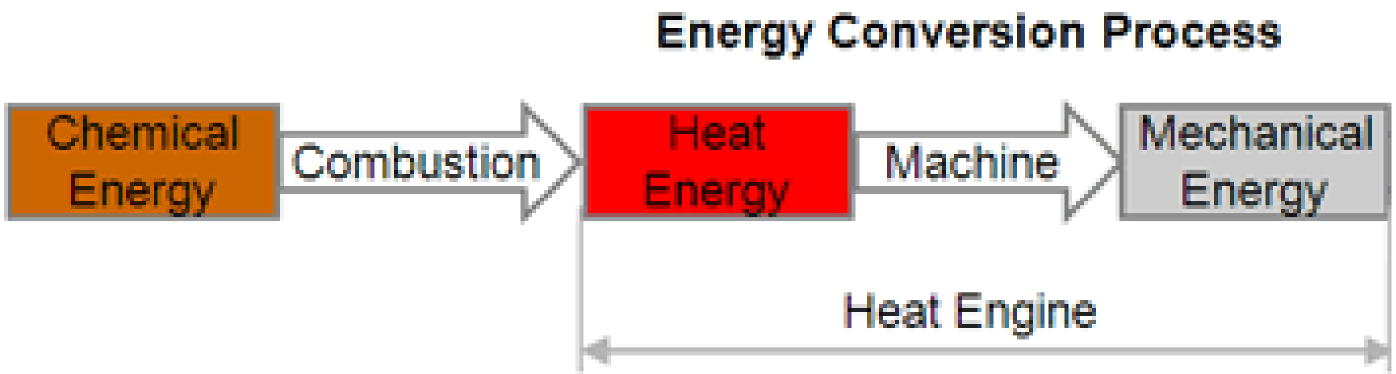
IC ENGINES

Engine

- Device transforms one form of energy to another form
- Heat engine- Engine which converts thermal energy in to mechanical energy. Ex: steam engine

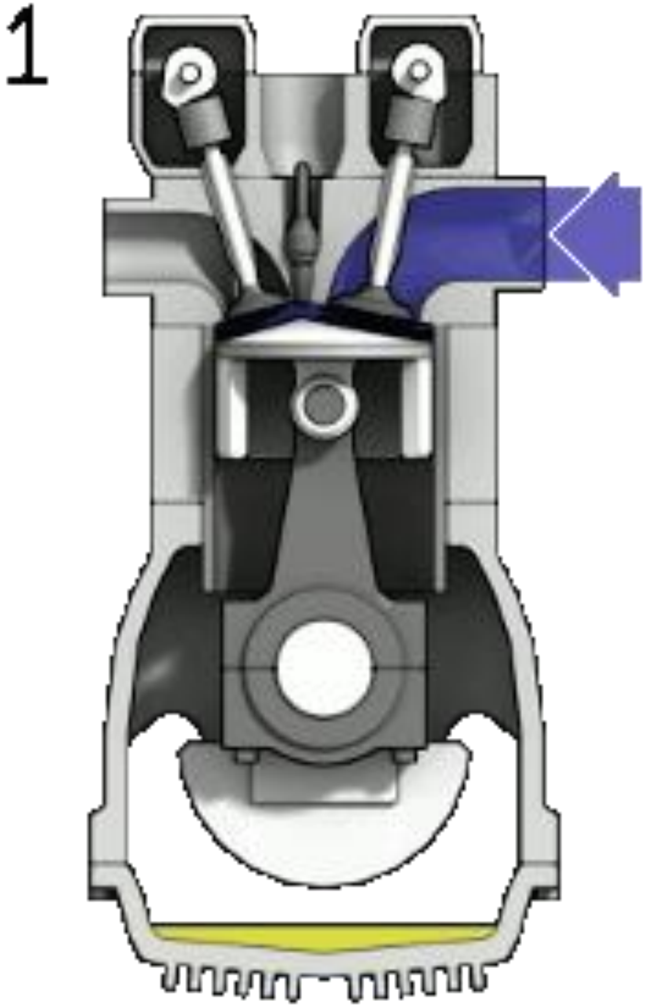


- Classified as
  - External Combustion engines (EC Engines)
  - Internal combustion engines(IC Engines)

- In an **External combustion engine**, working fluid gets energy by burning fossil fuels or any other fuel outside the mechanical engine system, thus the working fluid does not come in contact with combustion products.
  - Steam engine, where the working fluid is steam.
  - Stirling engine, where the working fluid is air.

- In an **Internal combustion engine**, combustion takes place within working fluid of the engine, thus fluid gets contaminated with combustion products.
  - Petrol & Diesel engines are examples of internal combustion engine, where the working fluid is a mixture of air and fuel

I C Engine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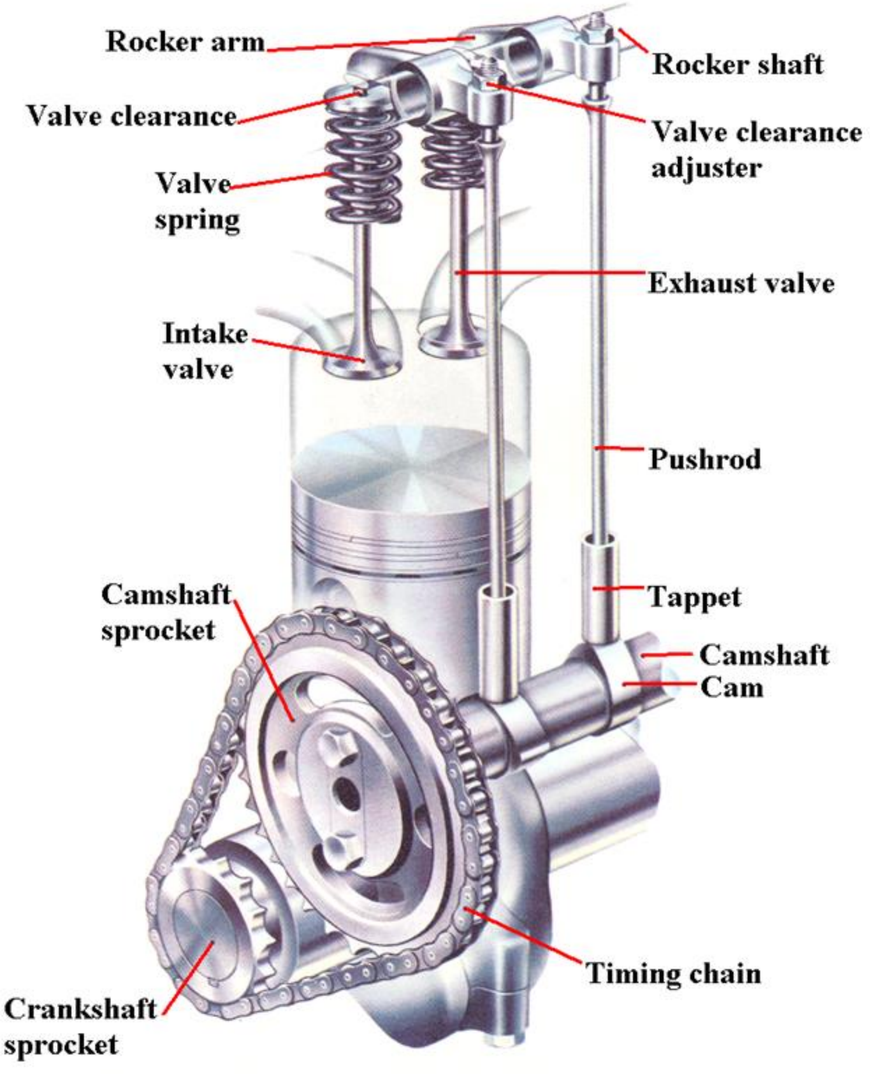
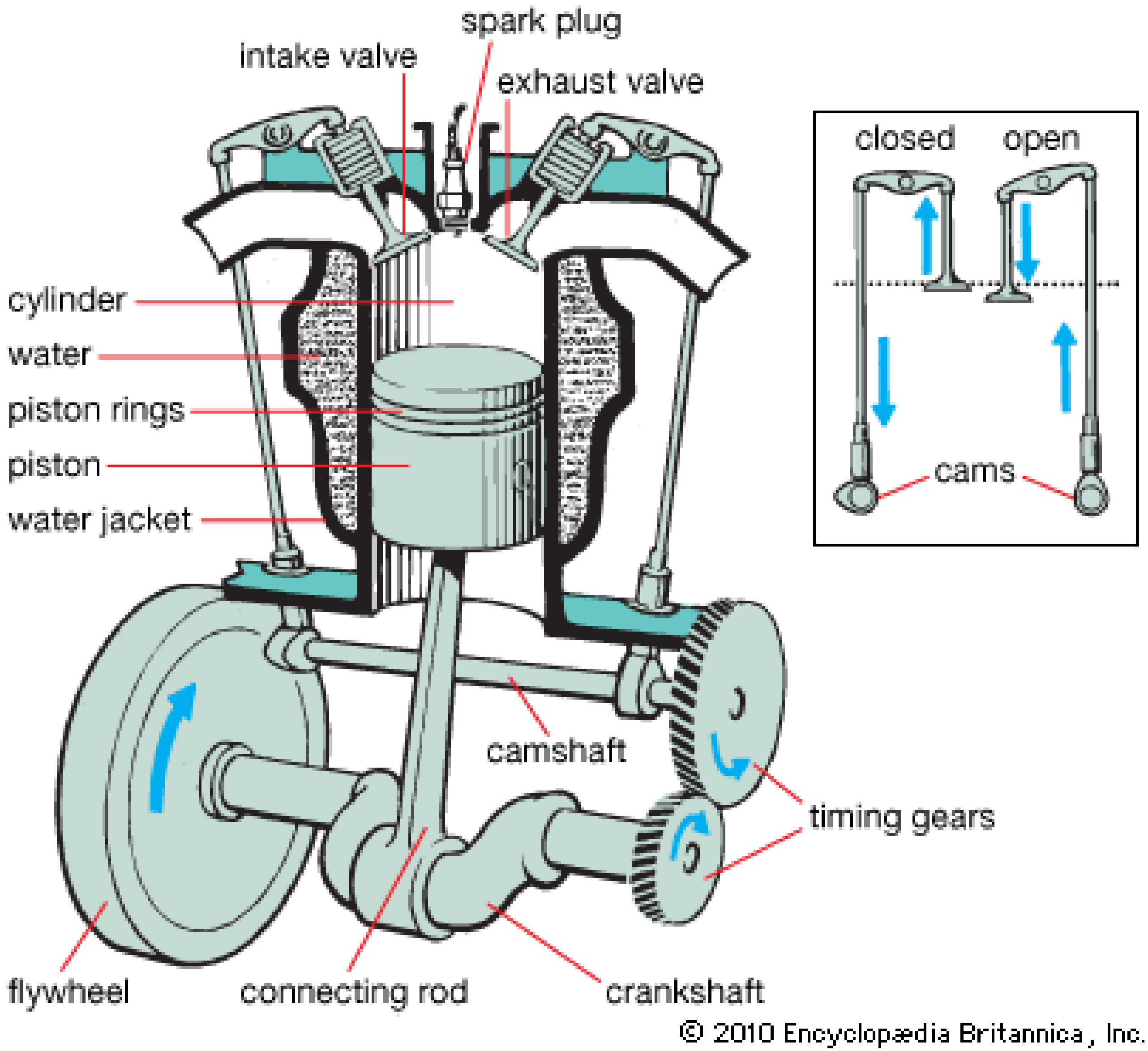
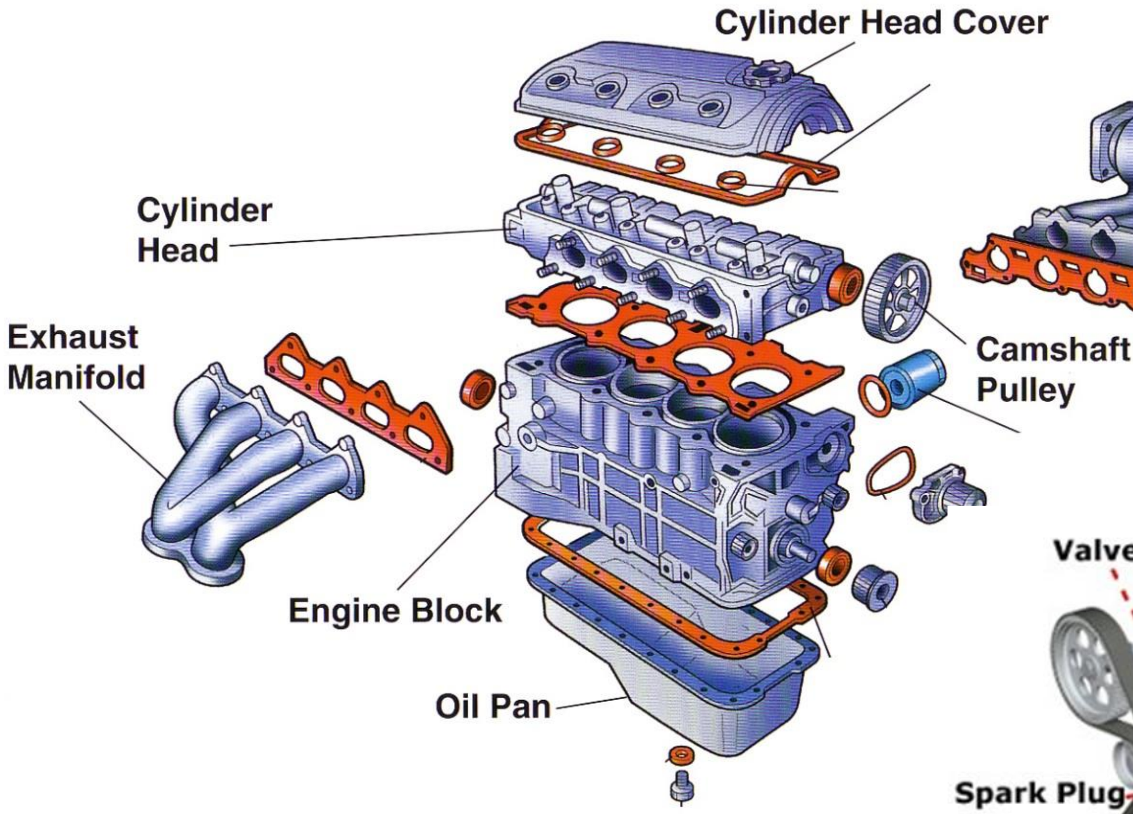
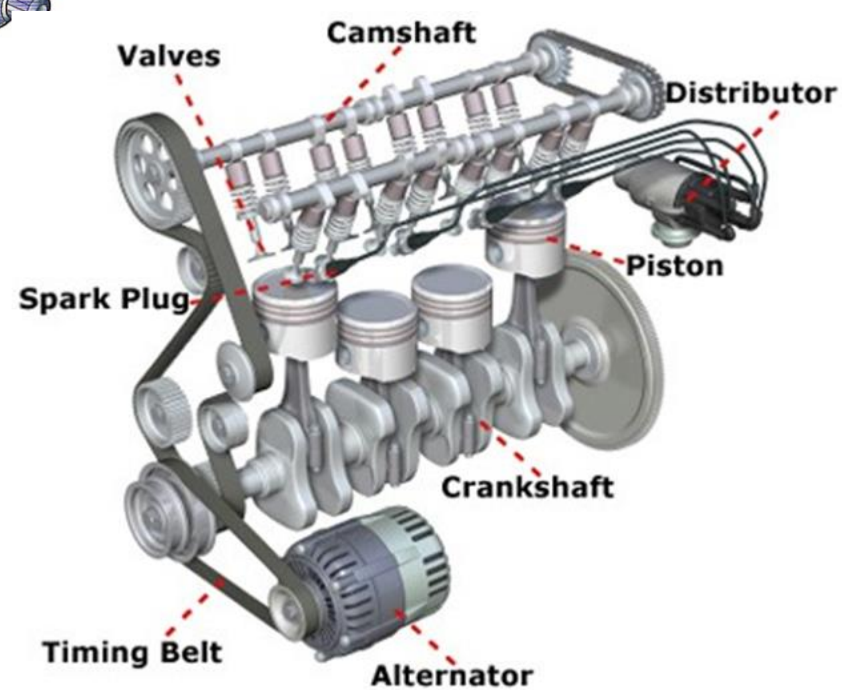

Rocker arm
Rocker shaft
Valve clearance
Valve clearance adjuster
Valve spring
Exhaust valve
Intake valve
Pushrod
Camshaft sprocket
Tappet
Camshaft
Cam
Timing chain
Crankshaft sprocket

Engine Components



Engine (Exploded View)



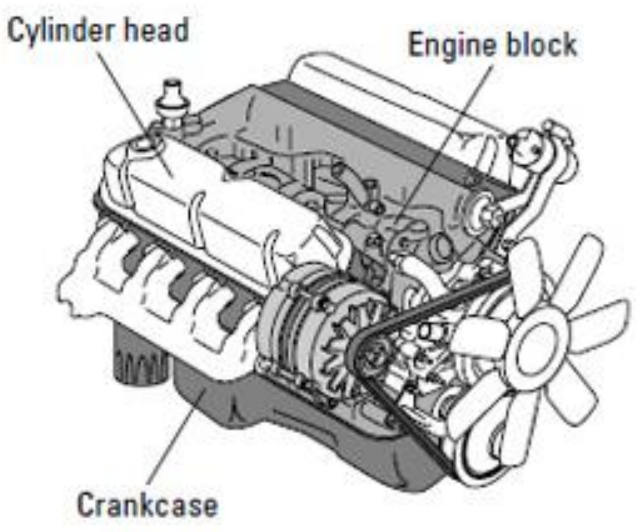


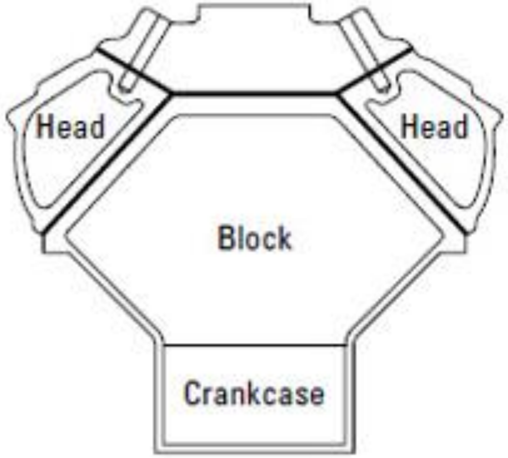
Cylinder

- The hollow cylindrical structure closed at one end with cylinder head in which the pistons reciprocate back and forth
- Made of hard and high thermal conductivity materials
- Combustion of fuel takes place inside the cylinder

Cylinder head

- Covers one end of the cylinder and consists of valves/ports & spark plug/injector





Piston

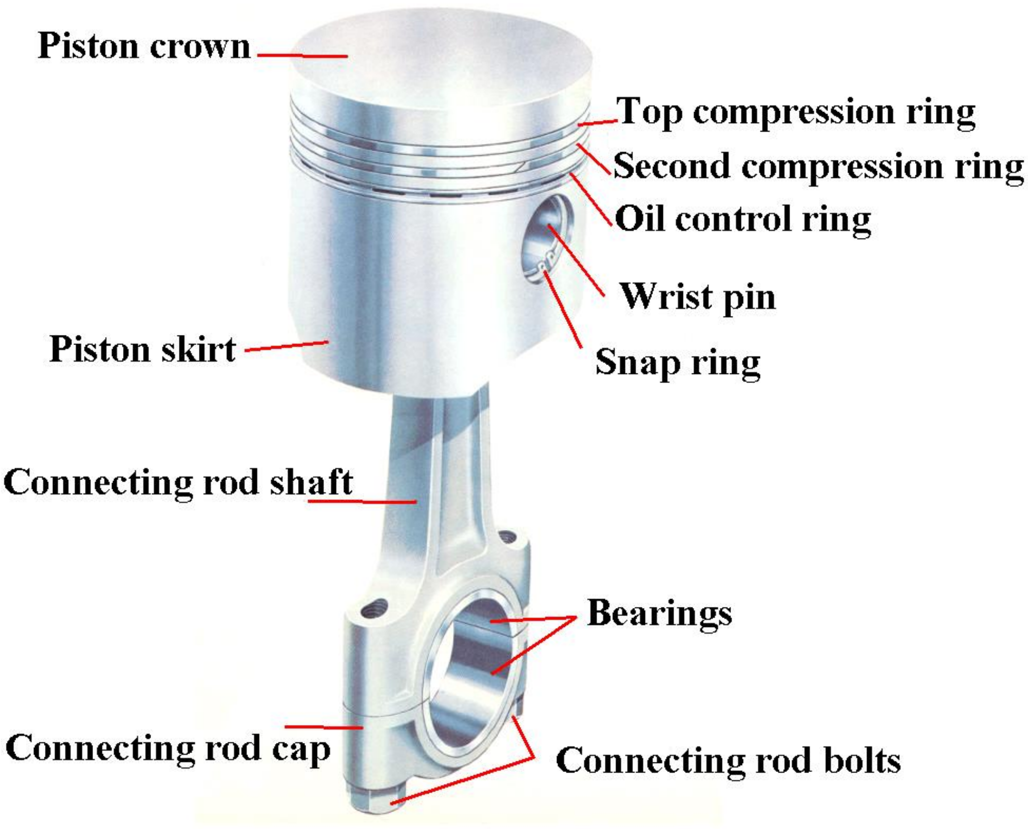
- It is a cylindrical component which is fitted perfectly inside the cylinder providing a gas tight space with piston rings and lubricants.
- The main function of piston is to transmit the force exerted by the burning of fuel to the connecting rod.

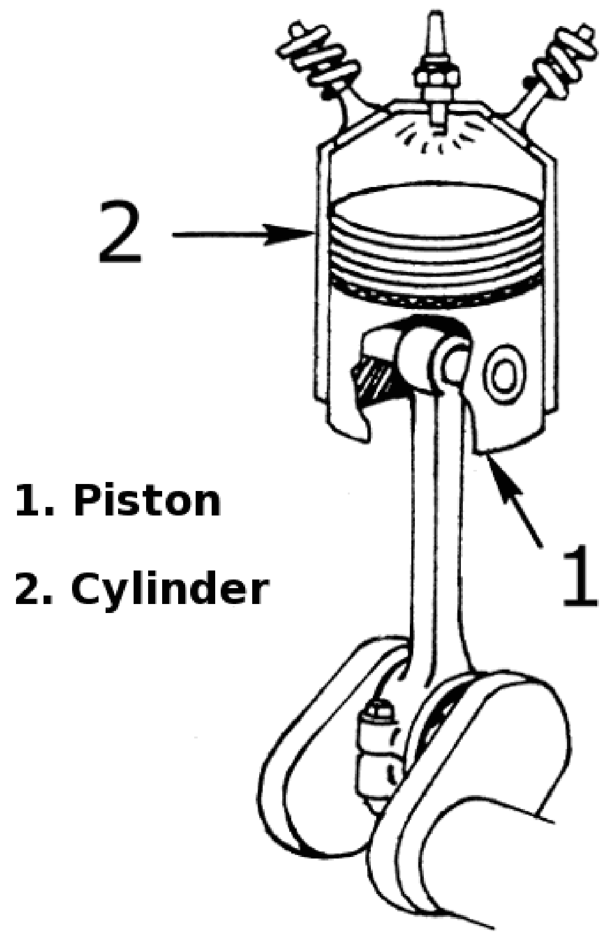
Piston Rings

- The outer periphery is provided with several grooves in to which the piston rings are fitted
- The upper ring is known as compression ring and the lower one is called oil rings

Water jackets

- Through which cooling water is circulated to prevent overheating of the engine


Piston crown
Top compression ring
Second compression ring
Oil control ring
Wrist pin
Snap ring
Piston skirt
Connecting rod shaft
Bearings
Connecting rod cap
Connecting rod bolts


2
1
1. Piston
2. Cylinder

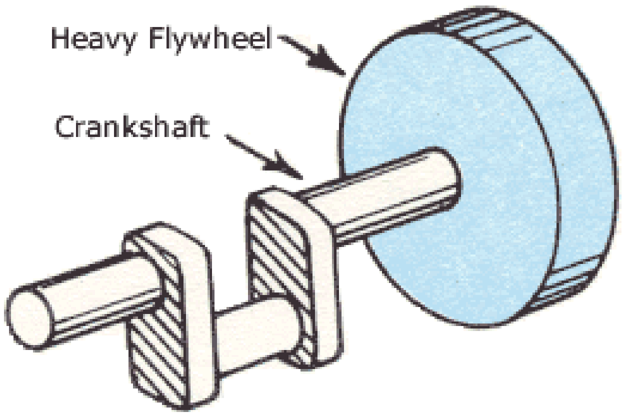
Connecting rod

- Element which interconnects piston and the crank.
- Transforms the reciprocating motion of the piston in to rotary motion of the crankshaft
- Two ends: 1. **Small end**-connected to the piston by **Gudgeon pin**

  2. **Big end**-connected to the crankshaft by **Crank pin**

Crank and crank shaft

- Crank is the rotating member which receives power from the connecting rod and transmits to the crank shaft
- Crank shaft is the principal rotating part of the engine which controls the sequence of reciprocating motions of the piston



Flywheel

- Heavy wheel mounted on the crank shaft
- It absorbs the energy during power stroke and release it during non power stroke
- Reduce the torque and speed fluctuations
- Absorbs vibration from the crankshaft
- Supports for clutch mechanism

Valves

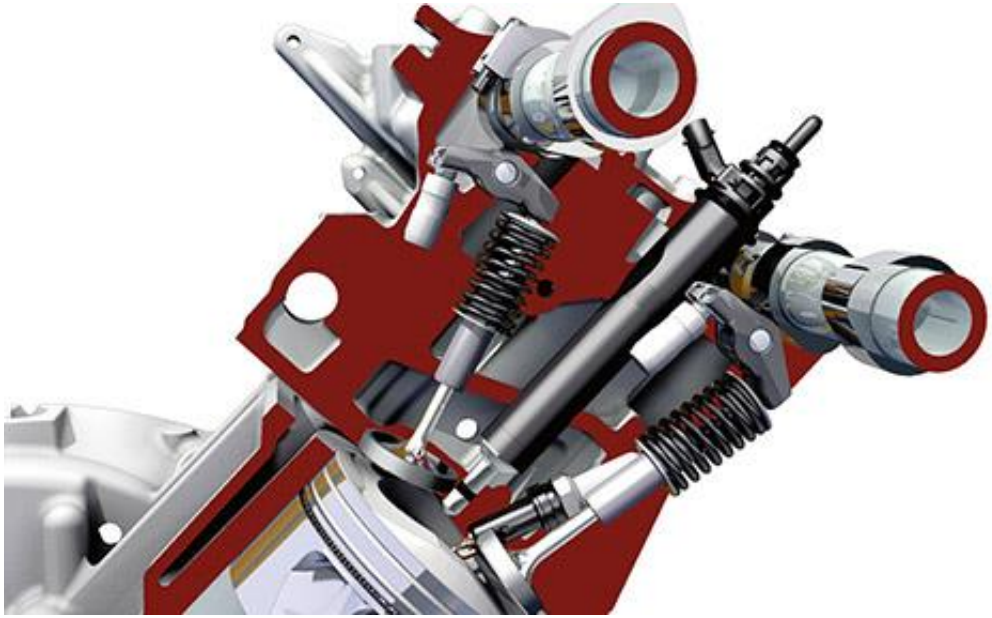
- Provided in the cylinder head for the admission of fresh air/air fuel mixture in to the engine cylinder and for rejection of burnt gases
- Operated by cams and camshaft

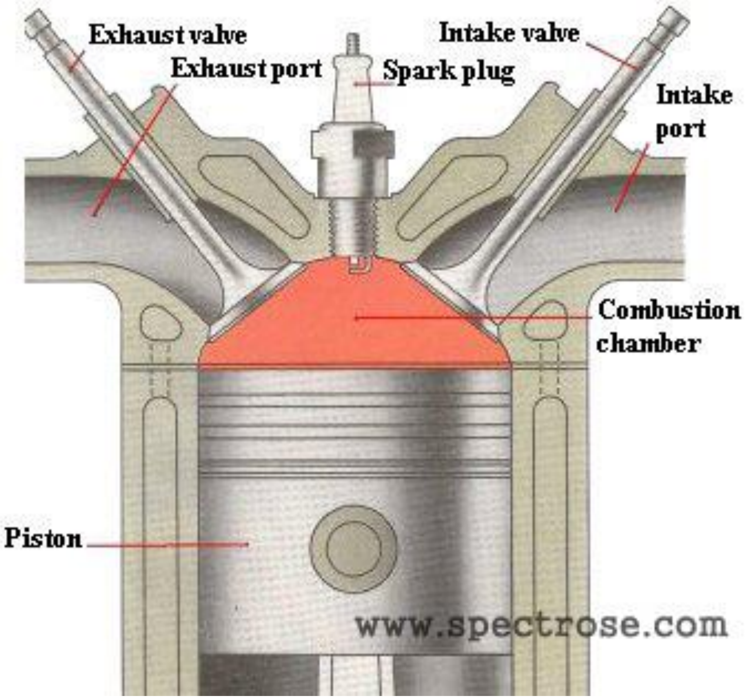
Inlet manifold

- The metal tube which connects the intake system to the inlet valve of the engine

Exhaust/ outlet manifold

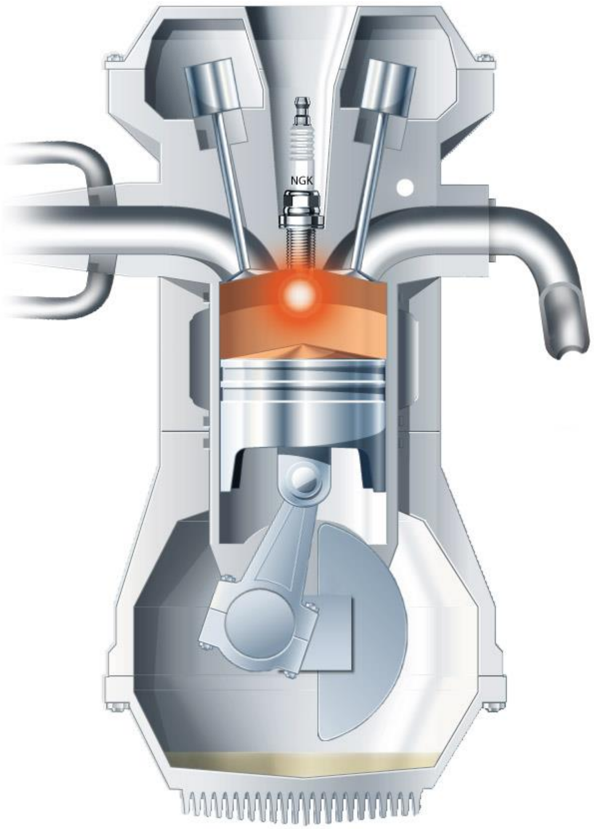
- Connects exhaust system to the exhaust valve of the engine




Exhaust valve
Exhaust port
Spark plug
Intake valve
Intake port
Combustion chamber
Piston
www.spectrose.com

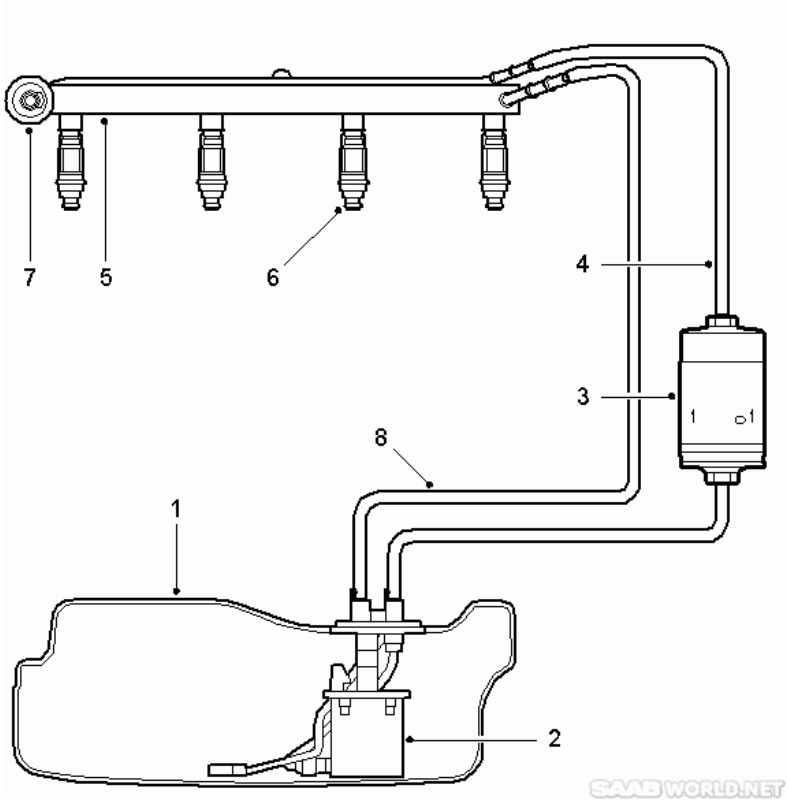
Spark plug

- Spark plug is located near the top of the cylinder of SI engine
- It initiates the combustion of the fuel

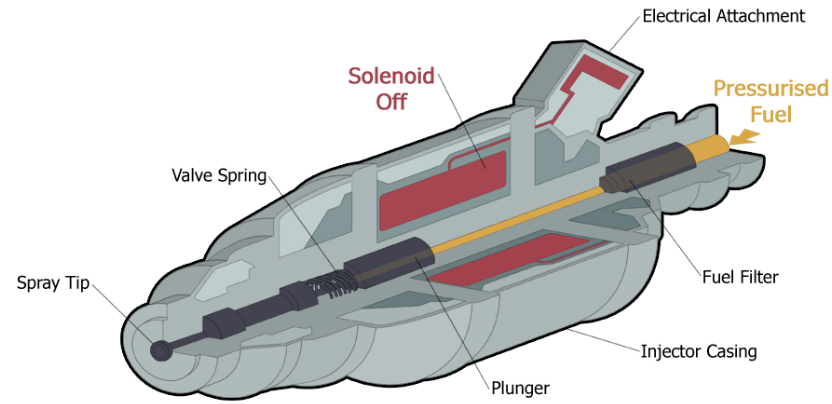


Fuel injector

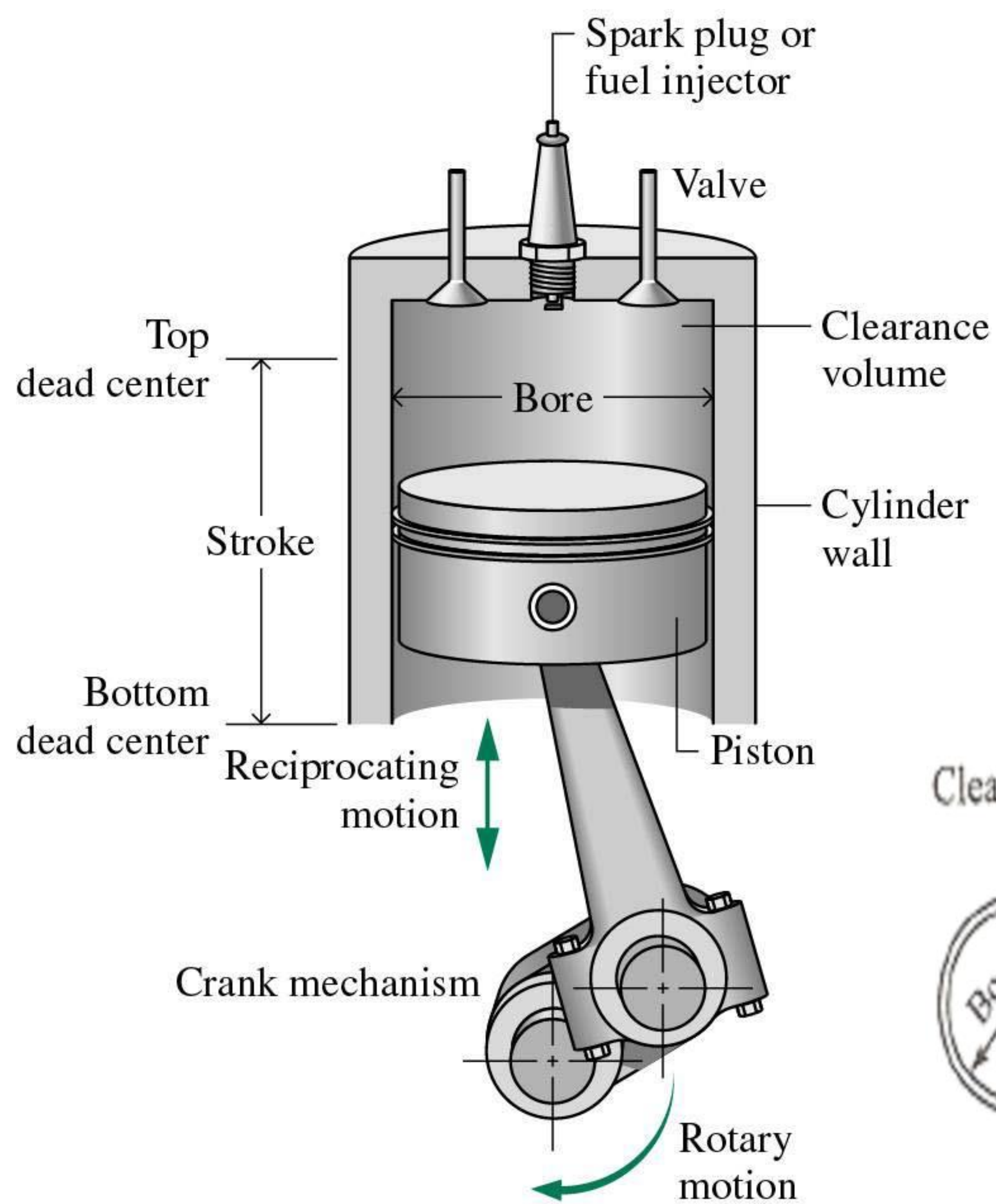
- Purpose of fuel injector is to supply the metered quantity of fuel at high pressure in to the cylinder of CI engine/ MPFI engine
- Fuel pump : Electrically or mechanically driven pump to supply fuel from the fuel tank (reservoir) to the engine.

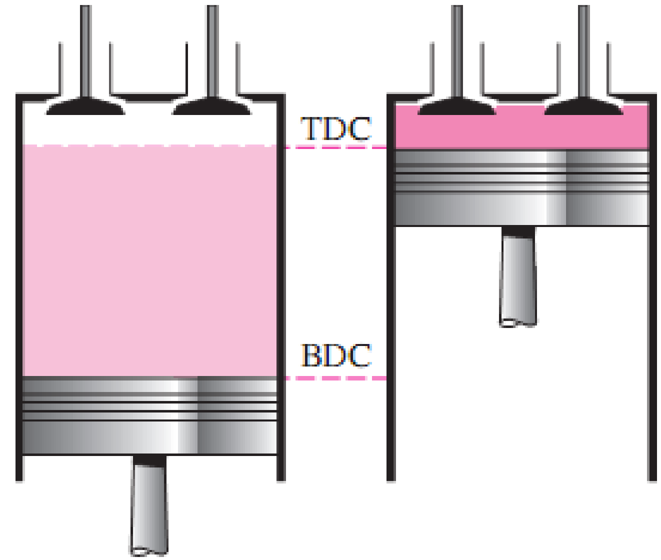


1. Fuel tank
2. Fuel pump
3. Fuel filter
4. Fuel line, delivery
5. Fuel rail
6. Injector
7. Pressure regulator
8. Fuel line, return



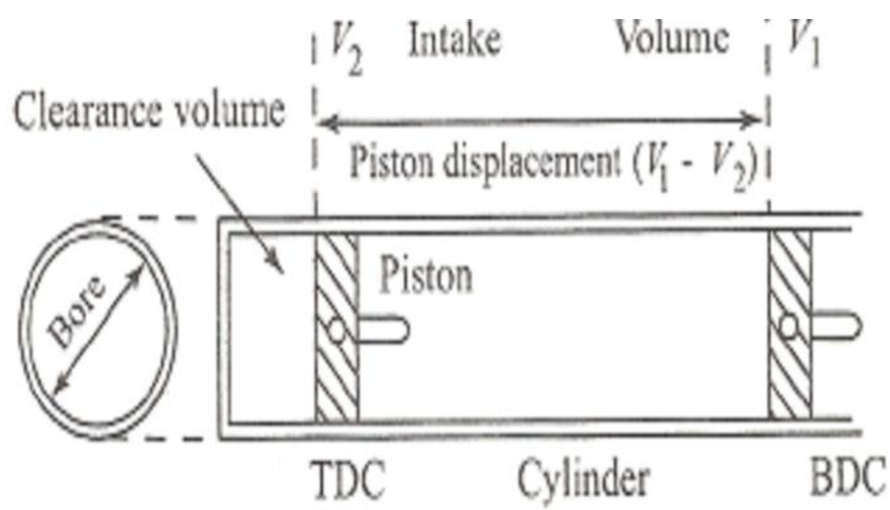
Nomenclature





(*a*) Displacement volume

(*b*) Clearance volume



Top Dead Center (TDC): Position of the piston when it stops at the furthest point away from the crankshaft.

Top because this position is at the top of the engines (not always), and dead because the piston stops as this point. In some engines **TDC** is not at the top of the engines(e.g: horizontally opposed engines, radial engines,etc,.)

When the piston is at TDC, the volume in the cylinder is a minimum called the clearance volume

Bottom Dead Center (BDC): Position of the piston when it stops at the point closest to the crankshaft.

- Some sources call this **Crank End Dead Center (CEDC)** because it is not always at the bottom of the engine.

Stroke (L) : Distance traveled by the piston from one extreme position to the other : TDC to BDC or BDC to TDC.

Bore (d) : It is defined as **c**ylinder diameter or piston face diameter; piston face diameter is same as cylinder diameter(minus small clearance).

Swept volume/Displacement volume (V_s) : Volume displaced by the piston as it travels through one stroke.

- Swept volume is defined as stroke times bore.

Clearance volume (V_c): It is the minimum volume of the cylinder available for the charge (air or air fuel mixture) when the piston reaches at its outermost point (top dead center or inner dead center) during compression stroke of the cycle.

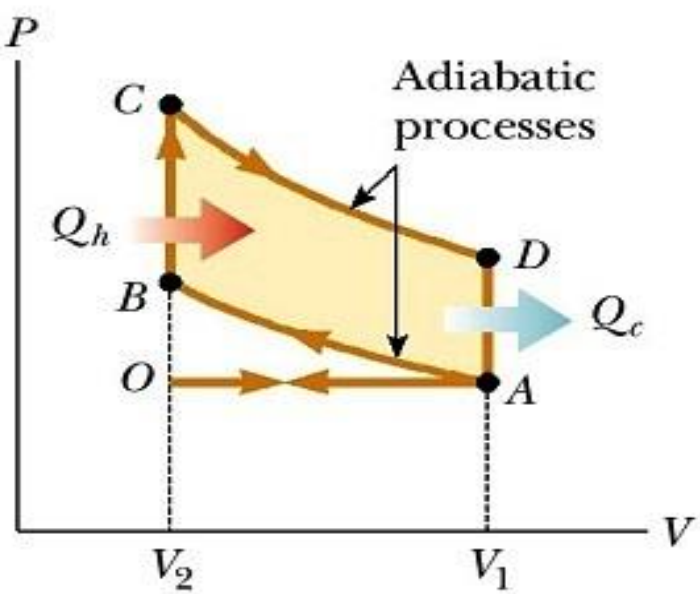
- Minimum volume of combustion chamber with piston at TDC.

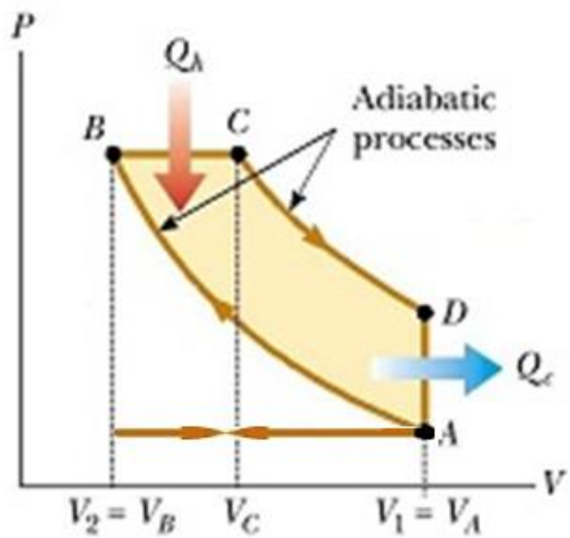
Compression ratio (r) : The ratio of total volume to clearance volume of the cylinder is the compression ratio of the engine.

- Compression ratio for SI engines varies form 8 to 12 and for CI engines it varies from 12 to 24

Classification of IC engine

- Based on working cycle
  - Otto cycle(eg. SI engine)
  - Diesel cycle(eg. CI engine)
  - Dual cycle





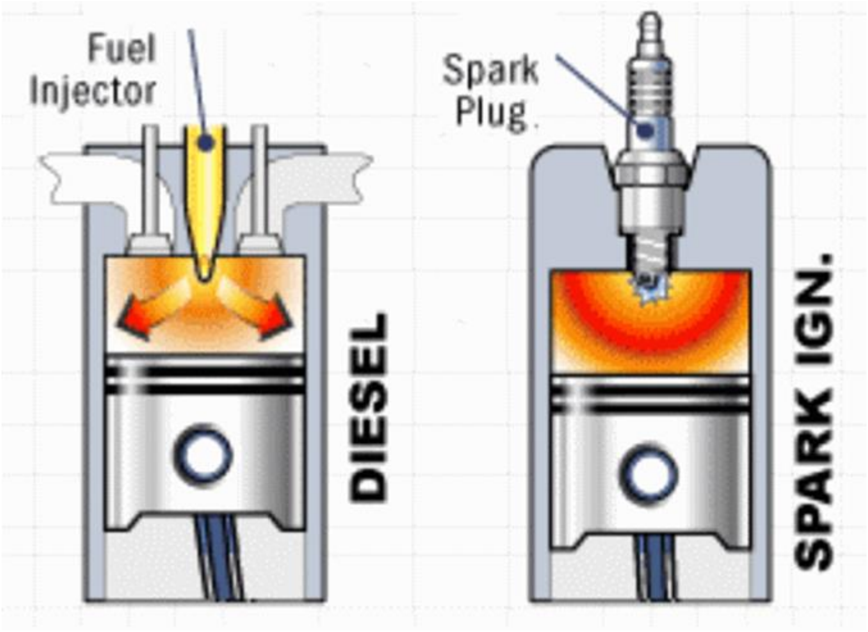
PV diagram for an ideal diesel engine.

- Based on application
  - Mobile
  - Stationary
- Based on no. of cylinders
  - Single cylinder
  - Multi cylinder
- Based on fuel used
  - Solid fuel(eg. coal)
  - Liquid fuel(eg. diesel)
  - Gaseous fuel (Natural gas)
- Based on cooling system
  - Air cooling
  - Liduid cooling
- Based on number of strokes per cycle
  - Two stroke
  - Four stroke

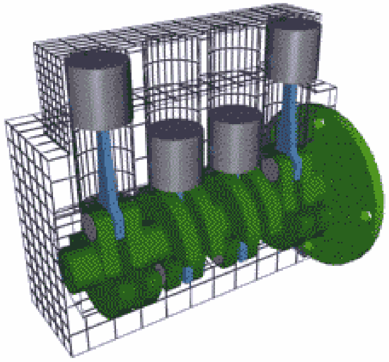
Classification based on ignition

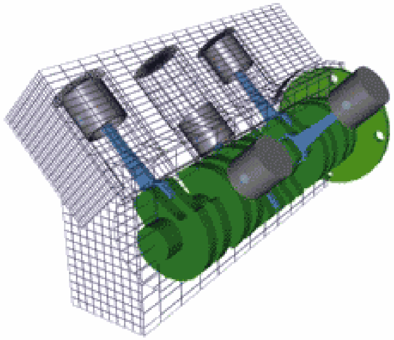
INTERNAL COMBUSTION ENGINES

- Spark Ignition engines (ex. Gasoline/Petrol Engine)
- Compression Ignition engines (ex. Diesel Engine)

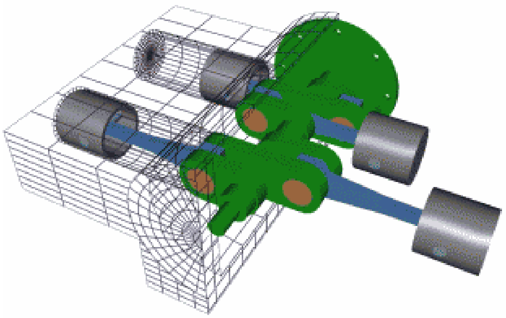


Configuration



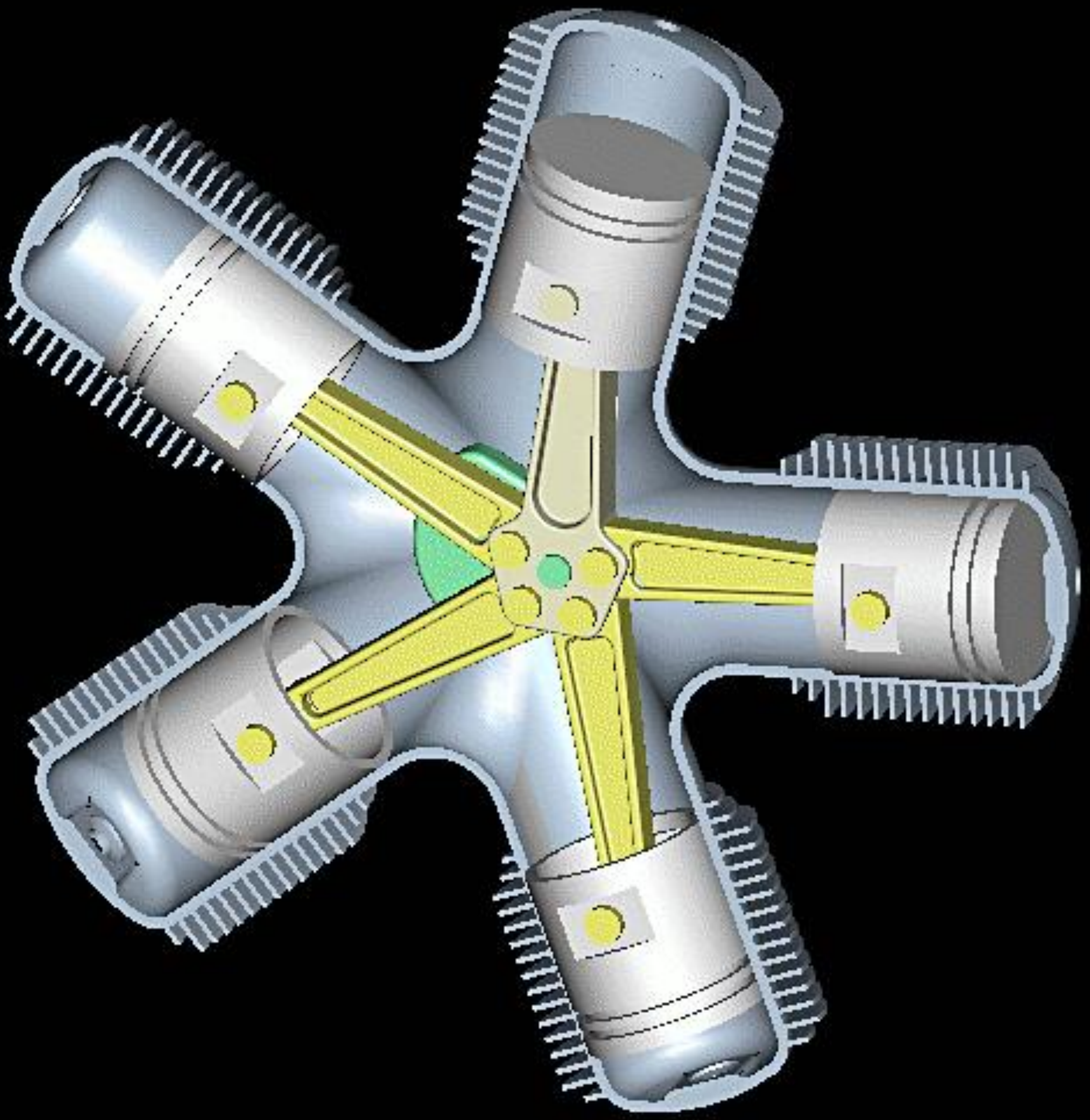


- Vertical Engines
- Horizontal Engines
- Inline Engines: The cylinders are arranged in a line, in a single bank.
- V Engines: The cylinders are arranged in two banks, set at an angle to one another.



- Opposed cylinder Engines: The cylinders are arranged in two banks on opposite sides of the engine

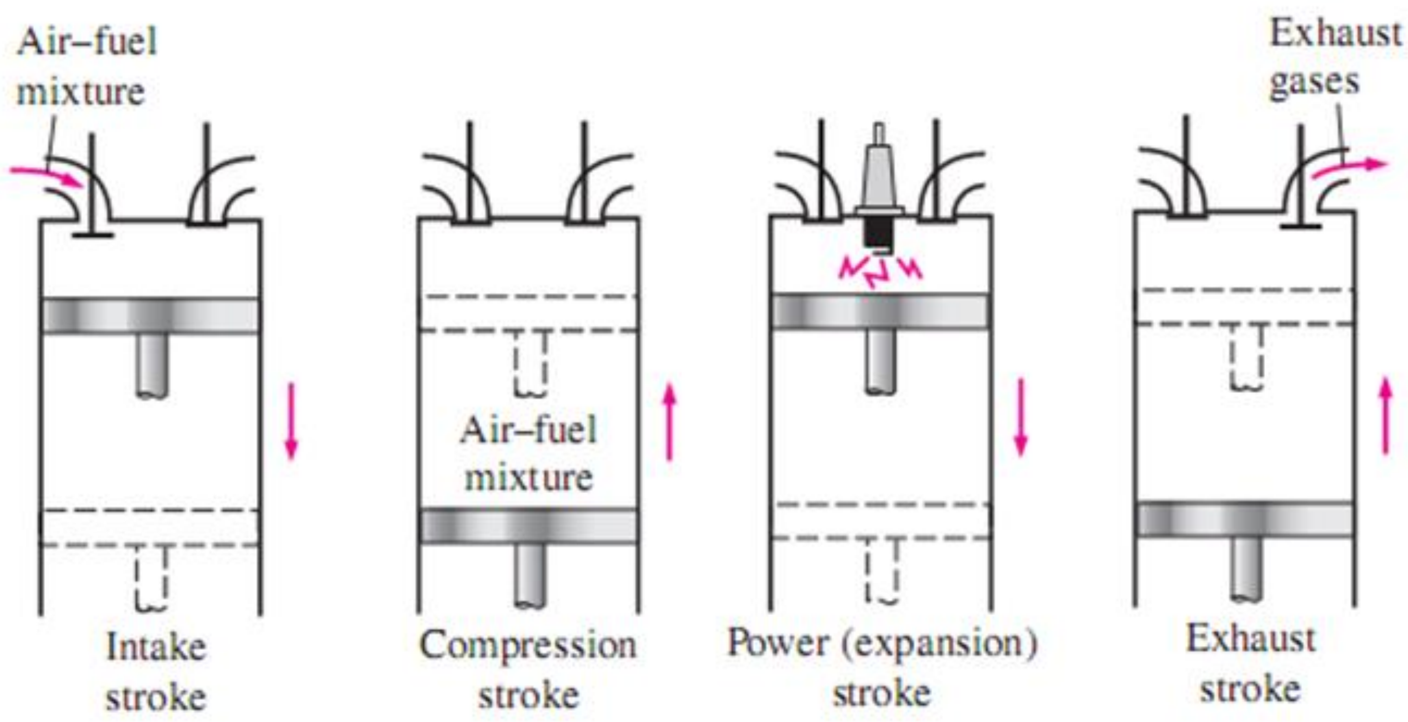
- Radial Engines: The cylinders are arranged radially and equally spaced around common crank shaft



Number of Strokes

- Four stroke engine : It has four piston strokes over two revolutions for each cycle.
- Two stroke engine : It has two piston strokes over one revolution for each cycle.

- 4 Stroke engine

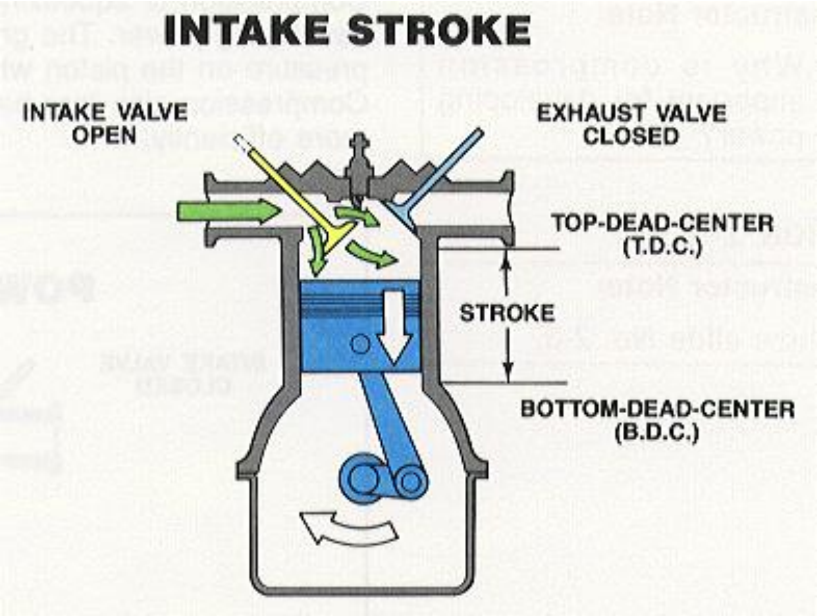


four-stroke spark-ignition engine

1. Suction/Intake stroke

Intake of air-fuel mixture in cylinder through intake manifold when piston moves from TDC to BDC.

- The piston travel from TDC to BDC with the intake valve open and exhaust valve closed.

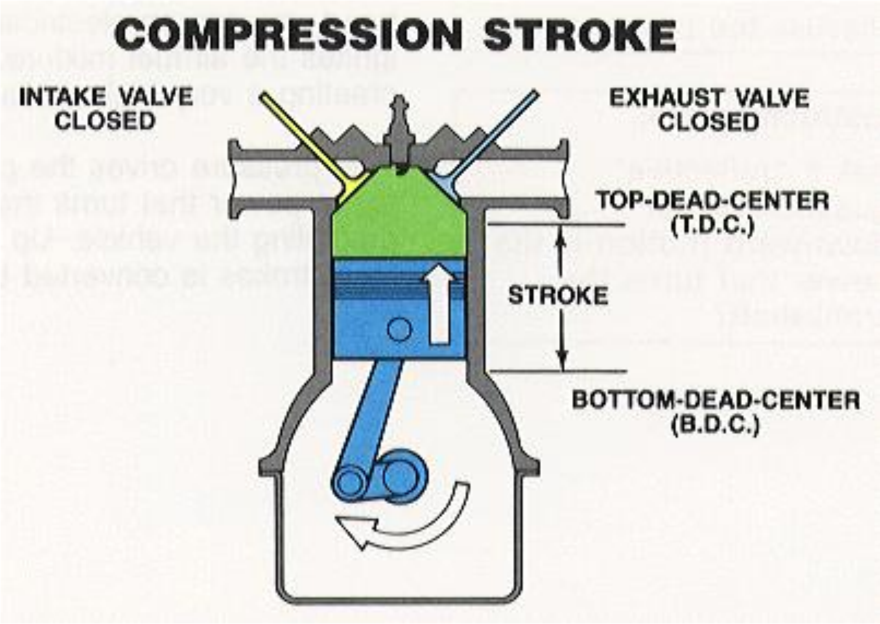


2. Compression stroke

When the piston reaches BDC, the intake valve closes and the piston travels back to TDC with all valves closed.

- This compresses air-fuel mixture, raising both the pressure and temperature in the cylinder.

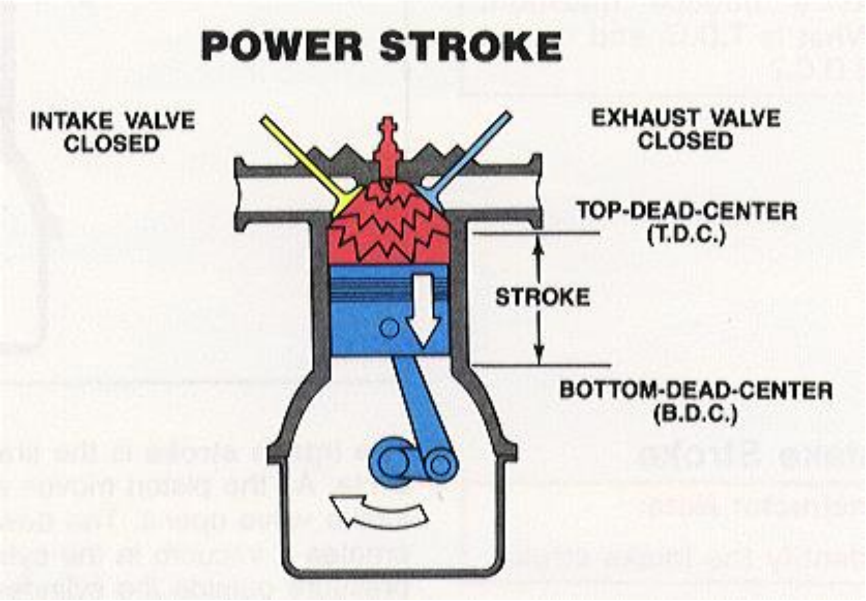
- Near the end of the compression stroke the spark is given, and the combustion is initiated.



3. Expansion stroke/Power stroke

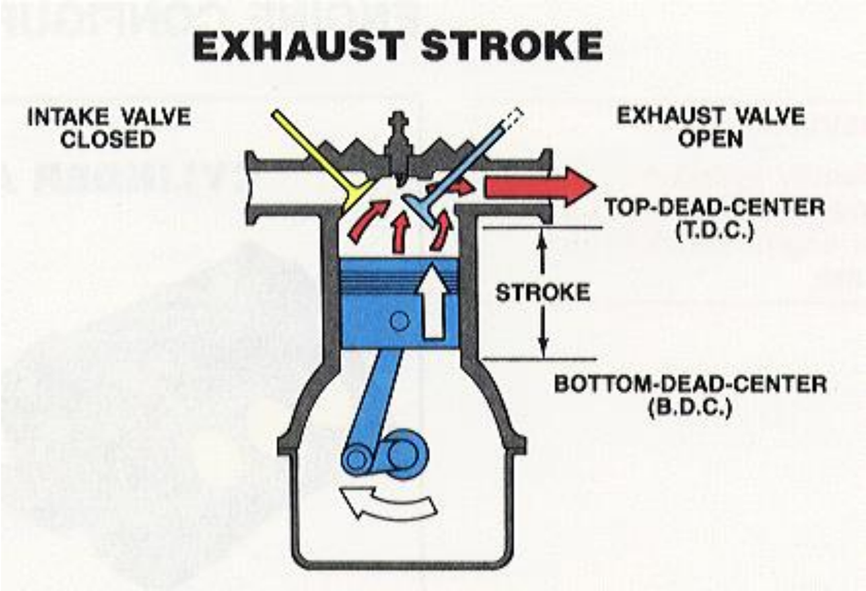
With all valves closed the high pressure created by the combustion process pushes the piston away from the TDC.

- This is the stroke which produces work output of the engine cycle.
- As the piston travels from TDC to BDC, cylinder volume is increased, causing pressure and temperature to drop.

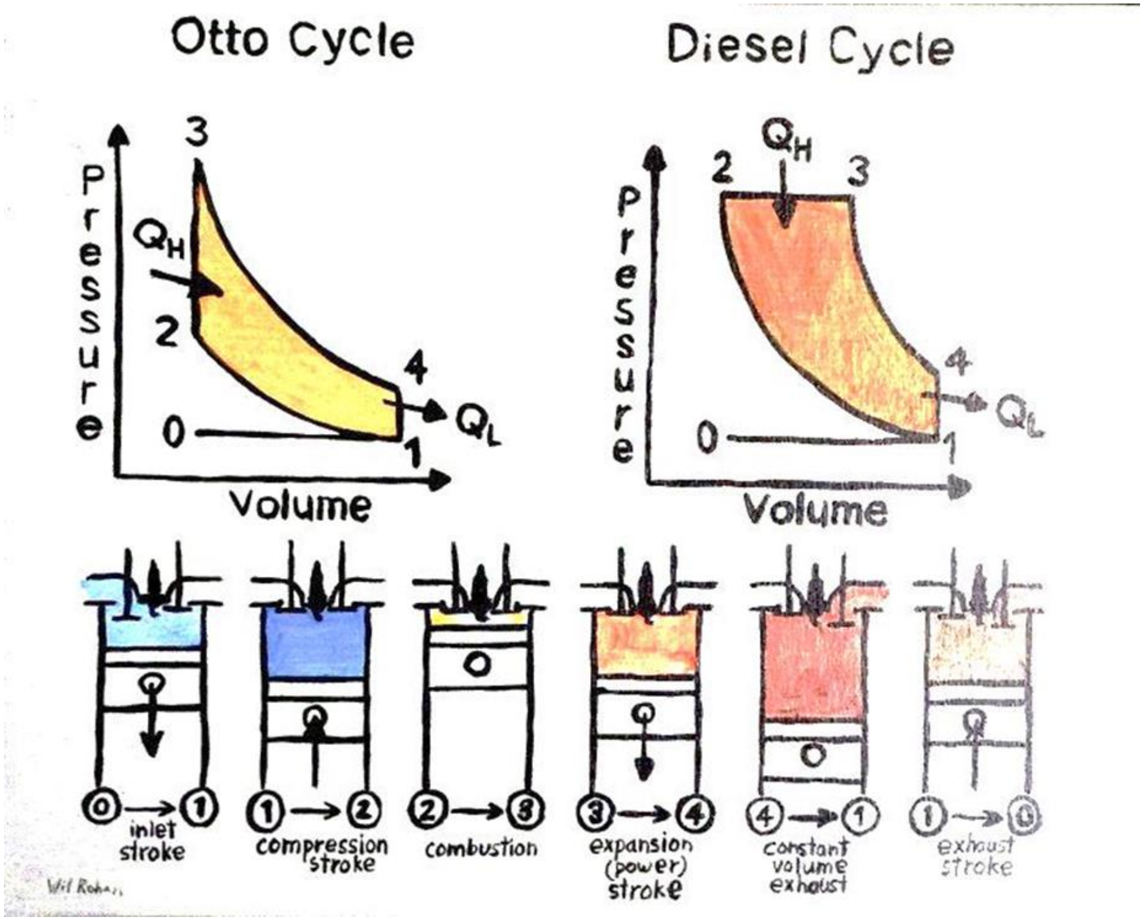


4. Exhaust stroke

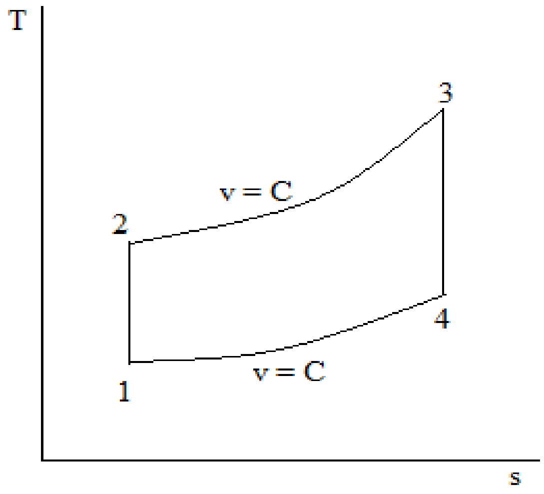
- With the exhaust valve remaining open, the piston travels from BDC to TDC in the exhaust stroke.
- This pushes most of the remaining exhaust gases out of the cylinder into the exhaust system at about atmospheric pressure, leaving only that trapped in the clearance volume when the piston reaches TDC.



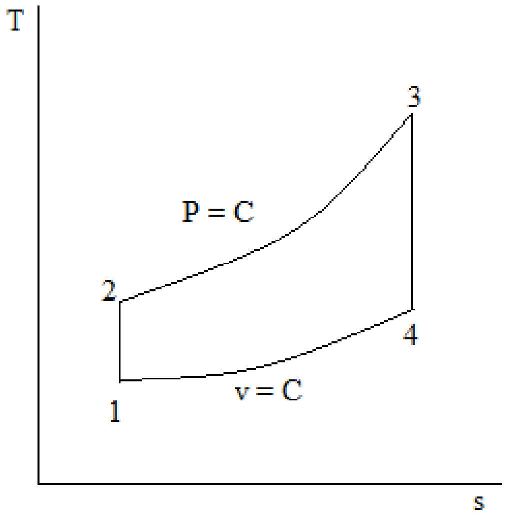
P-v Diagrams of S I & CI Engines



T-s Diagrams of S I & CI Engines



Otto Cycle



Diesel Cycle

Comparison

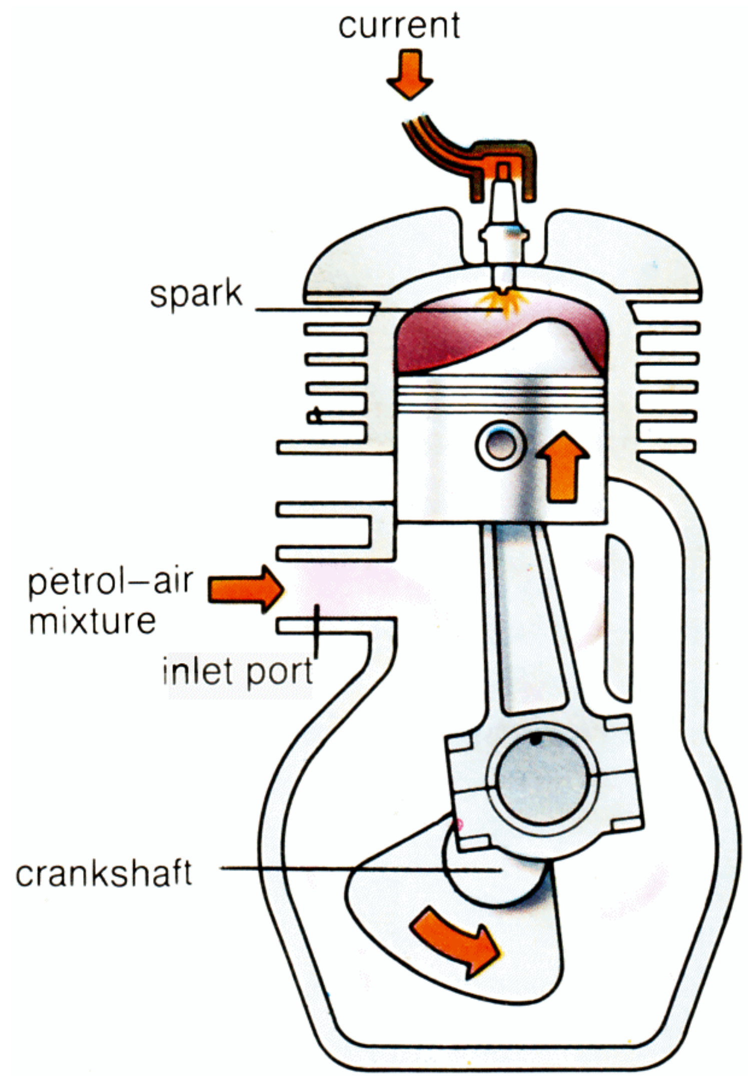
Description	SI	CI
Basic cycle	Otto	Diesel
Fuel	Volatile	Non-volatile
Introduction of Fuel	Carbureted/ Injected	Injected
Load control	Throttle Valve	Fuel Regulation
Ignition	Spark	Auto
r_k	6-10	16-20
Speed	High	Low
Thermal efficiency	Low (Low r_k)	High (High r_k)
Weight / Initial Cost	Low	High

Stroke 1

- The air fuel mixture in the cylinder compressed

- Air fuel mixture enters the crank case through inlet port

- Towards the end of the stroke, the fuel air mixture is ignited using the spark from the spark plug

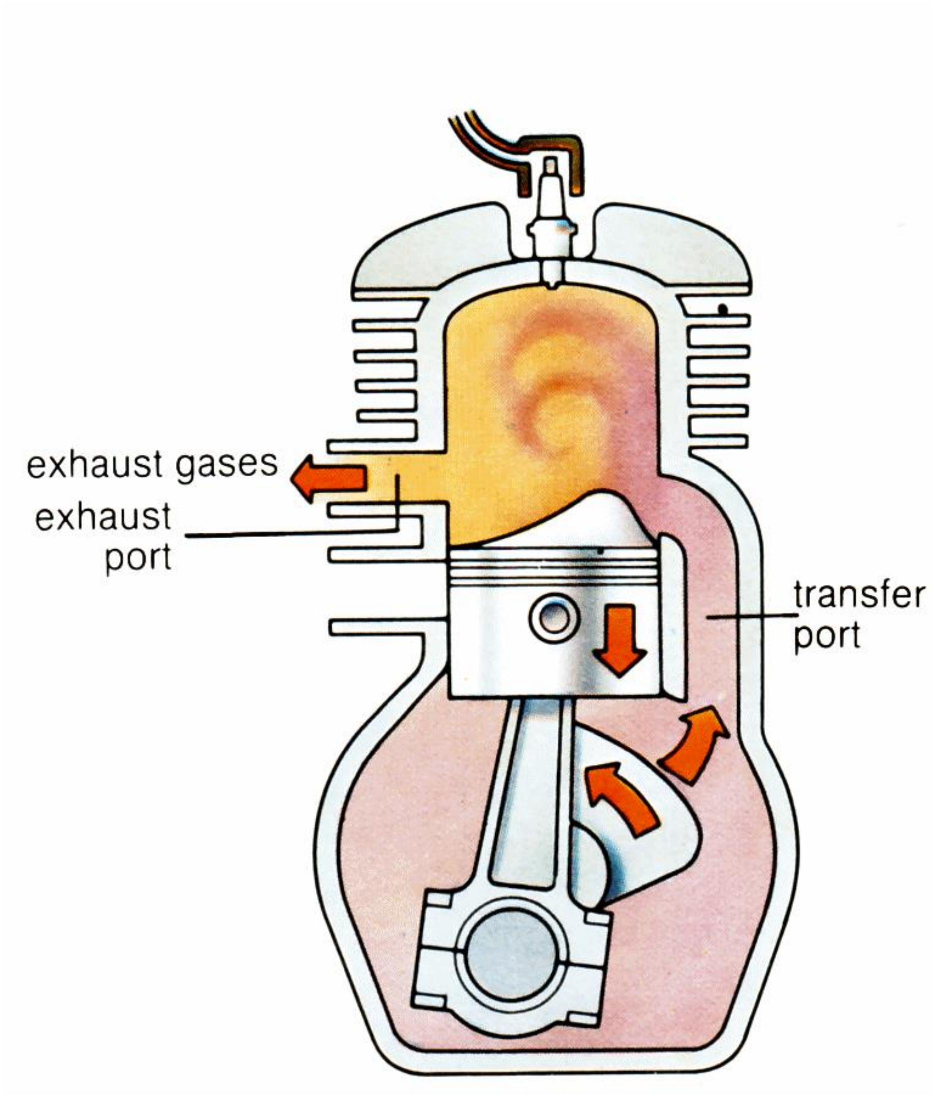


Stroke 2

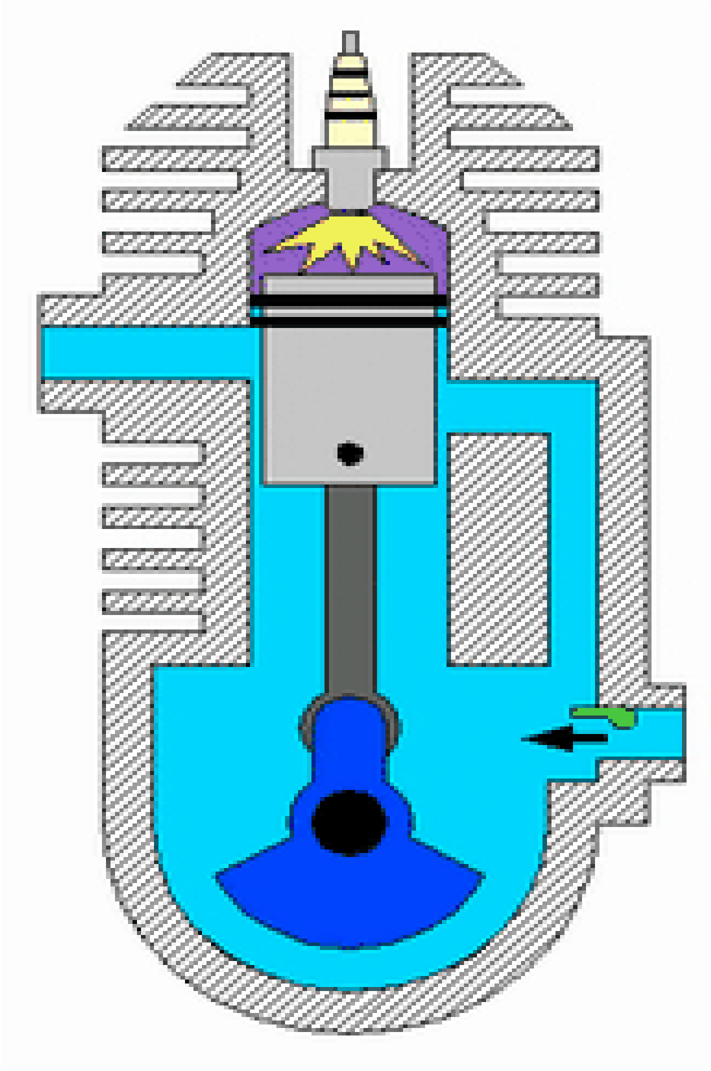
•Piston moves downward due to the expansion of the gases

•Near the end of stroke, piston uncovers exhaust port and burnt gases escape through the port.

•Transfer port is uncovered and compressed air fuel mixture from the crankcase flows in to the cylinder



Two stroke engine



Advantages

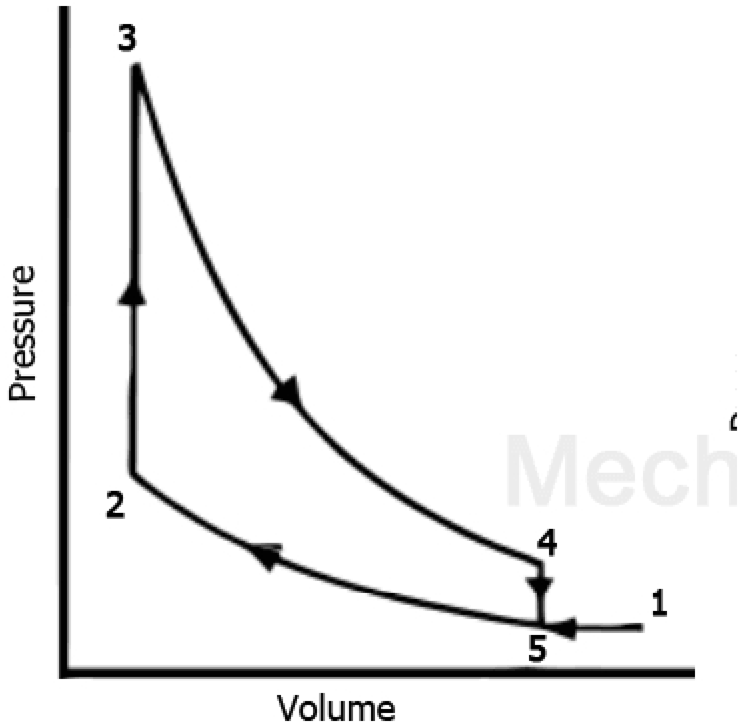
- Two-stroke engines do not have valves, which simplifies their construction and lowers their weight.
- Two-stroke engines fire once every revolution, while four-stroke engines fire once every two revolutions. This gives two-stroke engines a significant power boost.
- Theoretically Two-stroke engines develops twice the power into the same space because there are twice as many power strokes per revolution.
- More uniform torque on crank shaft hence it requires a lighter flywheel than that for a four-stroke engine

Disadvantages

- The engines do not last as long due to poor lubrication.
- You have to mix engine oil with gasoline.
- The engines do not use fuel efficiently.
- These engines produce a lot of pollution.

Description	Four Stroke	Two stroke
No of strokes/ cycle Power stroke	4 1 for every two revolutions	2 1 for every revolutions
Turning moment	Less uniform	More uniform
Power/weight	less	more
Cooling/lubrication	lesser	greater
Mixing of fresh fuel and exhaust gases	Less (exhaust stroke)	More
Inlet and exhaust	Valves required	No valves, only ports
Initial cost	more	less
Volumetric/thermal efficiency	More	lower

P-v diagram of two stroke petrol engine



Theoretical P-V Diagram for two-stroke petrol engine.

VALVE TIMING DIAGRAMS

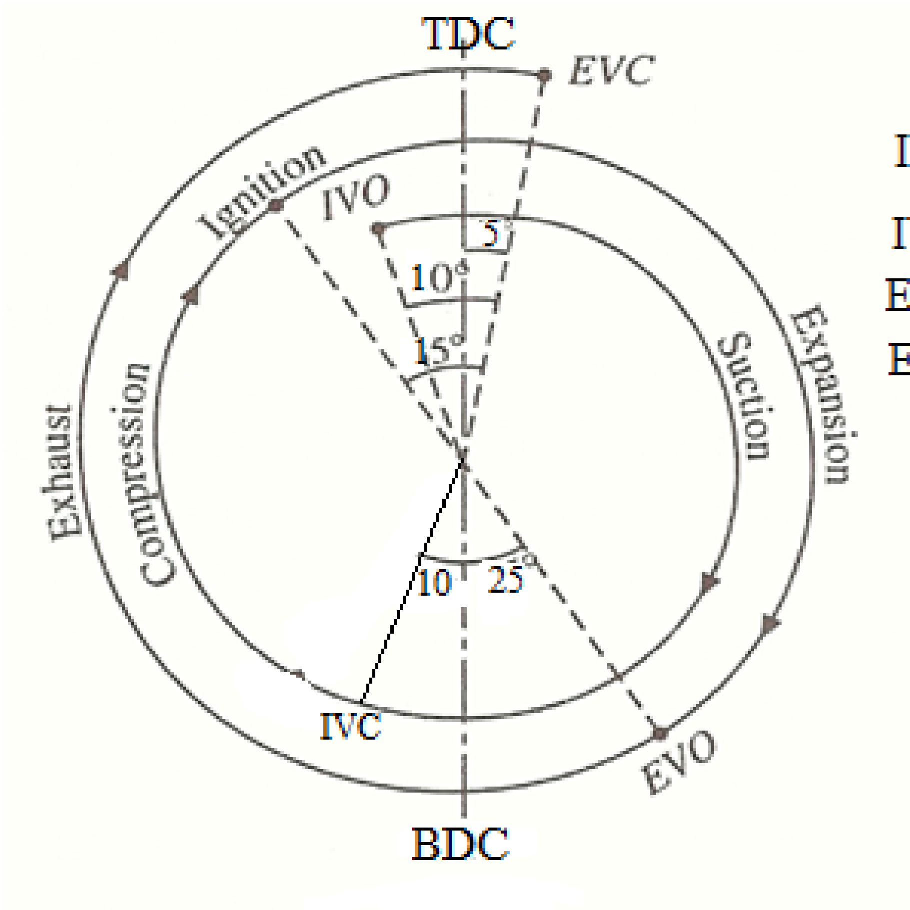
- Valve timingis the regulation of the points in the cycle at which the valves are set to open and close.

Reasons for actual valve timing:-

1. Mechanical Factor: - valves cannot be closed and opened abruptly because they are operated by cams. So that the opening of the valve must commence ahead of the time. (designed dead center)

2. Dynamic Factor: - actual valve timing is set taking into considering the dynamic effects of gas flow.

VALVE TIMING DIAGRAM FOR A FOUR-STROKE SI ENGINE



IVO - 10^0 bTDC

IVC - 10^0 - 60^0 aBDC

EVO - 25^0 - 55^0 bBDC

EVC - 5^0 - 20^0 aTDC

Intake valve timing

- The intake valve starts to open 10^0-20^0 before TDC.
- This is to ensure that the valve will be fully open and a fresh charge starts to flow into the cylinder as soon as the piston reaches TDC.
- As the piston moves out in the suction stroke, the fresh charge is drawn in through the intake valve, when the piston reaches the BDC and starts to move in the compression stroke, the inertia of the entering fresh tends to cause it to continue to move into cylinder.
- To take this advantage, inlet valve is closed 10^0-60^0 after TDC so that maximum air is taken in.
- This is called ram effect.

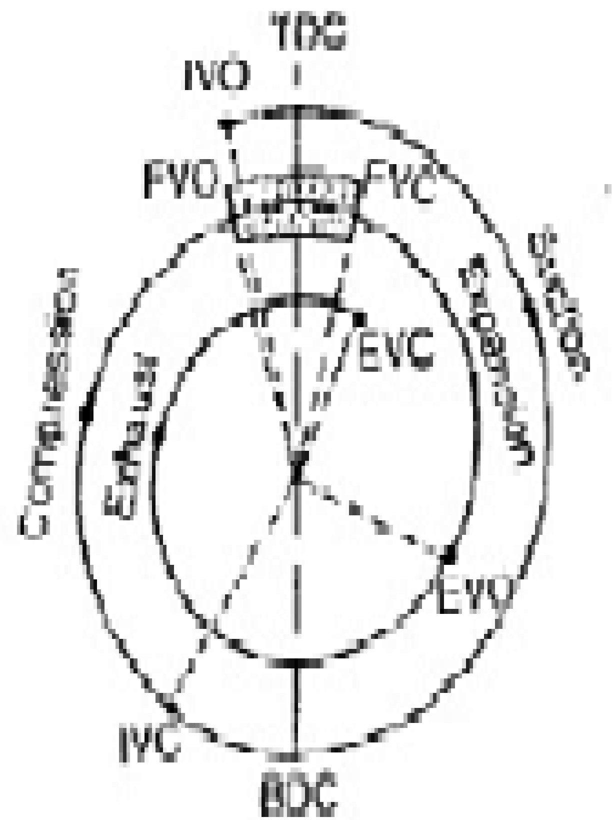
Exhaust valve timing

- Opening of exhaust valve earlier reduces the pressure near the end of the power stroke and thus causes some loss of useful work on this stroke.
- But it decreases the work necessary to expel the burned gases, results in overall gain in output.
- Closing of exhaust valve is delayed few degrees after TDC helps to scavenge the cylinder by carrying out a greater mass of exhaust gas due to its inertia force.
- This results in increased volumetric efficiency.

Valve overlap

- It is a period when both the intake and exhaust valves are open at the same time.
- 15^o for low speed engines and 30^o for high speed engines.
- This overlap should not be excessive otherwise it will allow the burned gases to be sucked into the intake manifold, or the fresh charge to escape through exhaust valve.

VALVE TIMING DIAGRAM FOR A FOUR-STROKE CYCLE DIESEL ENGINE



TDC : Top dead centre

BDC : Bottom dead centre

IVO : Inlet valve opens (10^0 - 20^0 before *TDC*)

IVC : Inlet valve closes (25^0 - 40^0 after *BDC*)

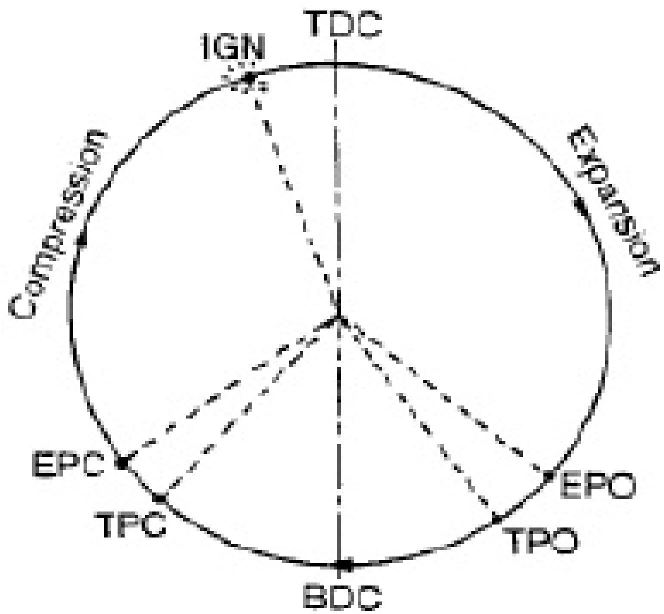
FVO : Fuel valve opens (10^0 - 15^0 before *TDC*)

FVC : Fuel valve closes (15^0 - 20^0 after *TDC*)

EVO : Exhaust valve opens (39^0 - 50^0 before *BDC*)

EVC : Exhaust valve closes (10^0 - 15^0 after *TDC*)

VALVE TIMING DIAGRAM FOR A TWO-STROKE CYCLE PETROL ENGINE



TDC : Top dead centre

BDC : Bottom dead centre

EPO : Exhaust port opens (35° - 50° before *BDC*)

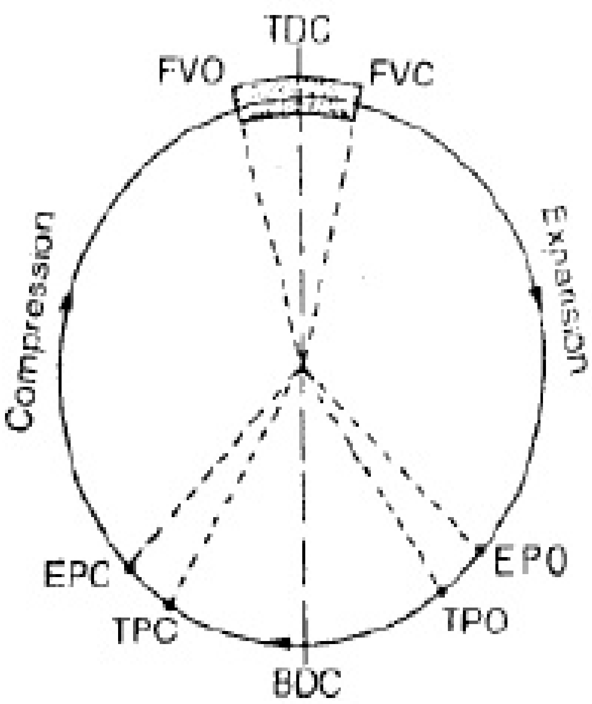
TPO : Transfer port opens (30° - 40° before *BDC*)

TPC : Transfer port closes (30° - 40° after *BDC*)

EPC : Exhaust port opens (35° - 50° after *BDC*)

IGN : Ignition (15° - 20° before *TDC*)

VALVE TIMING DIAGRAM FOR A TWO-STROKE CYCLE DIESEL ENGINE



TDC : Top dead centre

BDC Bottom dead centre

FVO : Fuel valve opens (10° - 15° before *TDC*)

FVC : Fuel valve closes (15° - 20° after *TDC*)

EPO : Exhaust port opens (35° - 50° before *BDC*)

TPO : Transfer port opens (30° - 40° before *BDC*)

TPC : Transfer port closes (30° - 40° after *BDC*)

EPC : Exhaust port closes (35° - 50° after *BDC*)