of its initial volume.
  - Toward the end of the compression stroke, combustion is initiated and the cylinder pressure rises more rapidly.
- **Power stroke or expansion stroke**
  - Which starts with the piston at TC and ends at BC as the high-temperature, high-pressure, gases push the piston down and force the crank to rotate.
  - About five times as much work is done on the piston during the power stroke as the piston had to do during compression.
  - As the piston approaches BC the exhaust valve opens to initiate the exhaust process and drop the cylinder pressure to close to the exhaust pressure.

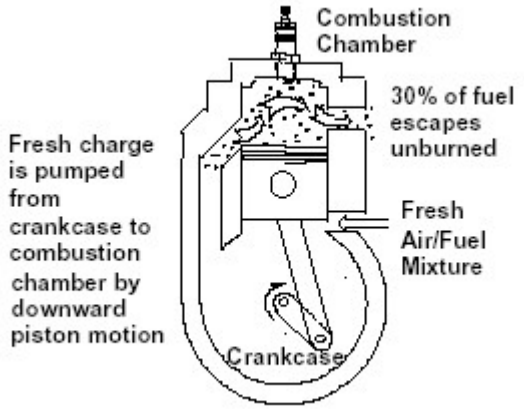
Introduction to four stroke cycle

❖ Exhaust stroke

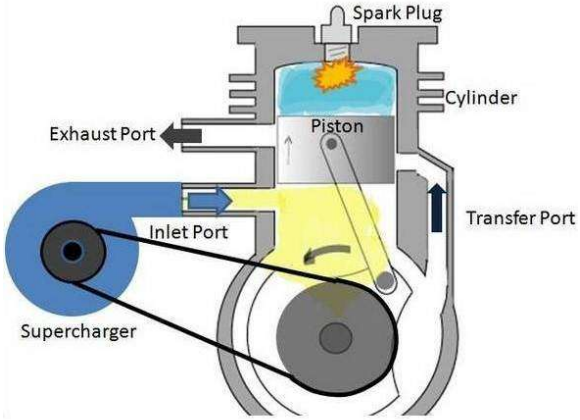
- Here the remaining burned gases exit the cylinder: first, because the cylinder pressure may be substantially higher than the exhaust pressure
- Then as they are swept out by the piston as it moves toward TC. As the piston approaches TC the inlet valve opens.
- Just after TC the exhaust valve closes and the cycle starts again.

Supercharging and Turbocharging

- In basic concept, a supercharger is nothing more than an air pump mechanically driven by the engine itself. Some of the engine power created is offset by the power required by the supercharger
- Usually, compress the fuel/air mixture after it leaves the carburetor
- Reduced exhaust stoke
- Reduced specific fuel consumption
- Increased mechanical efficiency
- Increased thermal stresses, heat losses, gas loading, valve overlap
- Increased cooling requirement for piston and valves



Crankcase scavenged

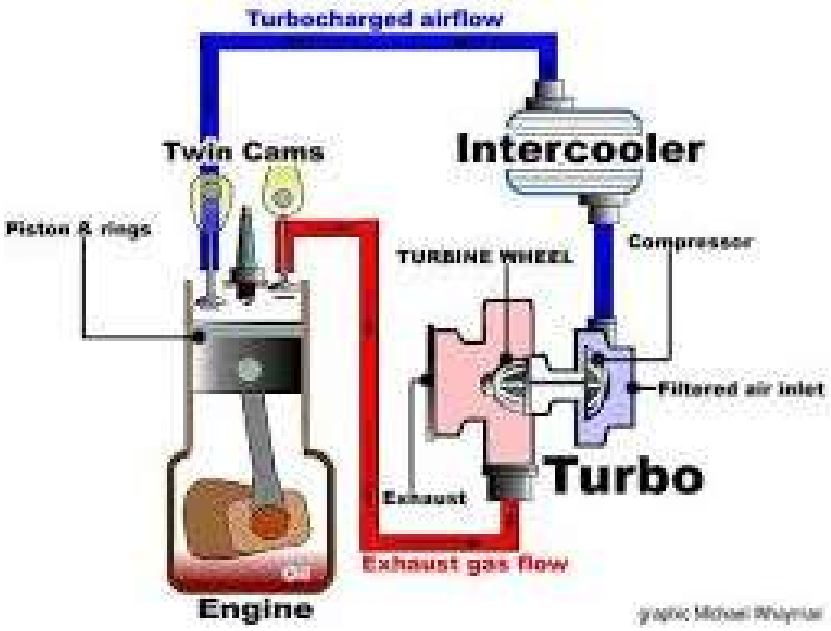


Supercharger

Turbocharger

Supercharging and Turbocharging

- The supercharger driven by gas turbine. It uses energy available in the exhaust gases
- No mechanical linkage between the engine and the supercharger
- The major parts of a turbocharger: turbine wheel, turbine housing, turbo shaft, compressor wheeel, compressor housing, bearing housing



★ **Thermodynamic cycle with supercharging**

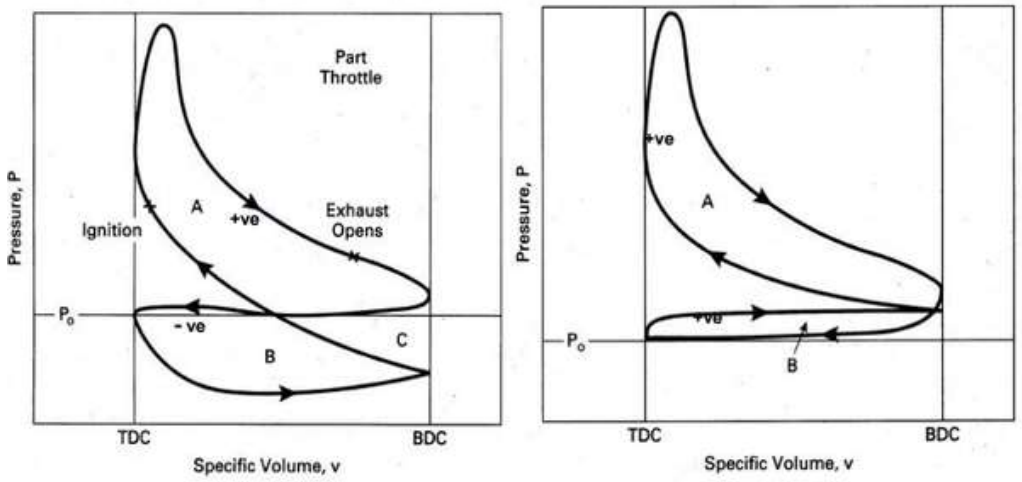


Figure. 1
a) P-V diagram of Naturally aspirated engines b) P-V diagram of Supercharged engines