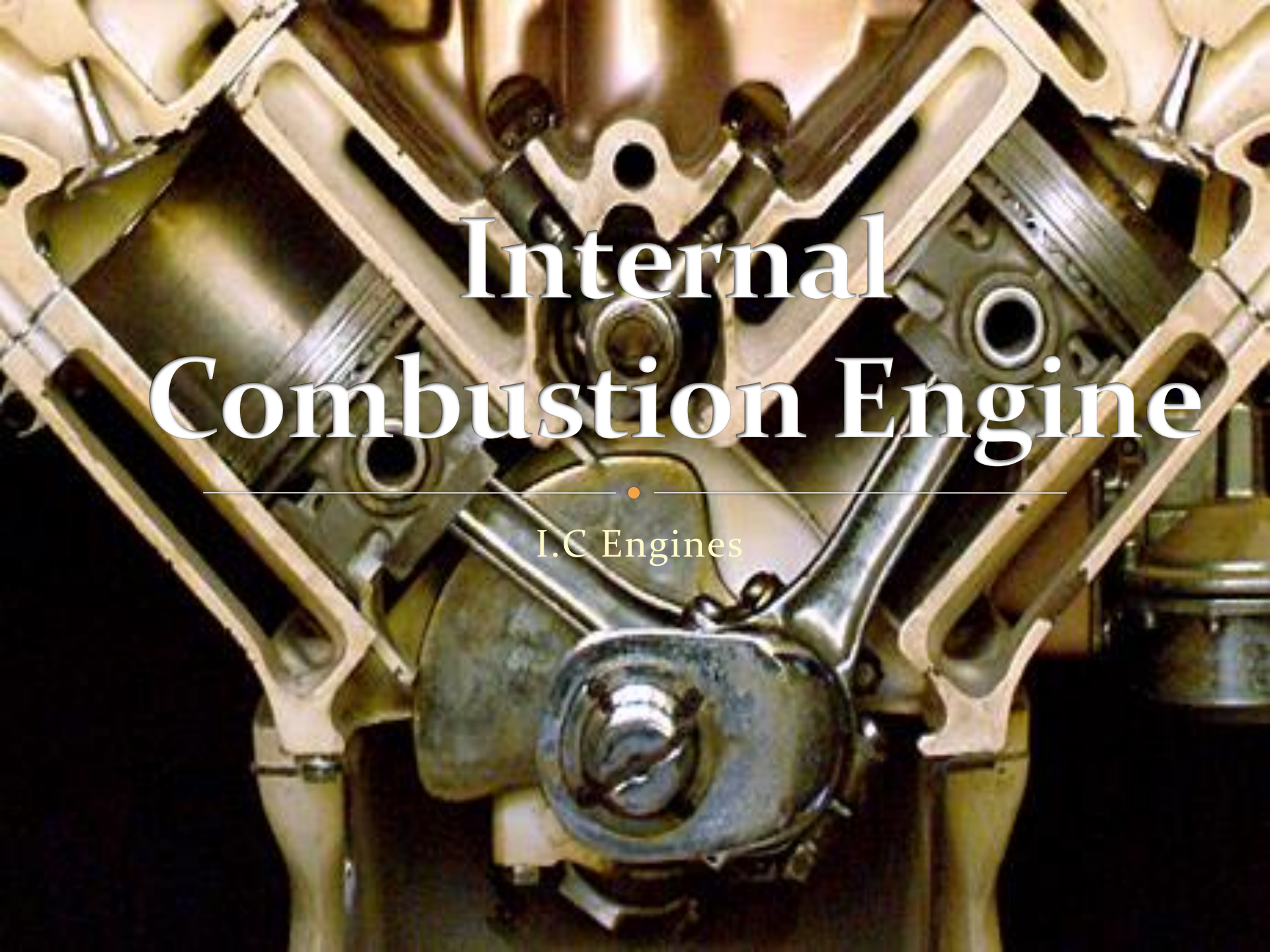


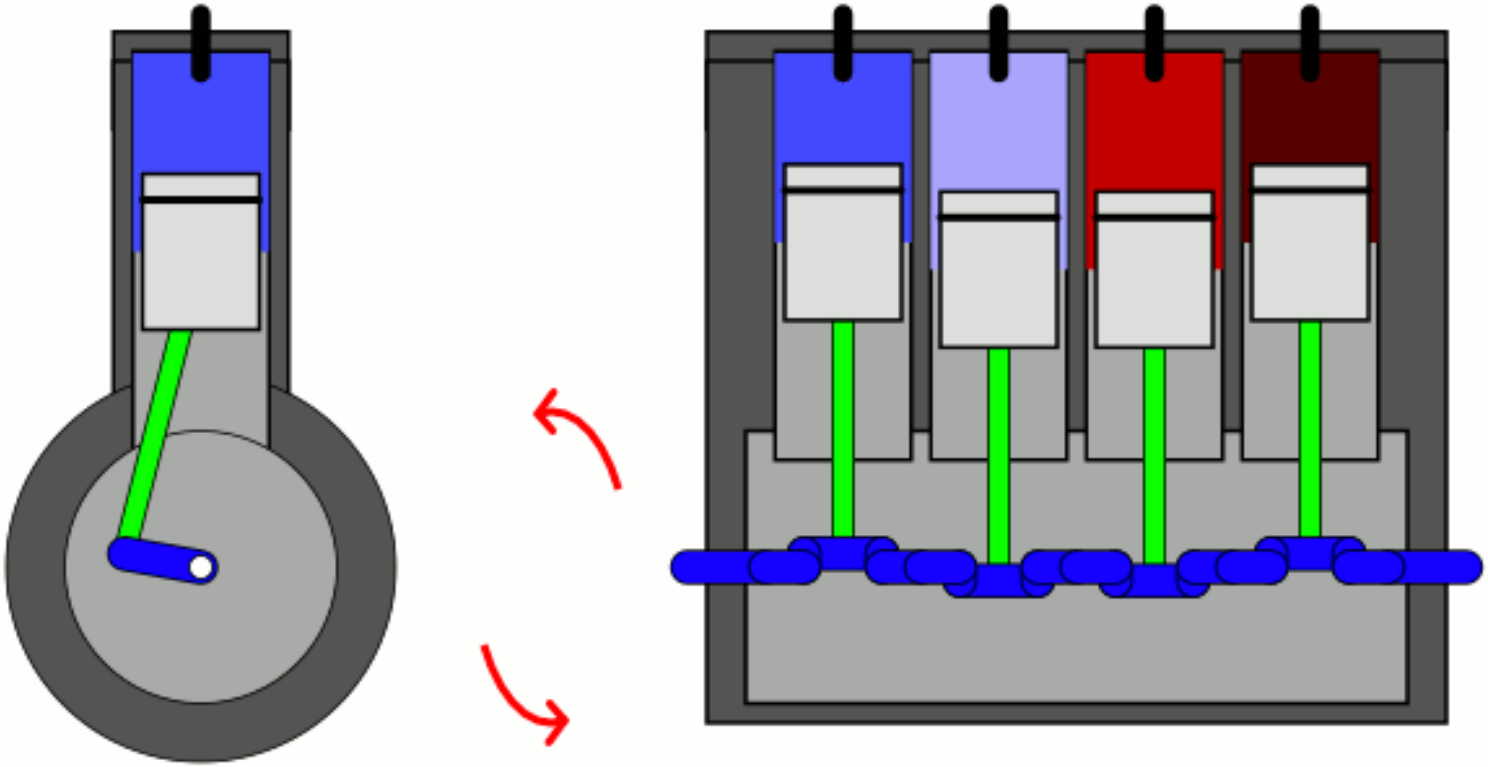
Internal Combustion Engine

I.C Engines

Introduction

- **Engine**: It is a device which converts the available input energy into the desired work output.
- **Heat Engine**: A heat engine is a machine which converts the chemical energy of the fuel into heat energy, and ultimately converts this heat energy into mechanical work.

- Heat engines are classified as 1) External Combustion engines (EC engines); and 2) Internal Combustion engines (IC engines).



A slider-crank mechanism working animation, and the working principle of a 4-cylinder engine.

A slider-crank mechanism is a set-up of four unique rigid link, interconnected in such a way that it can convert a reciprocating motion into a rotary motion (or vice-versa)

Classification

- According to type of fuel used.
  - Petrol engine.
  - Diesel engine.
  - Gas engine.

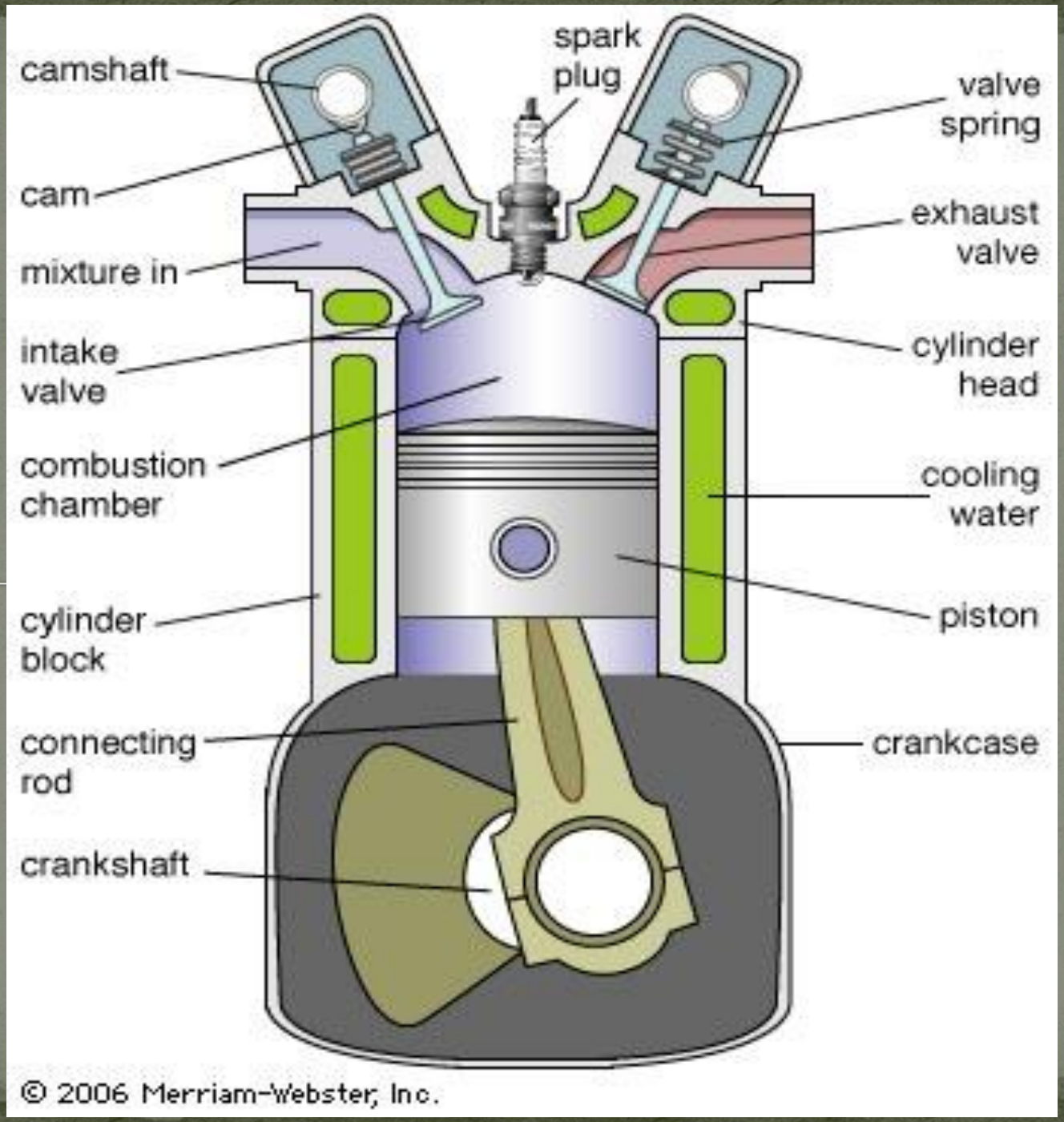
- According to number of strokes per cycle.
  - 4 – stroke engines.
  - 2 – stroke engines.

Classification

- According to method of ignition.
  - Spark ignition.
  - Compression ignition.
- According to the cycle of combustion.
  - Otto cycle.
  - Diesel cycle.
  - Duel combustion.
- According to the number of cylinders.
  - Single cylinder.
  - Multi cylinder.

Classification

- According to the arrangement of cylinders
  - Vertical engine.
  - Horizontal.
  - Inline engine.
  - Radial engine.
  - V- engine.
- According to method of cooling
  - Air cooled engine.
  - Water cooled engine.


camshaft
cam
mixture in
intake valve
combustion chamber
cylinder block
connecting rod
crankshaft
spark plug
valve spring
exhaust valve
cylinder head
cooling water
piston
crankcase
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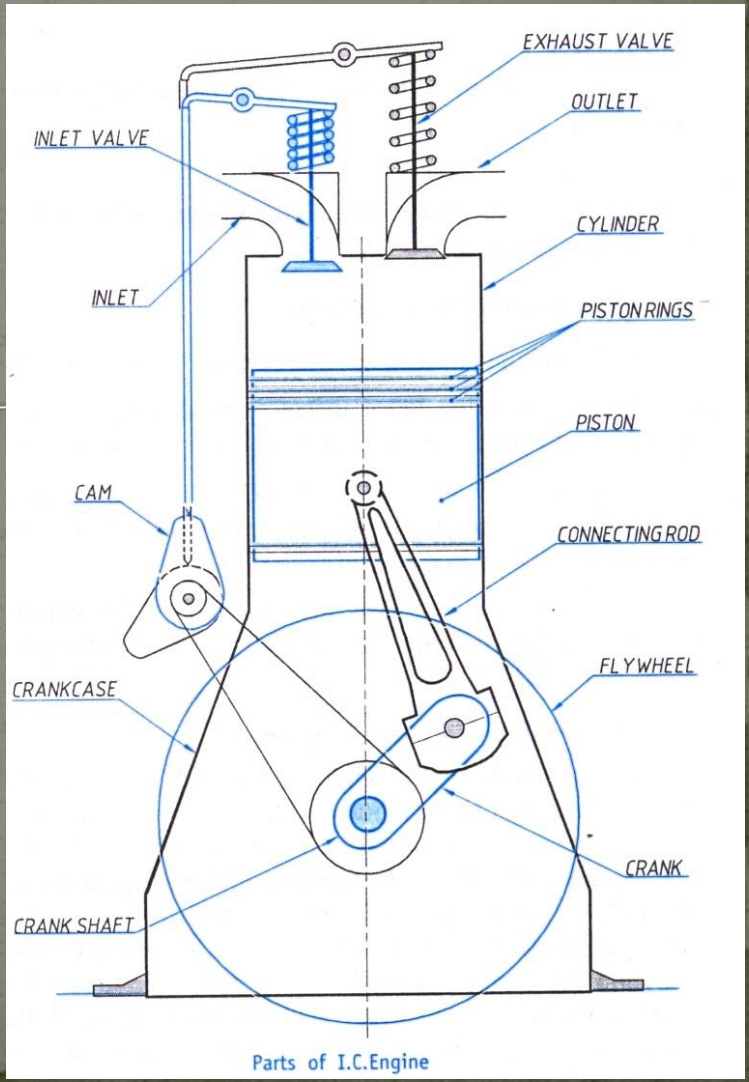
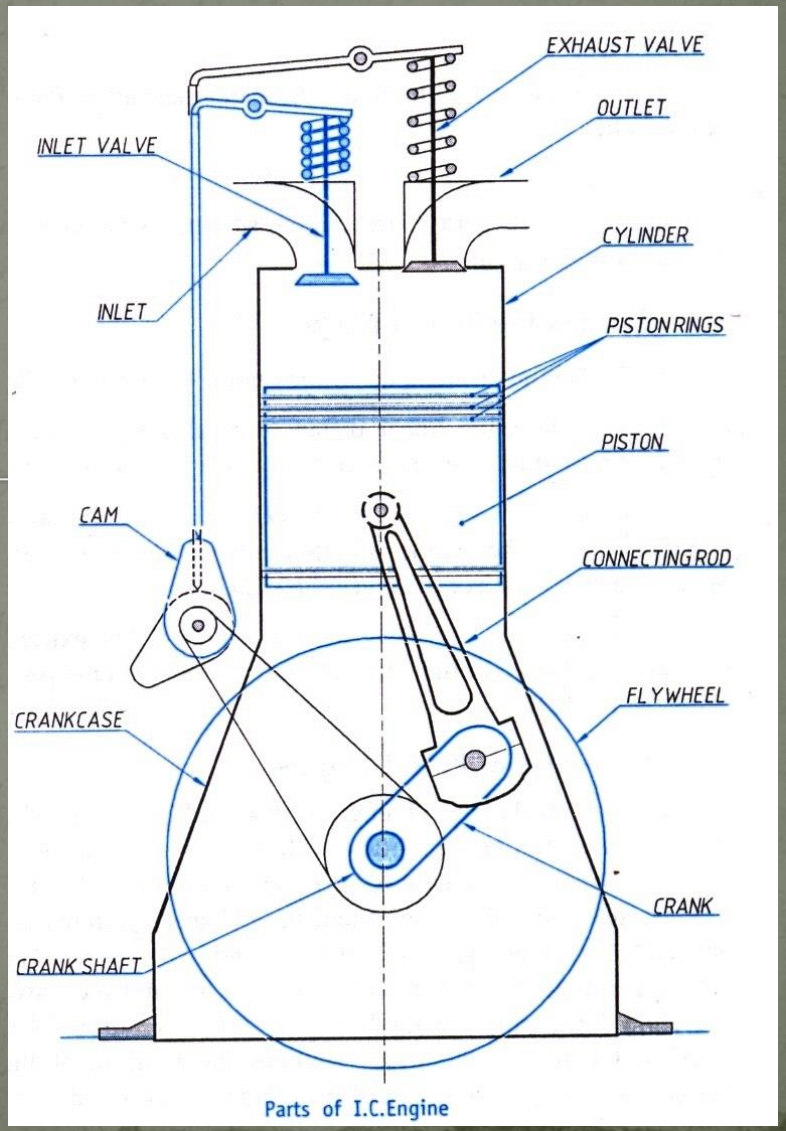
Parts of I.C Engine

1. *Cylinder*
2. *Piston*
3. *Piston rings*
4. *Connecting rod*
5. *Crank and crankshaft*
6. *Valves*
7. *Flywheel*
8. *Crankcase*
9. *Cam and its actuating mechanism*
10. *Spark plug / fuel injector*



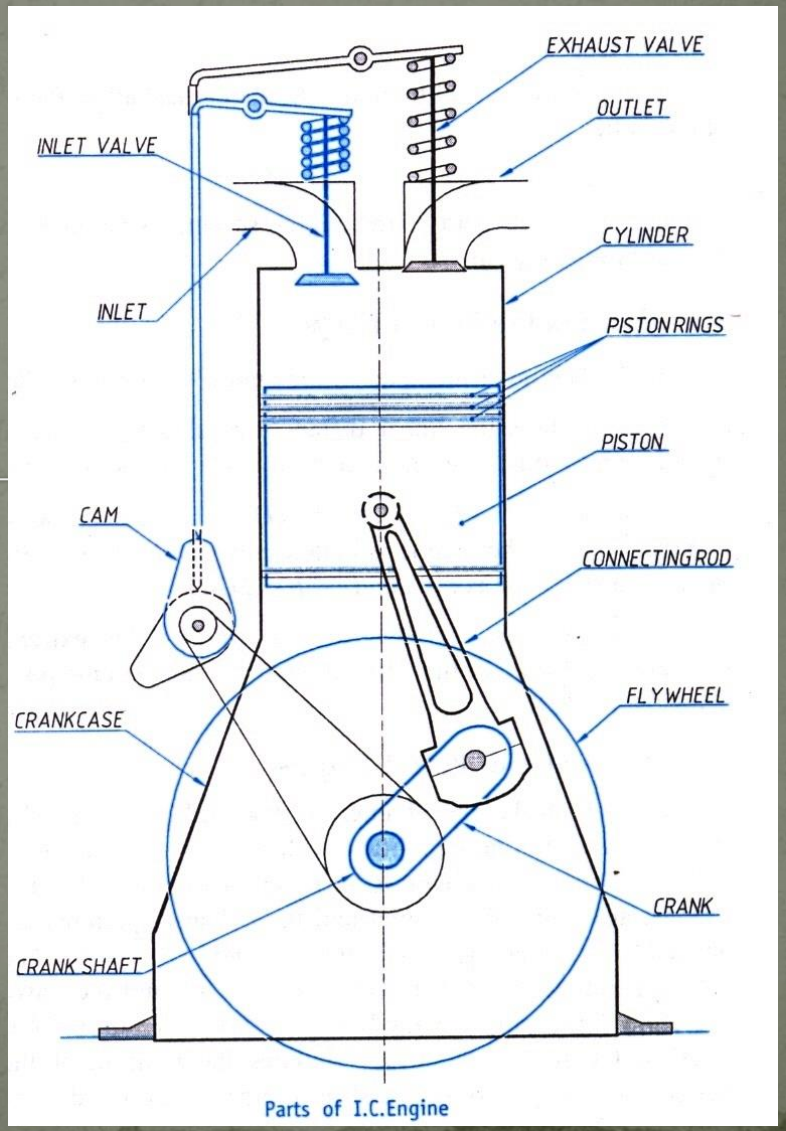
1. Cylinder

- Part of the engine where fuel is burnt and power is developed.
- Inside diameter is called as *bore*.
- Sleeve is fitted tightly in the cylinder to prevent wearing of block.



2. Piston

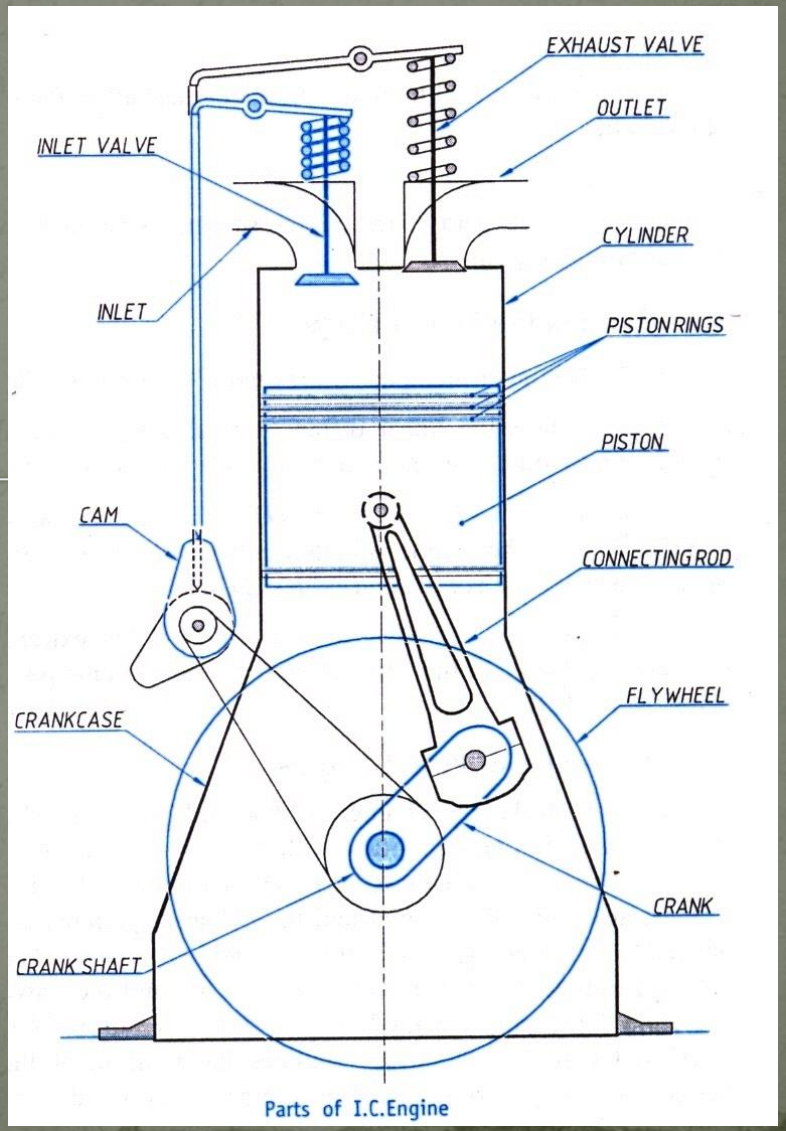
- Close fitting hollow – cylinder plunger moving to and fro in the cylinder.
- *Function* – power developed by the combustion of fuel is transmitted by piston to the crank-shaft through the connecting rod.



3. Piston rings

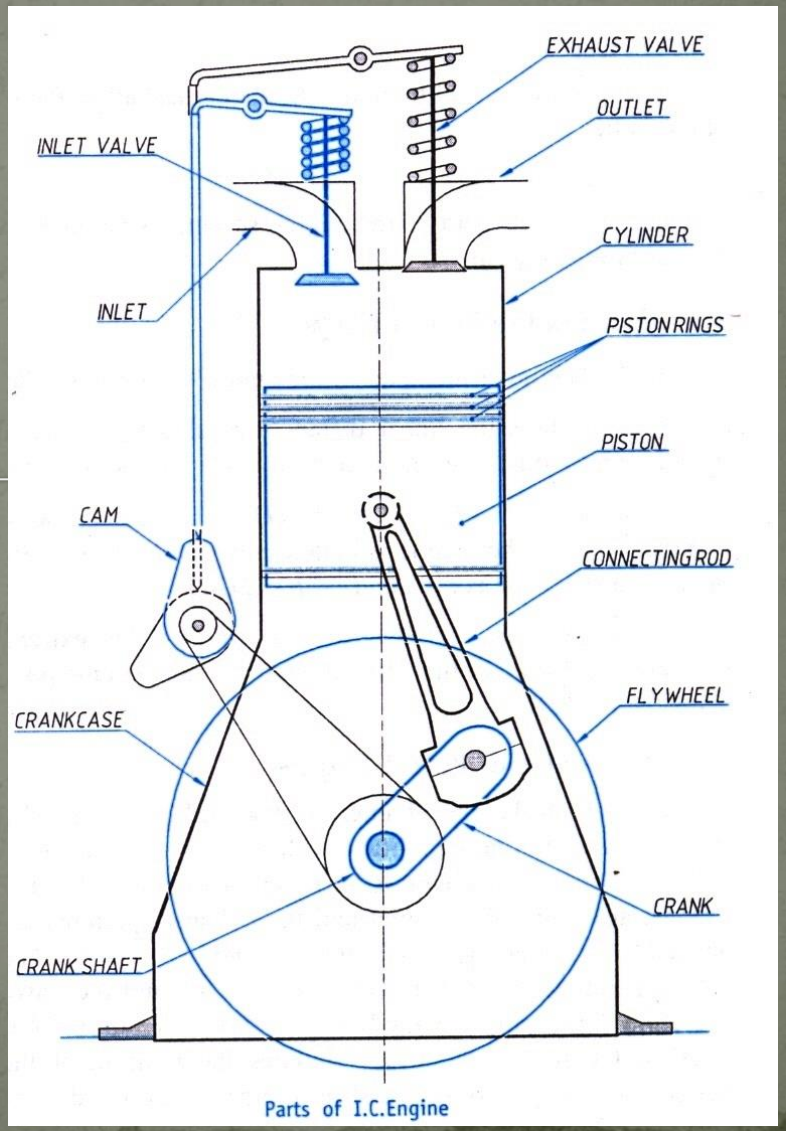
Metallic rings inserted into groves provided at top end of the piston.

Function – it maintains a gas-tight joint between the piston and the cylinder, and for wiping the inner walls of cylinder in each stroke.



4. Connecting rod

- Link that connects the piston and crankshaft by means of pin joint.
- *Function* – it converts the rectilinear motion of the piston (means, to and fro motion) into rotary motion of crank and crankshaft.

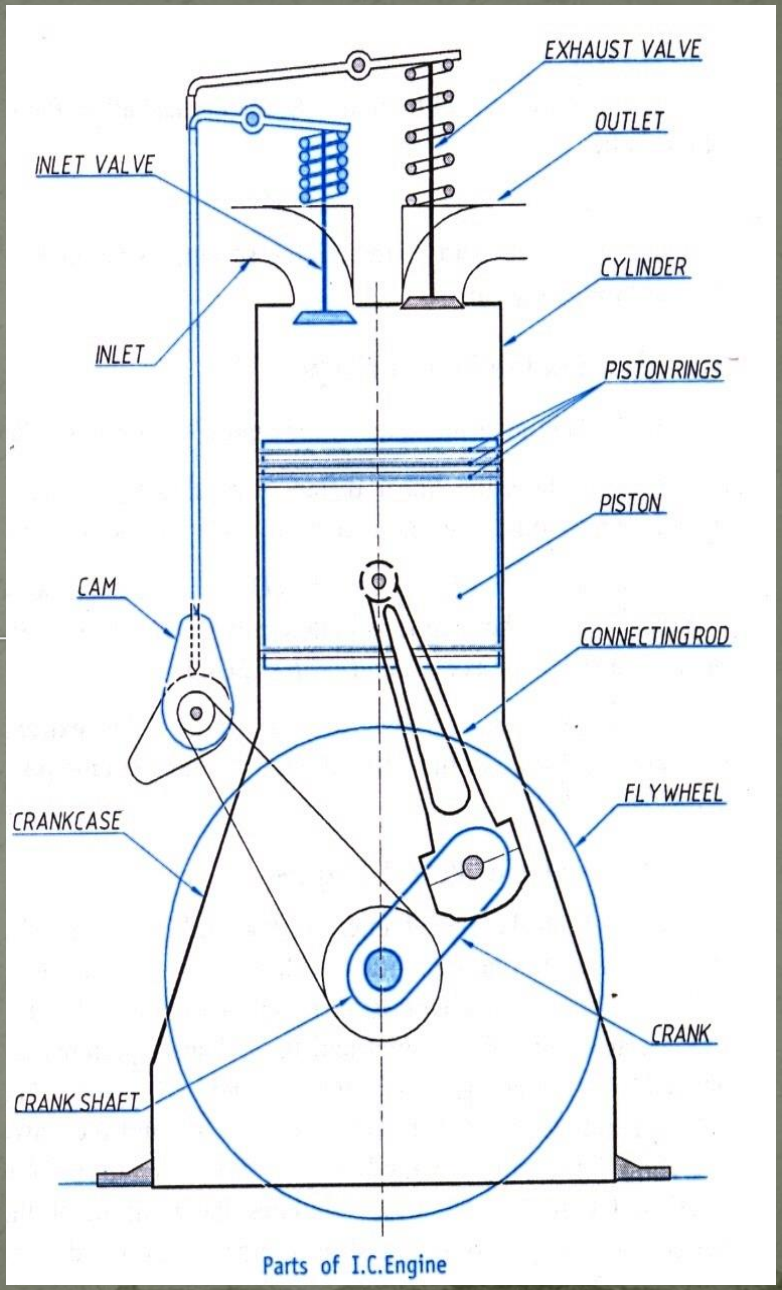


5. Crank and crankshaft

Crank is a rotatory lever that connects crankshaft and piston rod (connecting rod). It is the first rotating element in the engine. Crank causes rotation of the crank-shaft.

6. Valves

These are components which control the flow of intake and exhaust gases. Valves are controlled by valve-rods and springs assembly, which, in turn, controlled by a push-rod and a toggle link.

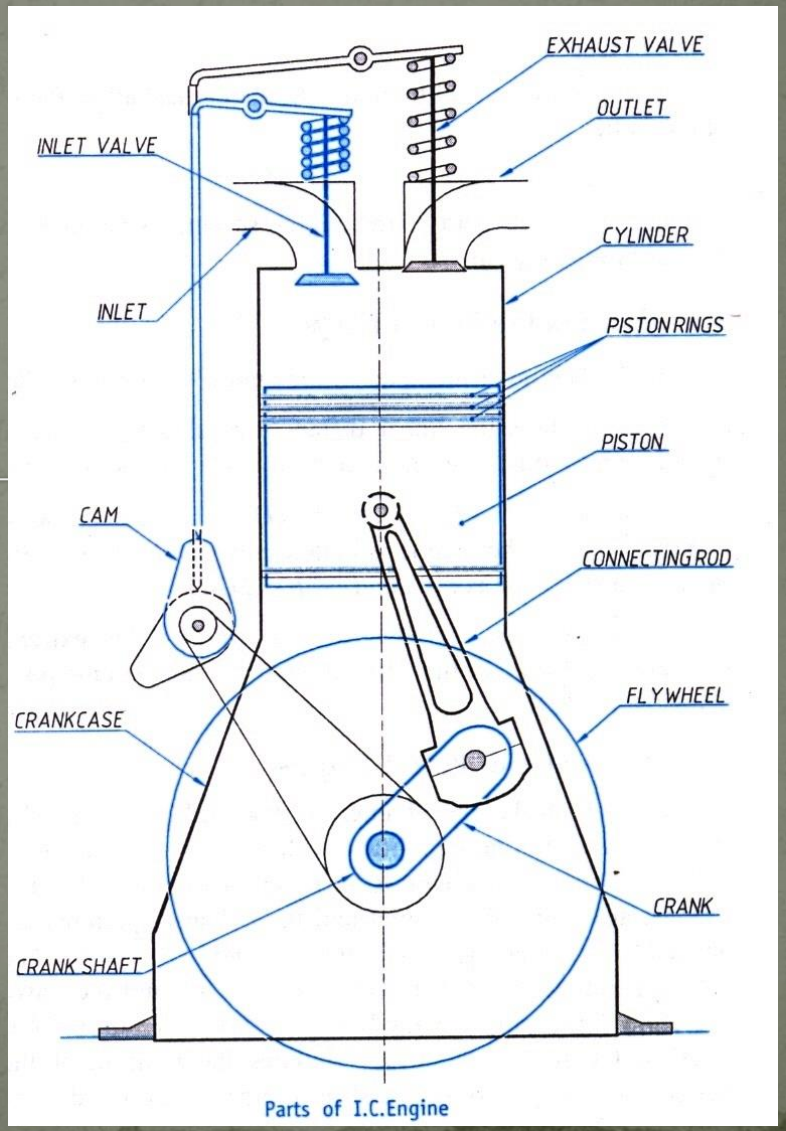


7. Fly wheel

A heavy wheel Mounted on crankshaft on one side, to maintain uniform rotation of crankshaft i.e. to avoid speed fluctuations. It acts like an energy reservoir and stores surplus energy; and delivers energy when required.

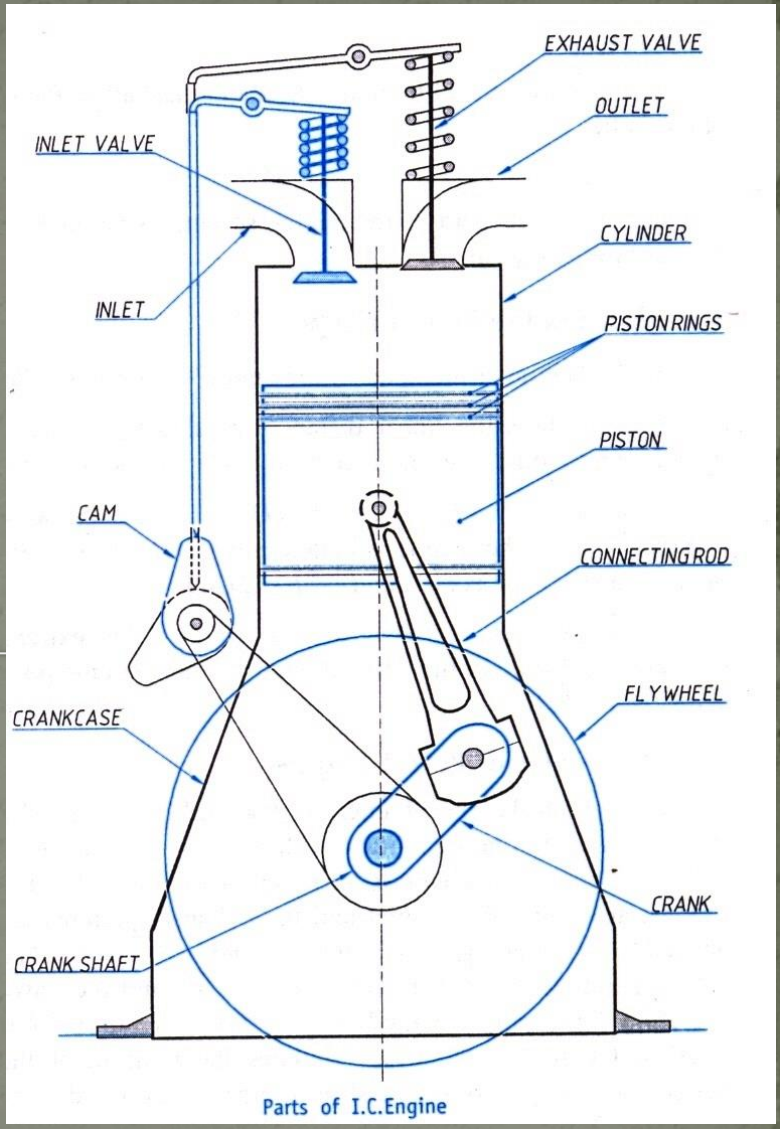
8. Crankcase

Enclosure for crankshaft and sump for lubricating oil.



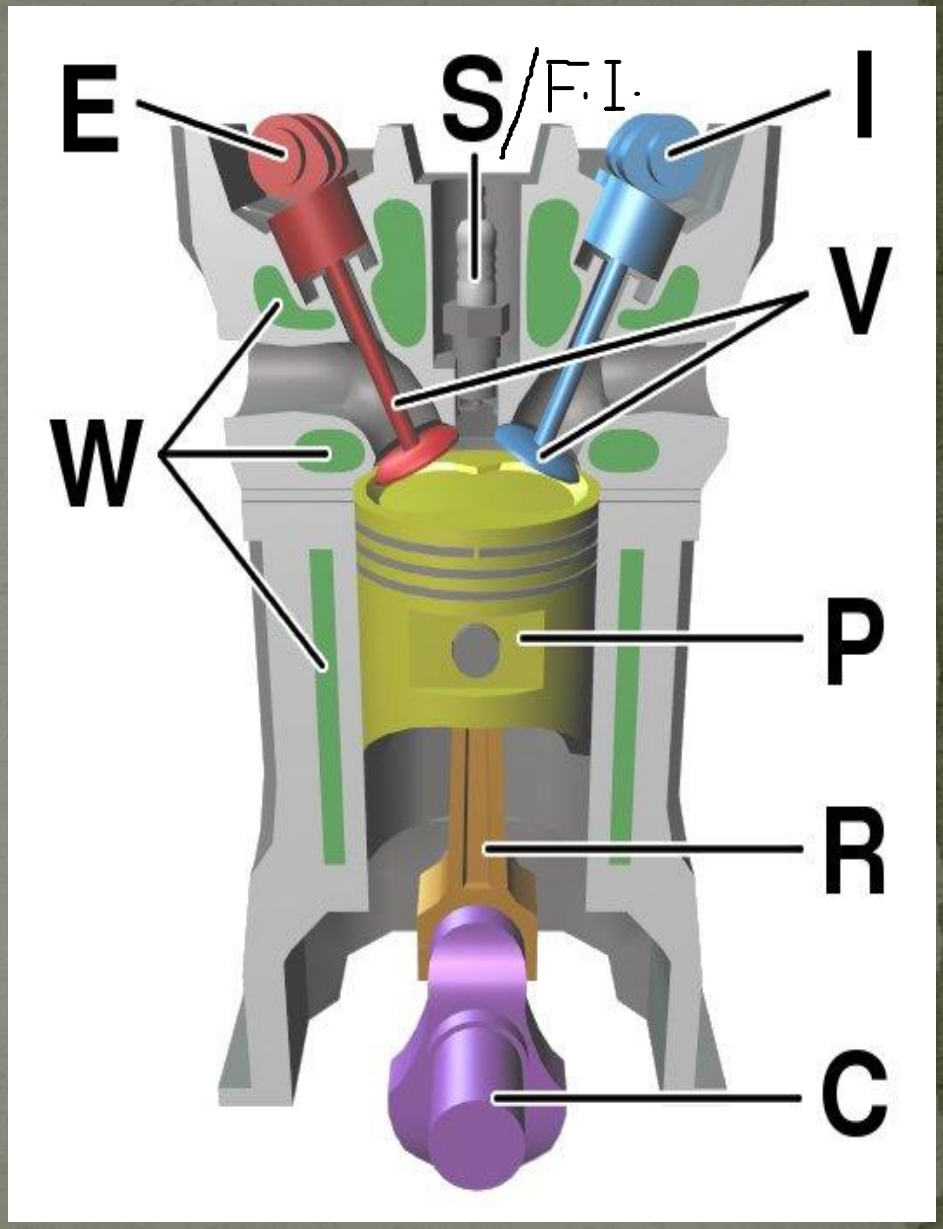
Parts of I.C.Engine

9. Cam and its actuation mehcanism : It is a rigid metallic member which converts rotatory motion into rectilinear motion (to-and-fro motion). It helps in opening /closing of the inlet/outlet valves of the engine. A valve actuating rod and toggle link is also used with it.



Spark plug / Fuel injector

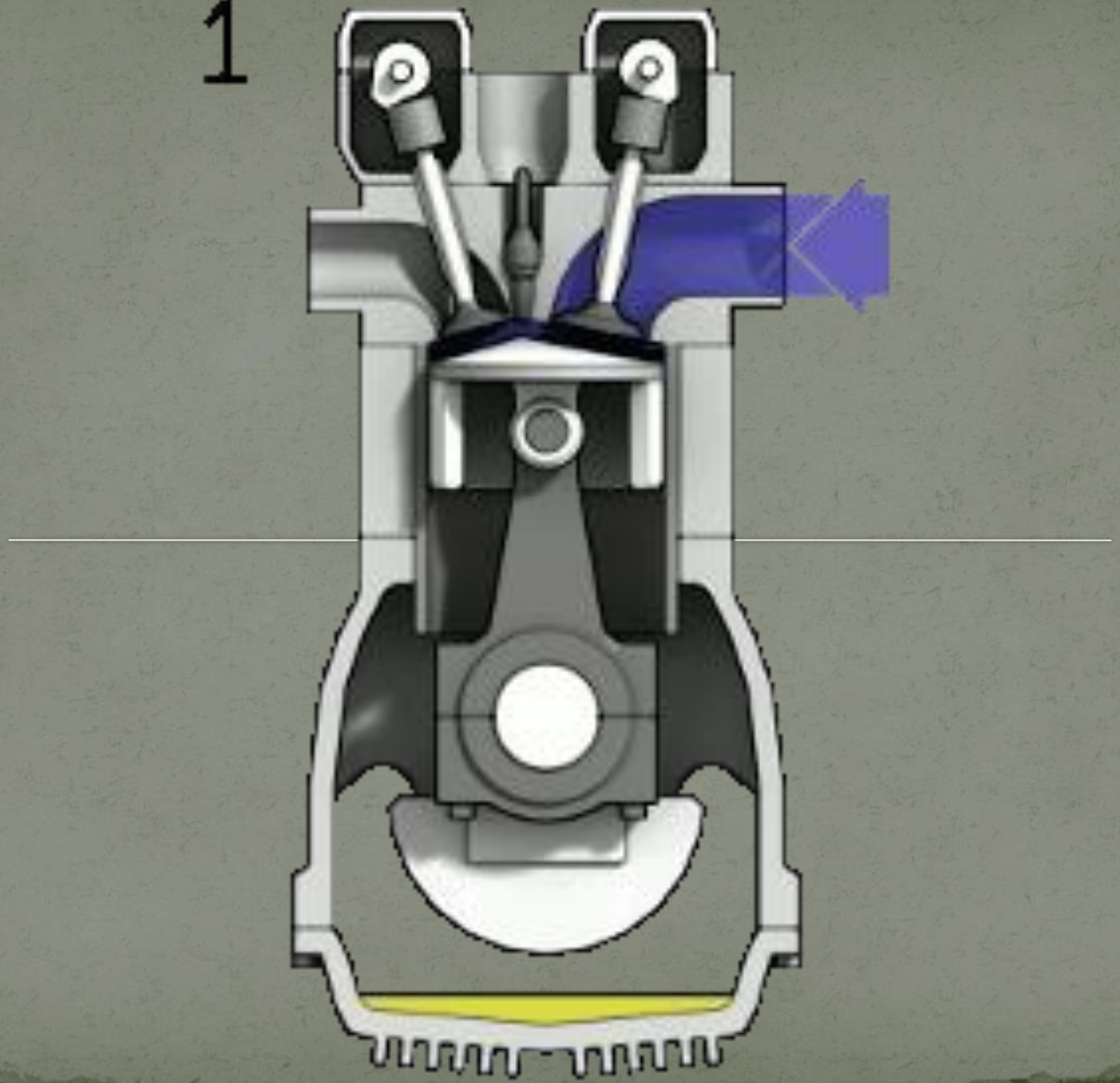
- These are used for ignition or entrance of the fuel inside the combustion chamber.
- A spark plug is used in SI engines (Petrol engines) for creating a spark for ignition.
- A fuel injector is used in CI engines (Diesel engines) for entrance of diesel inside combustion chamber).
- Both of these devices operate at the end of compression stroke (2nd stroke) and just before the power stroke (3rd stroke).



Terms used in the previous slide image…

- E – Exhaust valve
- S/FI – Spark plug *or* Fuel Injector
- I – Intake valve
- W – Water jackets (for cooling)
- V- Valves
- P – Piston
- R- Connecting Rod
- C- Crankshaft

1



Four stroke petrol engine

Four stroke petrol engine consists of

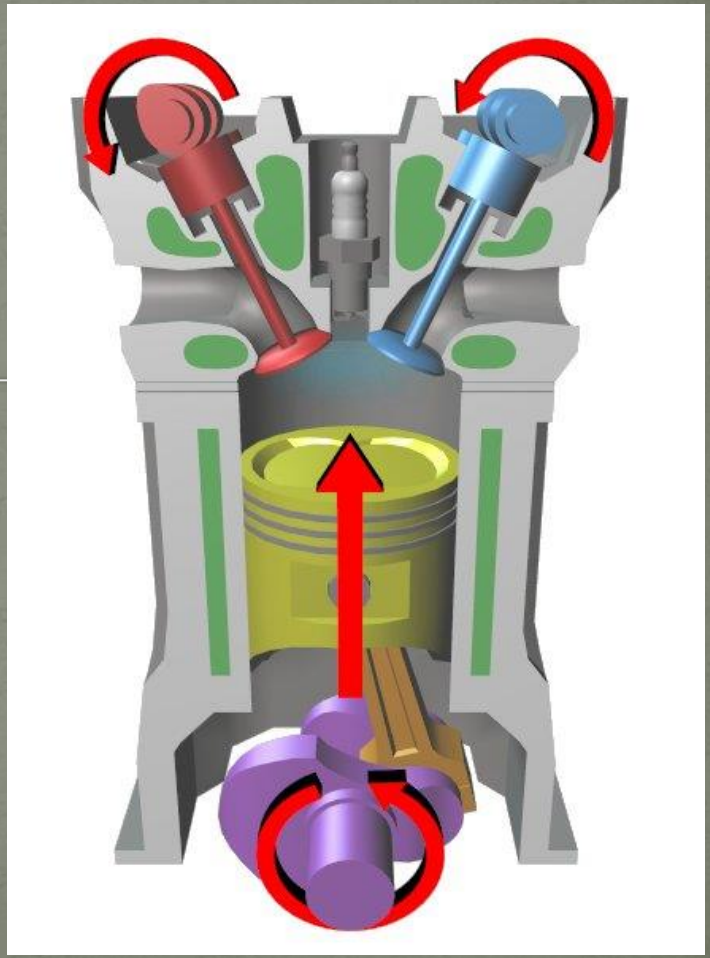
Cylinder

Cover

Mechanically operated valves

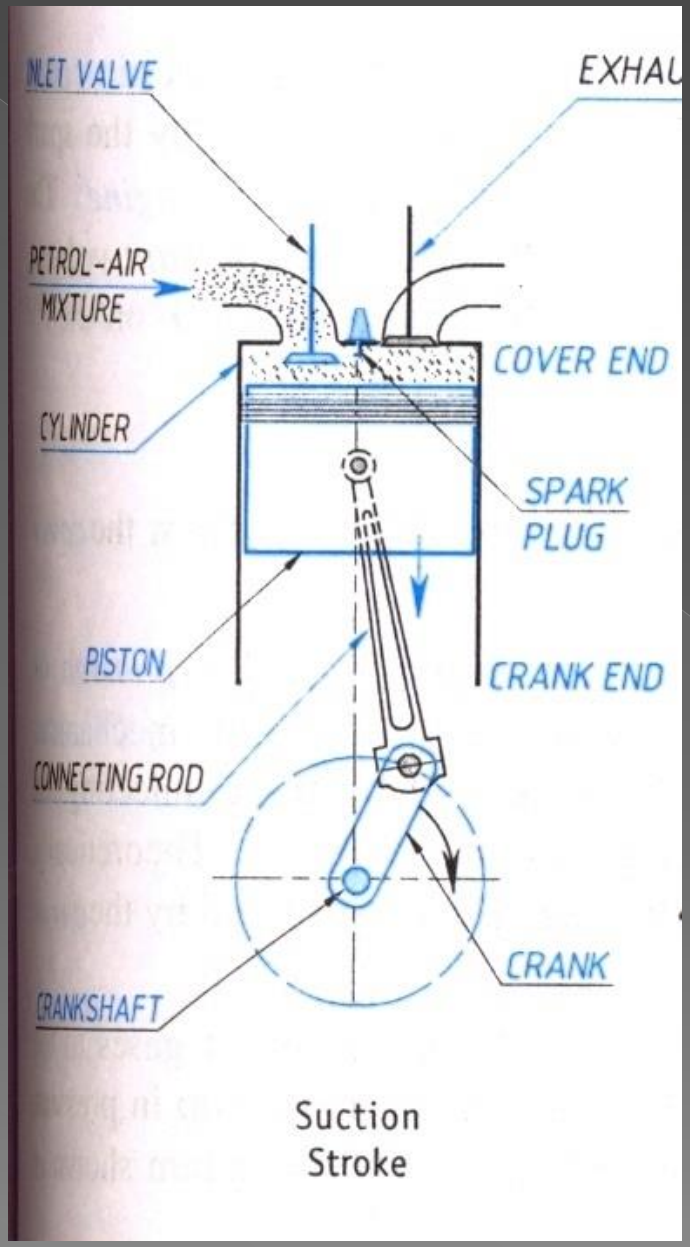
Spark plug

Connecting rod and crank



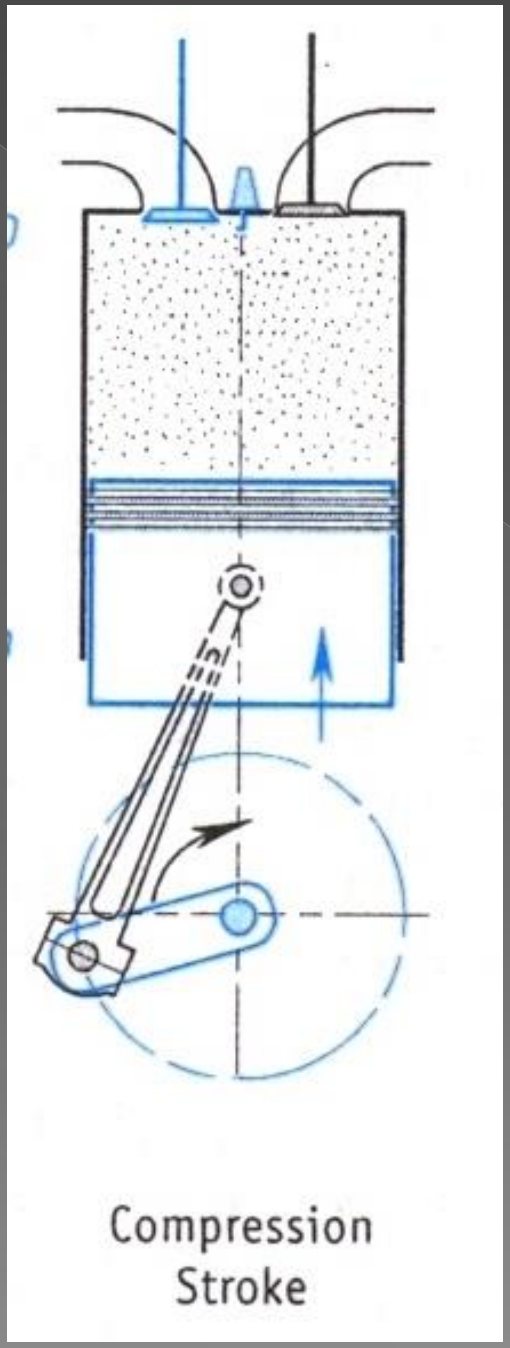
Four stroke petrol engine

- Suction stroke
- Compression stroke
- Power stroke (Expansion stroke)
- Exhaust stroke



SUCTION STROKE

- Inlet is open exhaust is closed.
- Piston moves from TDC to BDC.
- Crankshaft revolves half the rotation.
- Cranking
- Petrol air mixture drawn into cylinder due to pressure difference.

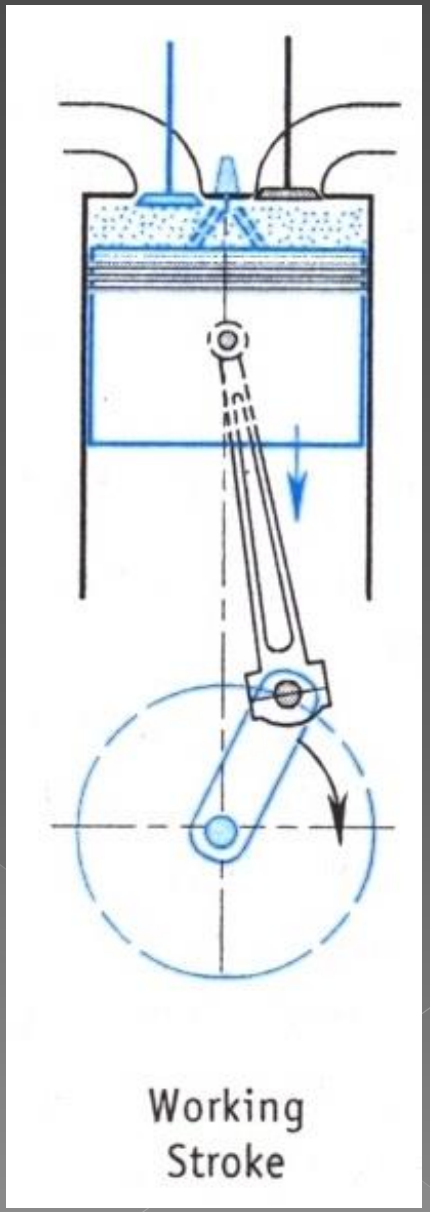


COMPRESSION STROKE

- Both inlet and exhaust are closed.
- Piston moves from BDC to TDC.
- Crankshaft revolves half the rotation.
- Cranking
- Petrol air mixture is compressed to a ratio of 1:11.
- This mixture is ignited by spark plug.

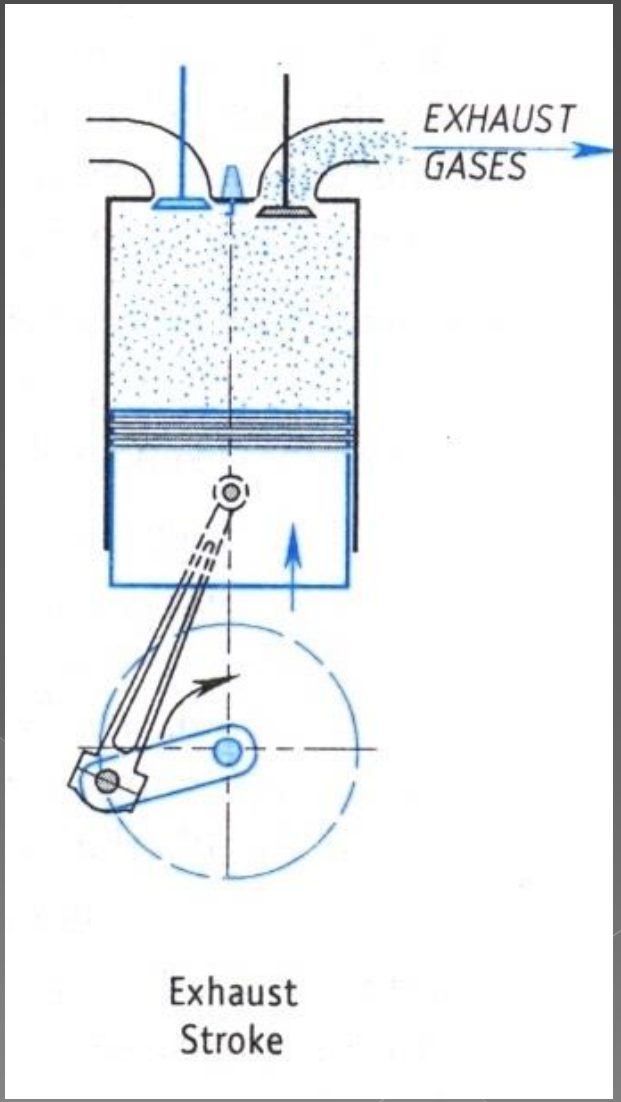
POWER STROKE

- Piston moves from TDC to BDC due to expansion of burnt gases.
- Crankshaft revolves half the rotation.
- burnt gases generate energy and force the piston to move down.

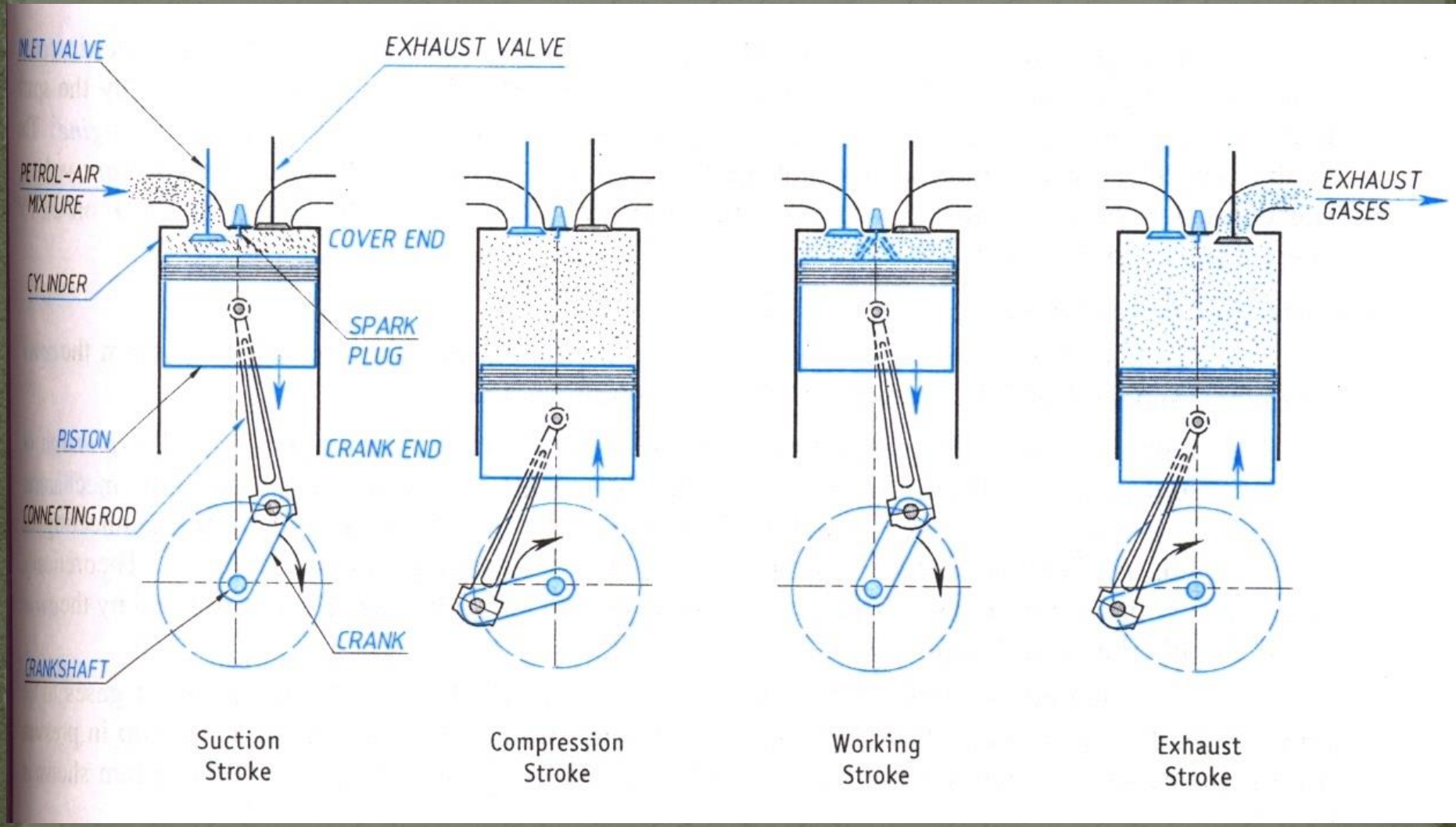


EXHAUST STROKE

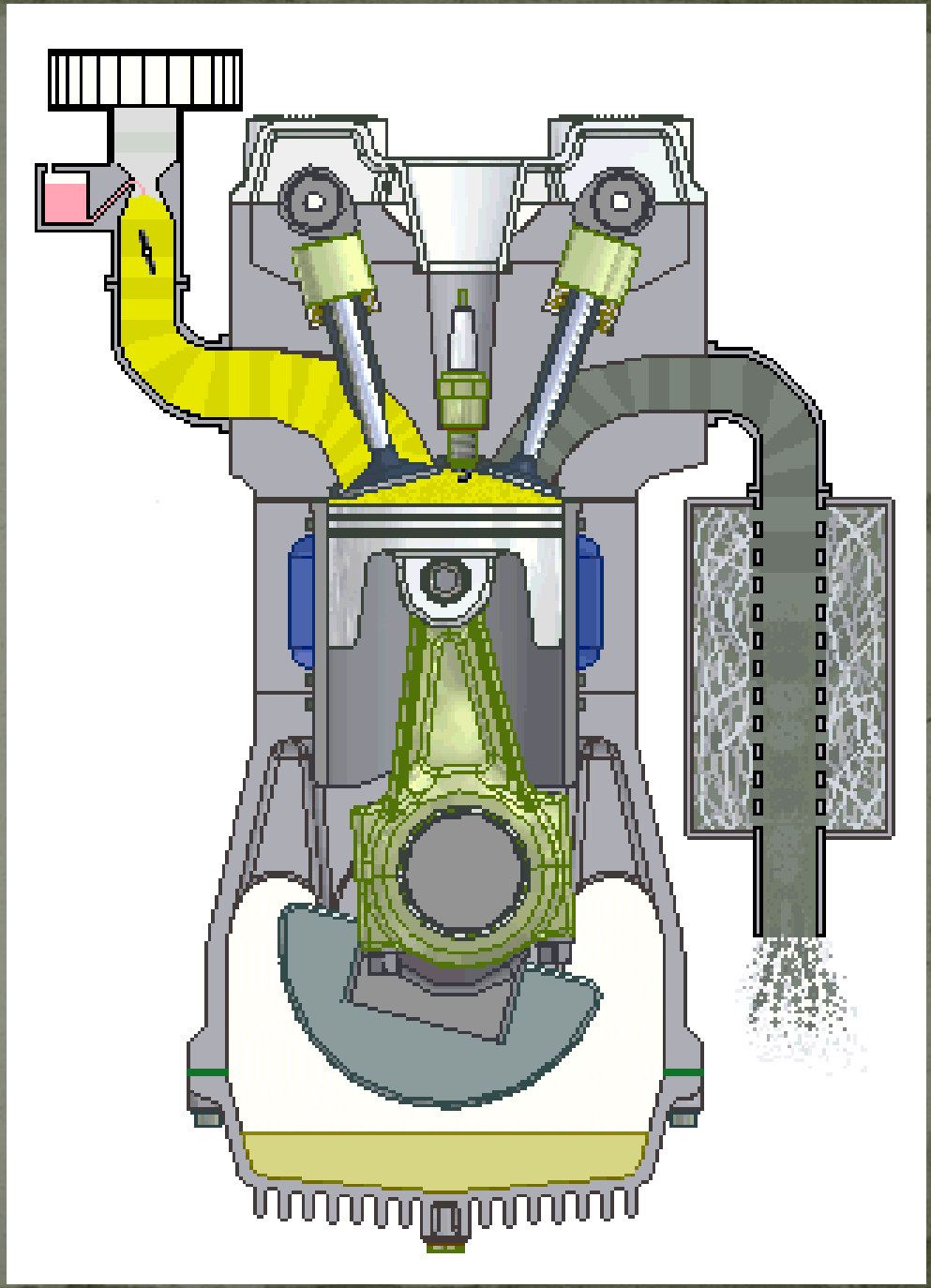
- exhaust is open and inlet is closed.
- Piston moves from BDC to TDC.
- crankshaft revolves half the rotation.
- energy for this stroke is supplied by flywheel.
- Burnt gases are expelled out through outlet port.



Four stroke petrol engine

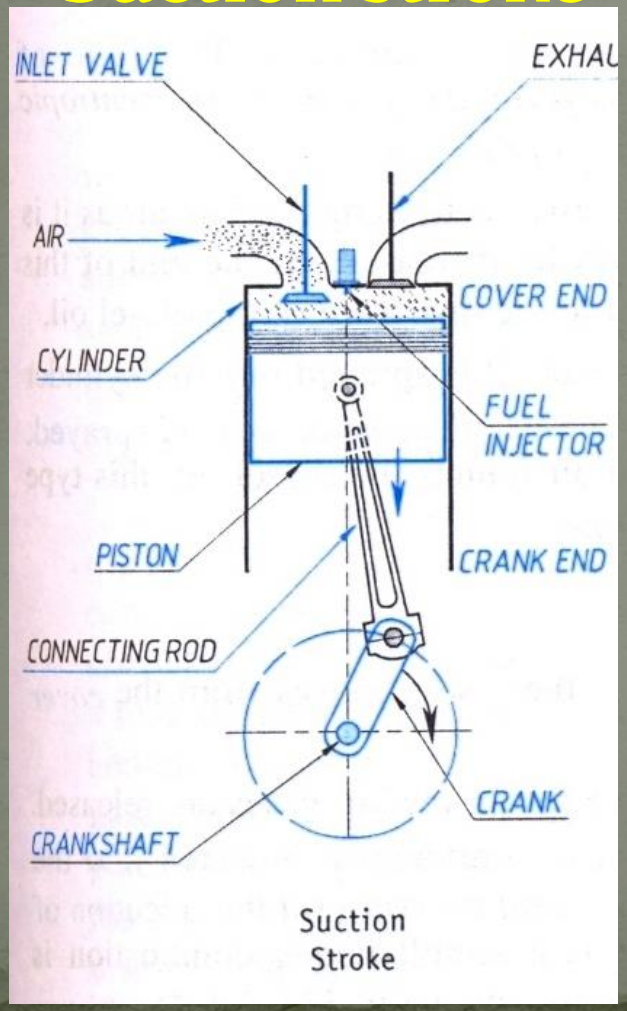


4 stroke petrol engine (SI engine) working animation



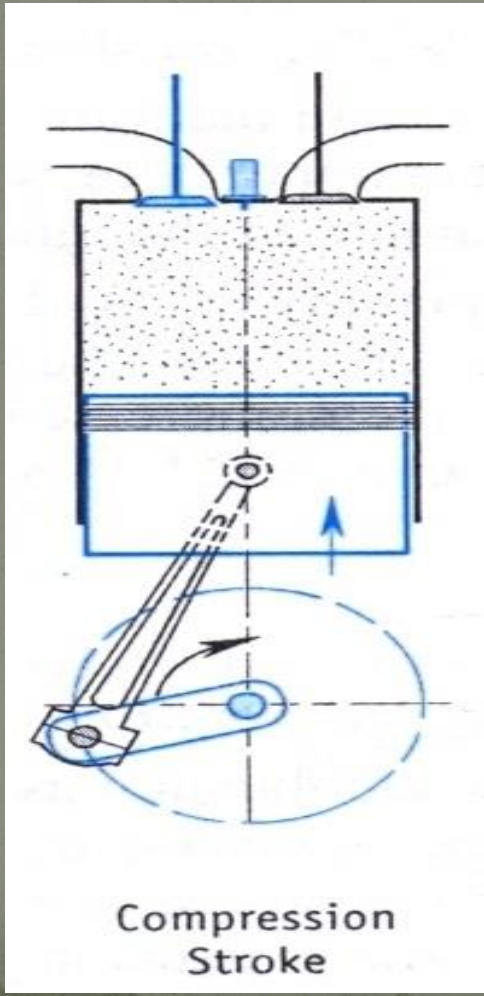
4 Stroke Diesel Engine

Suction stroke



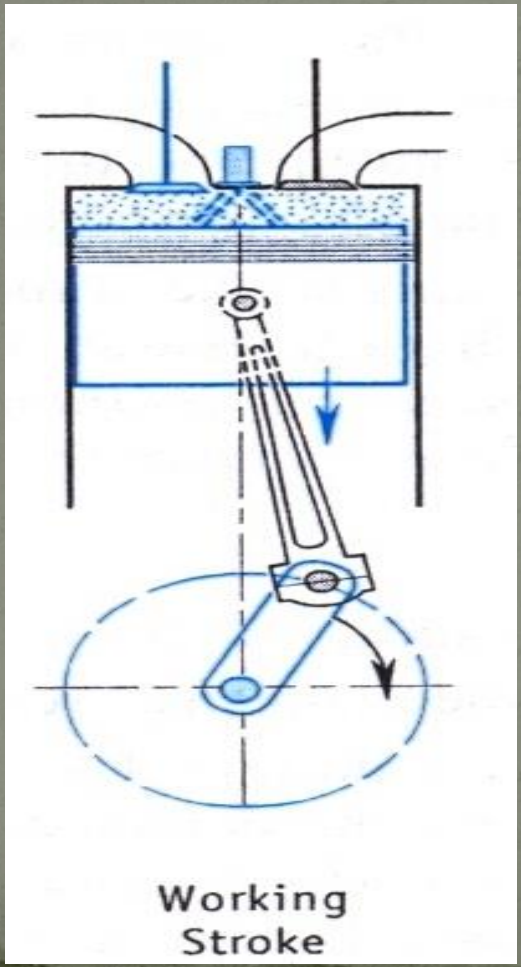
- Inlet is open exhaust is closed.
- Piston moves from TDC to BDC and crankshaft revolves half the revolution.
- Cranking during first cycle.
- Due to the pressure difference *air enters the cylinder* through air filter.

Compression stroke



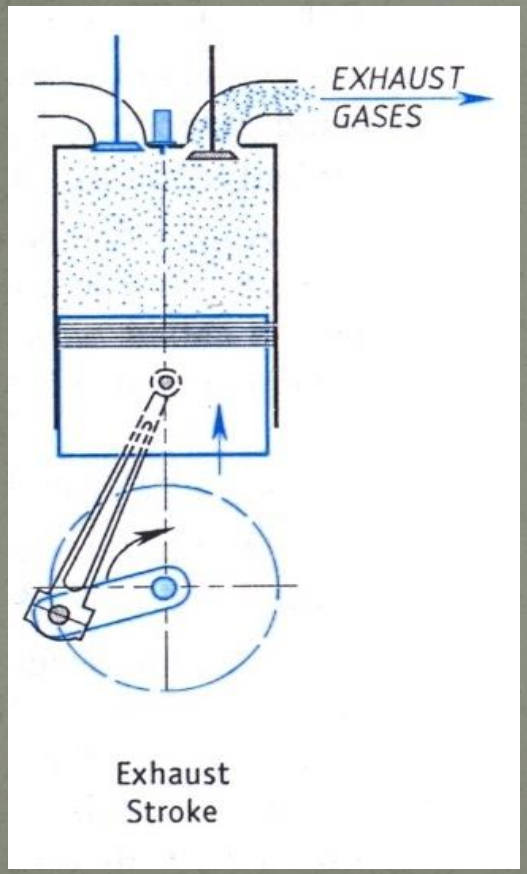
- Inlet and exhaust are closed.
- Piston moves from BDC to TDC.
- Cranking required in first cycle.
- Air will be compressed to a ratio of 1:20.
- Diesel oil is *sprayed* into cylinder by *injector* and *auto-ignition* takes place.

Power stroke



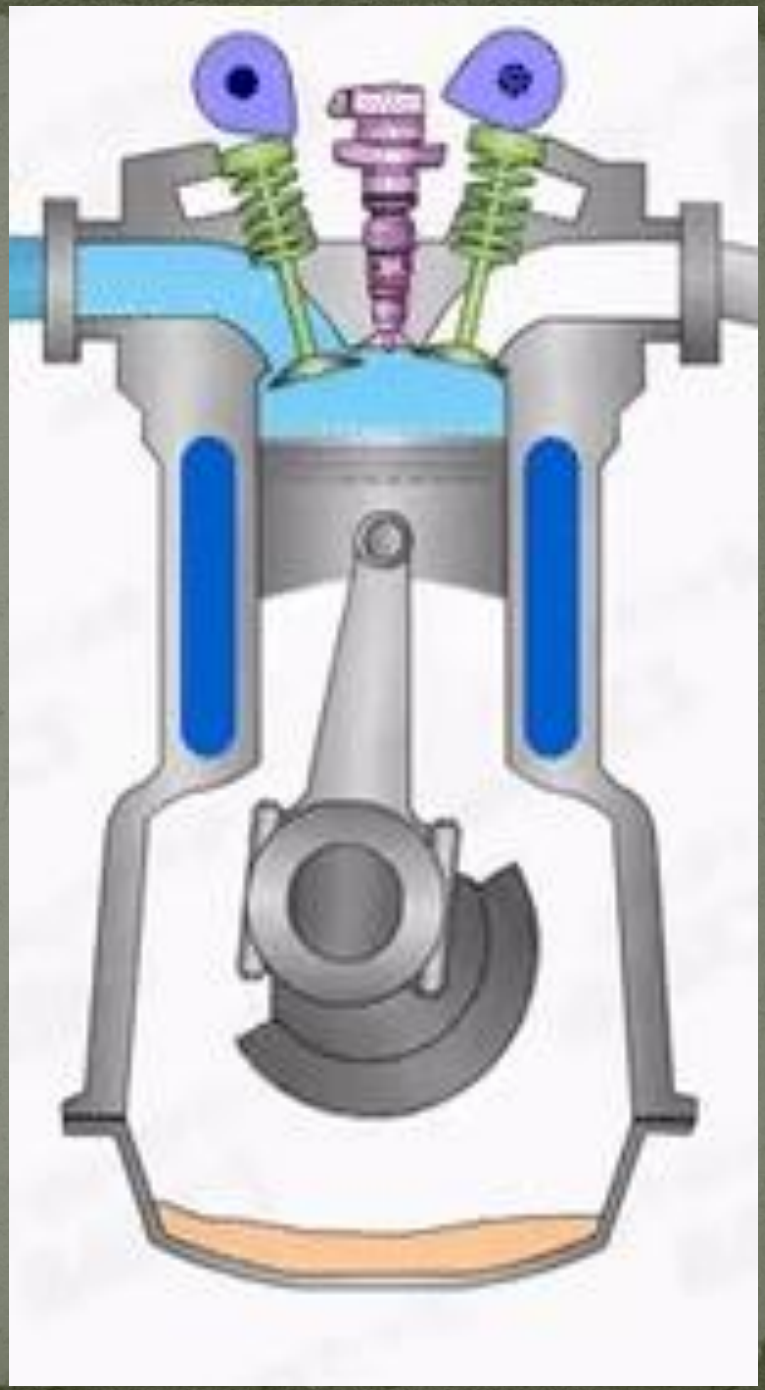
- Piston moves from TDC to BDC.
- Inlet and exhaust valves are closed.
- burnt gases generate energy and force the piston to move down till injection of fuel is complete.

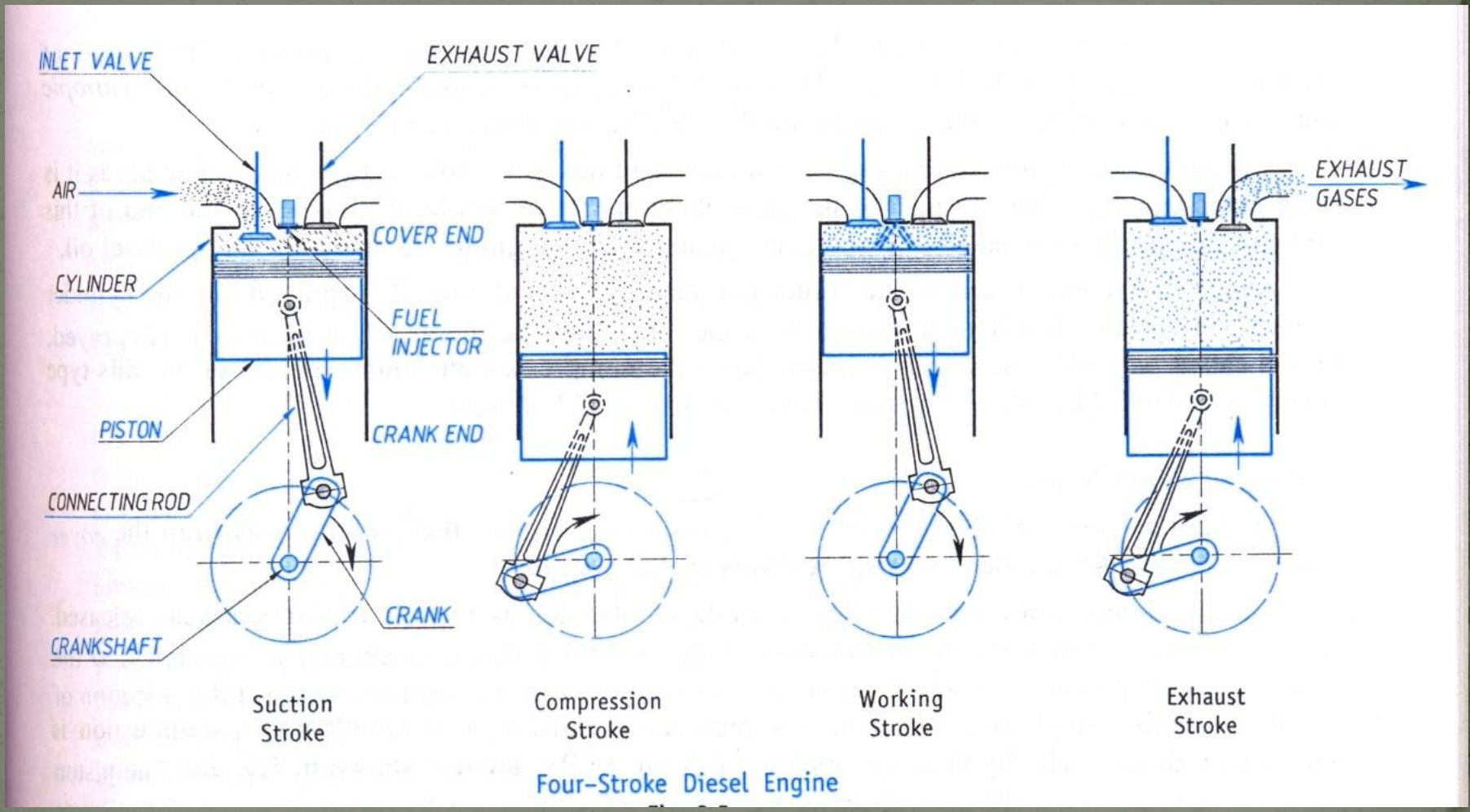
Exhaust stroke



- exhaust is open and inlet is closed.
- Piston moves from BDC to TDC.
- crankshaft revolves half the rotation.
- energy for this stroke is supplied by flywheel.
- Burnt gases are expelled out through outlet port.

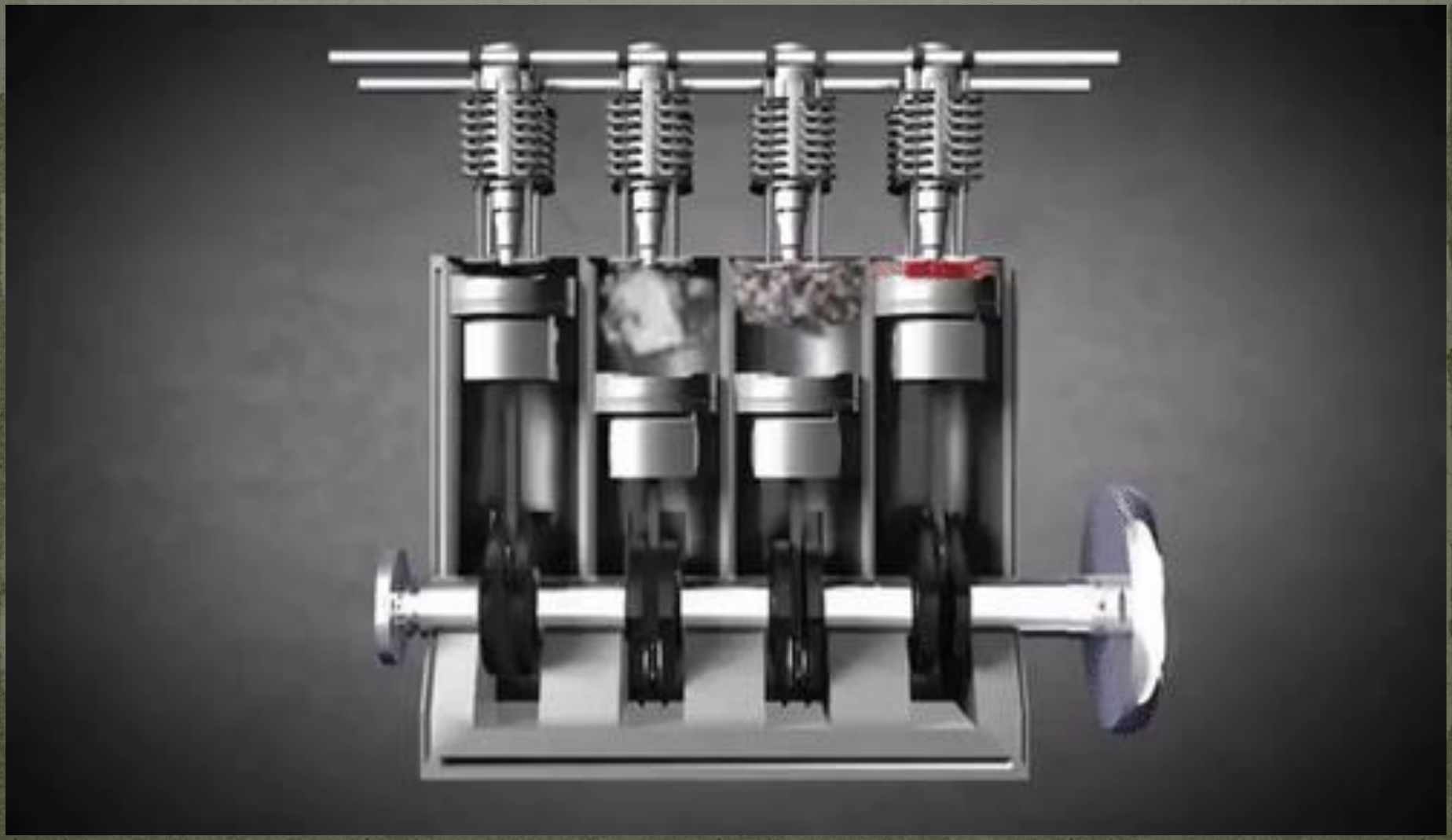
4 stroke diesel engine (CI engine) working animation

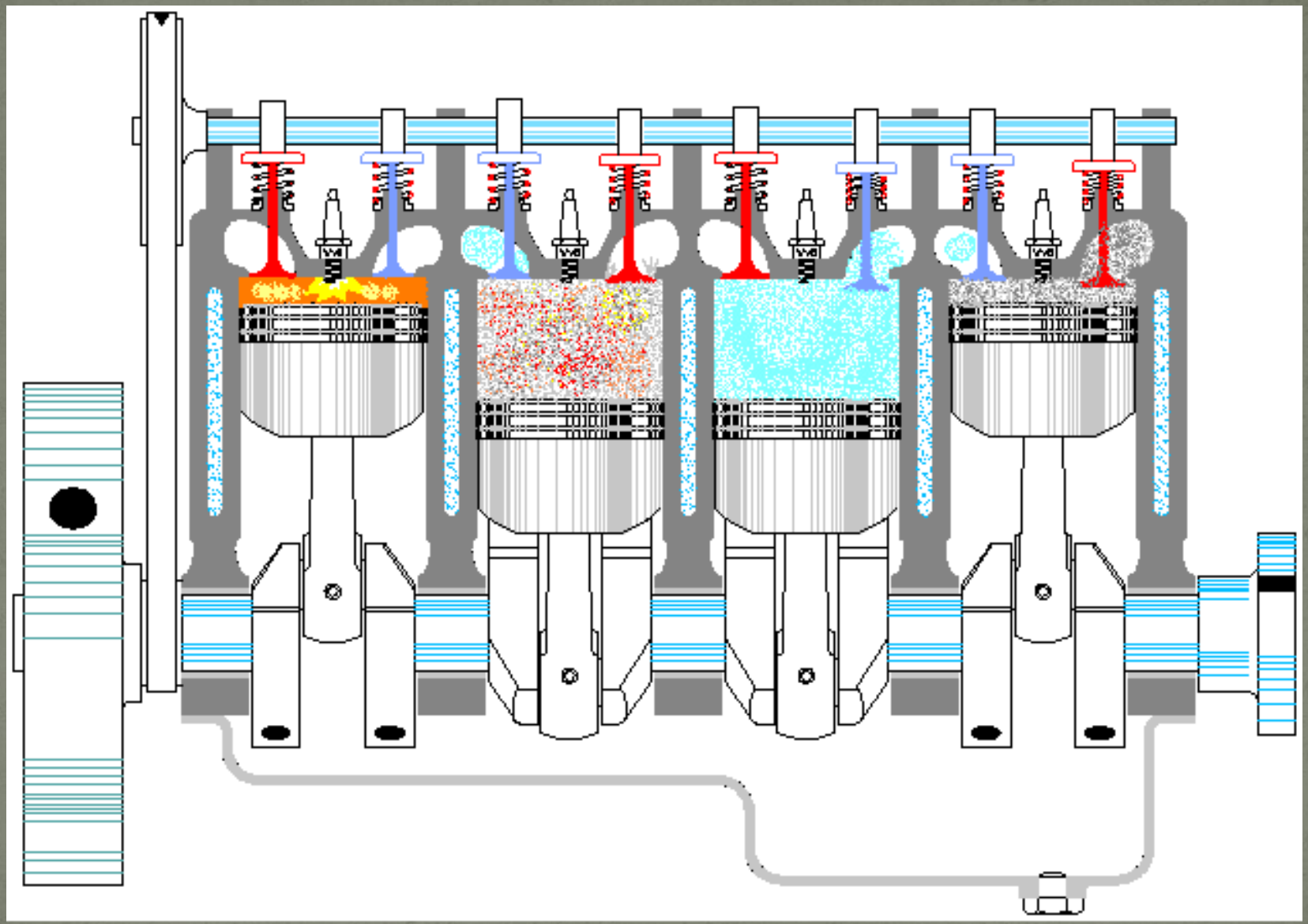


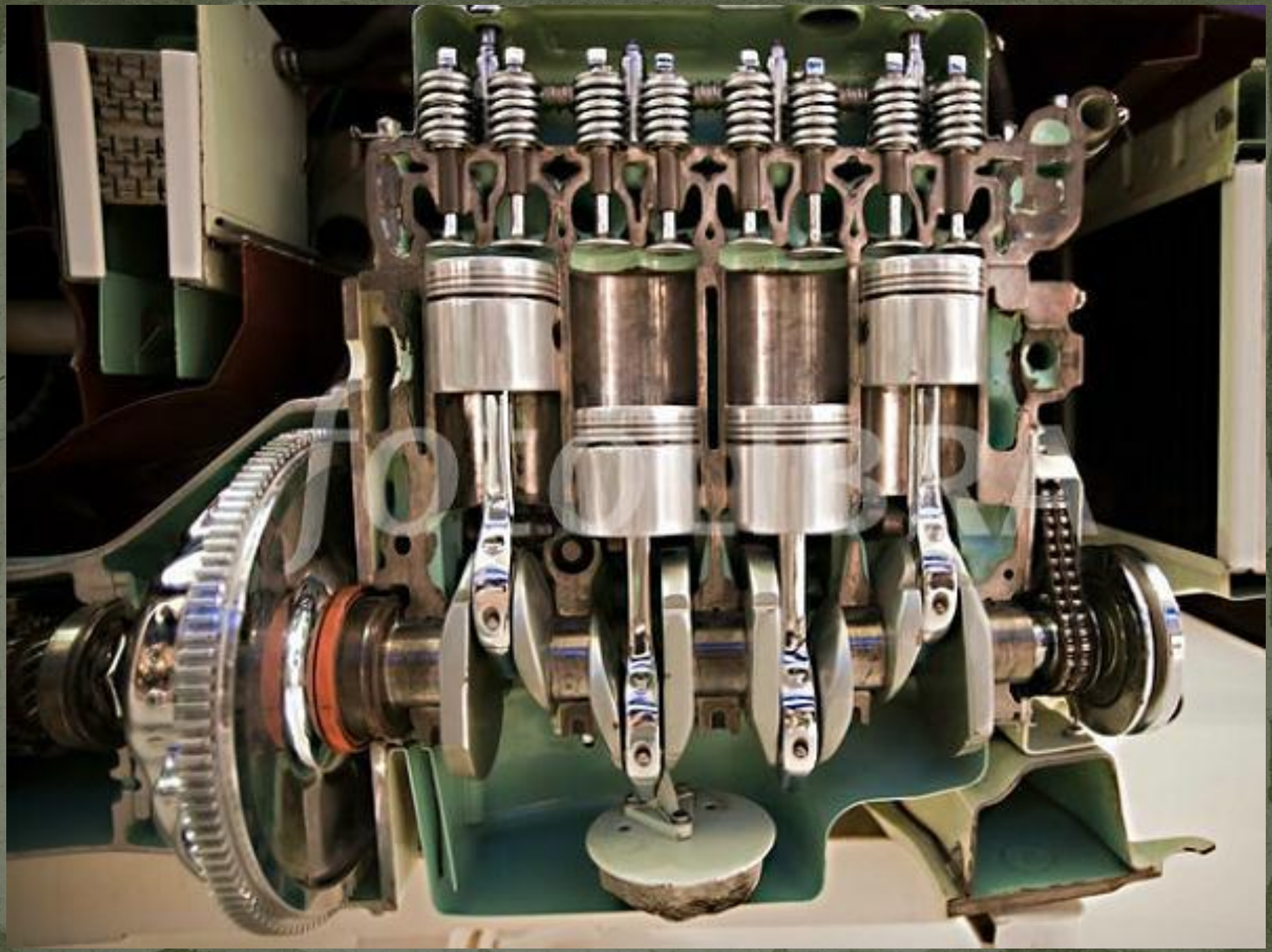


Four-Stroke Diesel Engine

4 Cylinder 4-stroke IC Engine working animation







Some definitions related to IC Engines

- **Bore** : The internal diameter of the combustion chamber is known as bore.
- **TDC** : Top Dead Centre. The top most position of the piston in a vertically aligned engine. The volume of the combustion chamber is minimum in this position, and piston is farthest from the crank case.
- **BDC** : Bottom Dead Centre. The bottom most position of the piston in a vertically aligned engine. The volume of the combustion chamber is maximum in this position, and piston is closer to the crank case.

Some definitions related to IC Engines

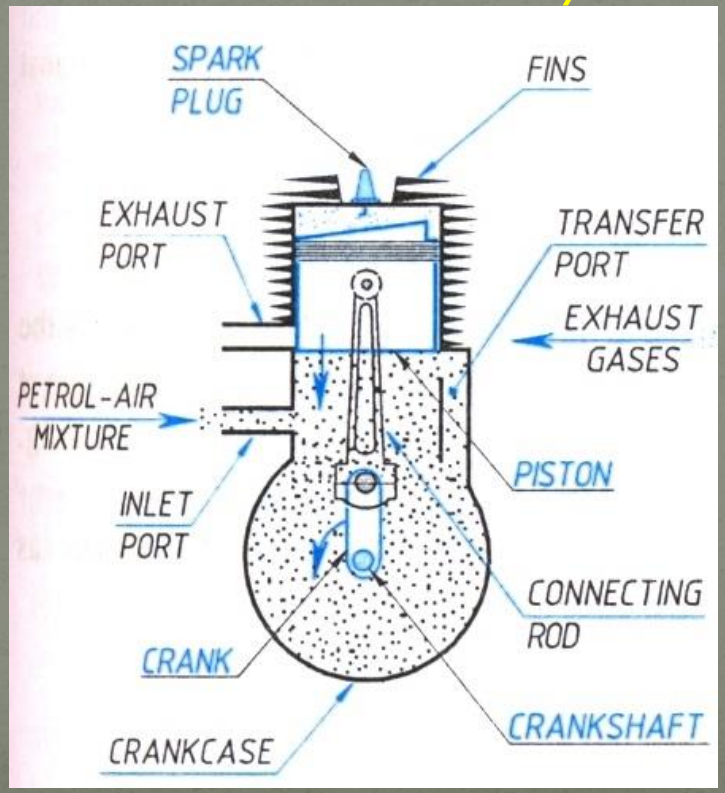
- **IDC** : Inner Dead Centre. The inner most position of the piston in a horizontally aligned engine. The volume of the combustion chamber is minimum in this position.
- **ODC** : Outer Dead Centre. The outer most position of the piston in a horizontally aligned engine. The volume of the combustion chamber is maximum in this position.
- **Stroke** : The movement of the piston from TDC to BDC, IDC to ODC or vice versa is called as a stroke. i.e., it is the movement of the piston between its two extreme positions. In one stroke, the crank rotates by an angle of 180 degrees, i.e. half rotation.

Some definitions related to IC Engines

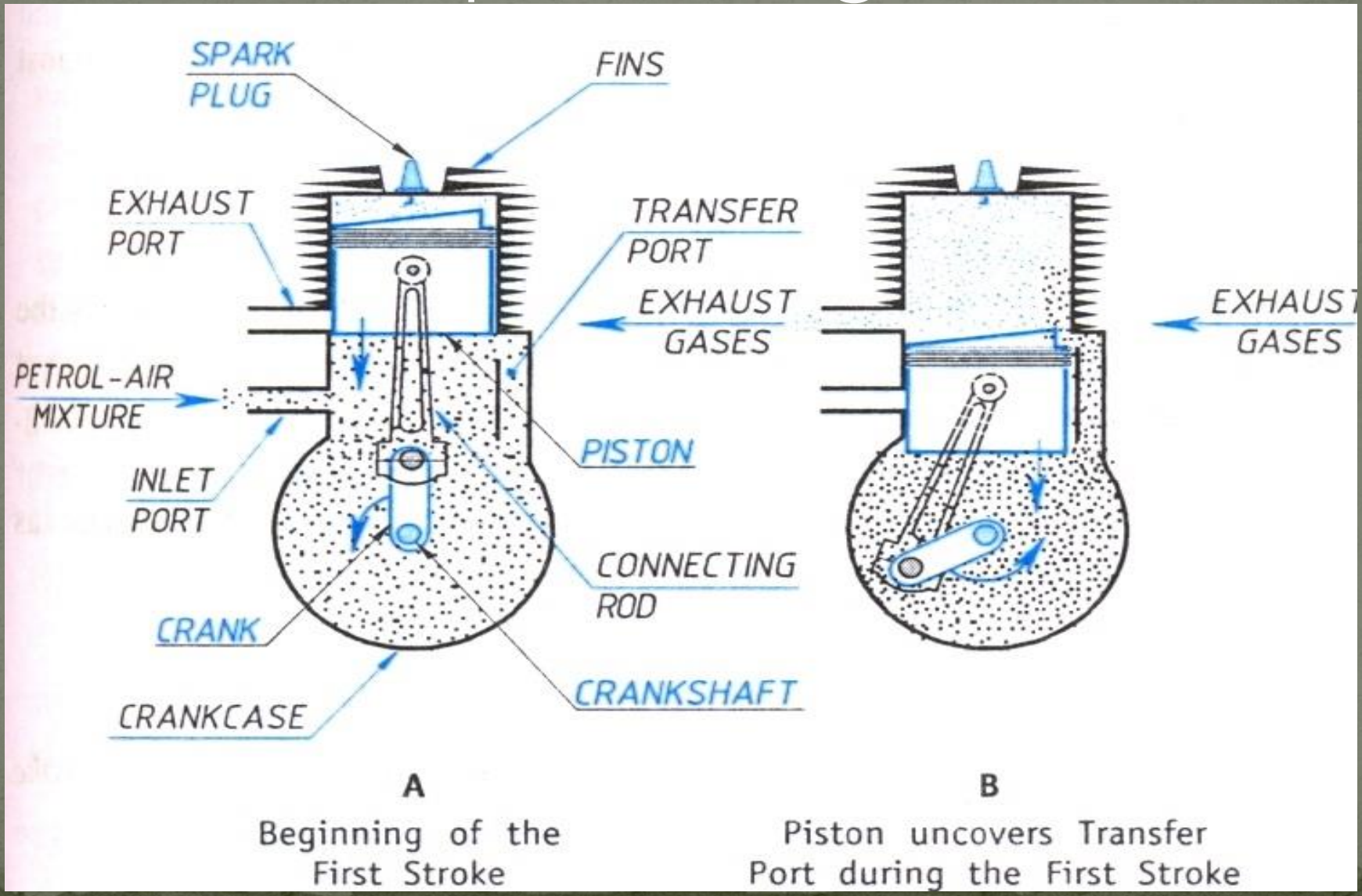
- **Clearance Volume** : It is the minimum possible volume of the fuel+Air mixture (or only air) at the end of compression stroke.
- **Compression Ratio** : It is the ratio of maximum volume inside the combustion chamber to the clearance volume. It shows to what extent the air or fuel+air mixture is compressed by the moving piston inside the combustion chamber. It varies between 8 to 12 for SI engines (petrol engines) and 16-22 for CI engines (diesel engines)

Two stroke petrol engine

- Performs two strokes to complete one working cycle.
- Works on *theoretical Otto cycle*.

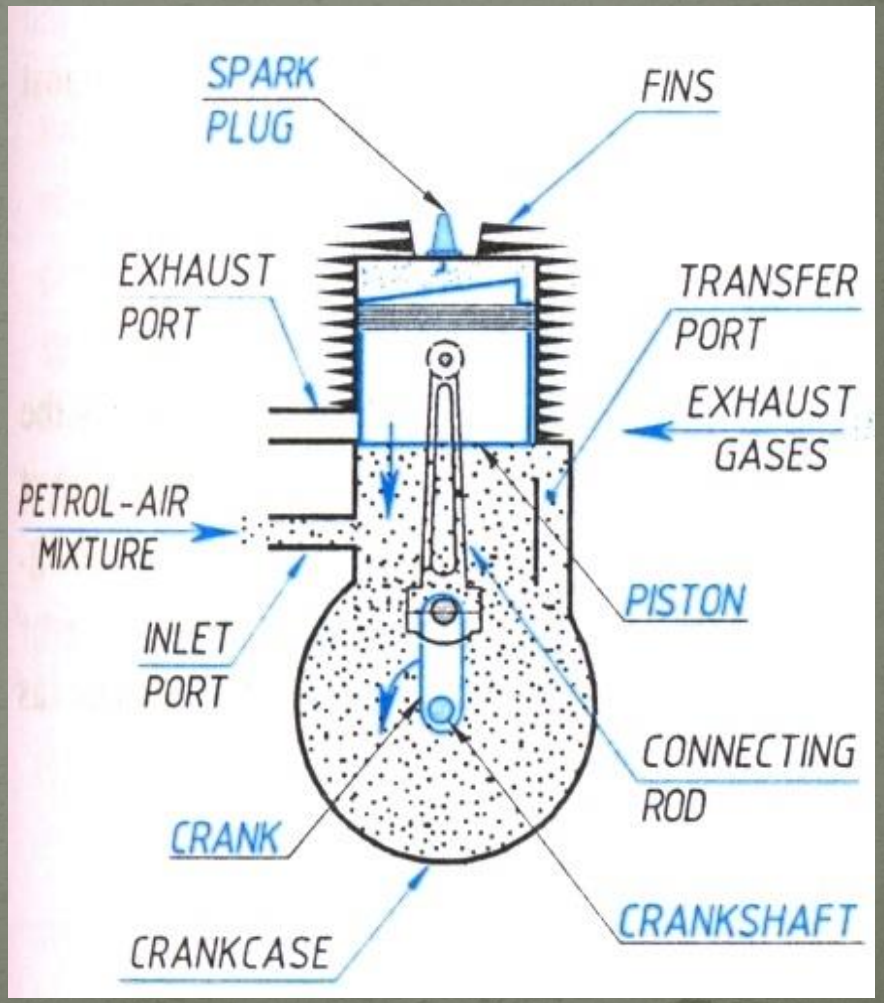


Two stroke petrol engine

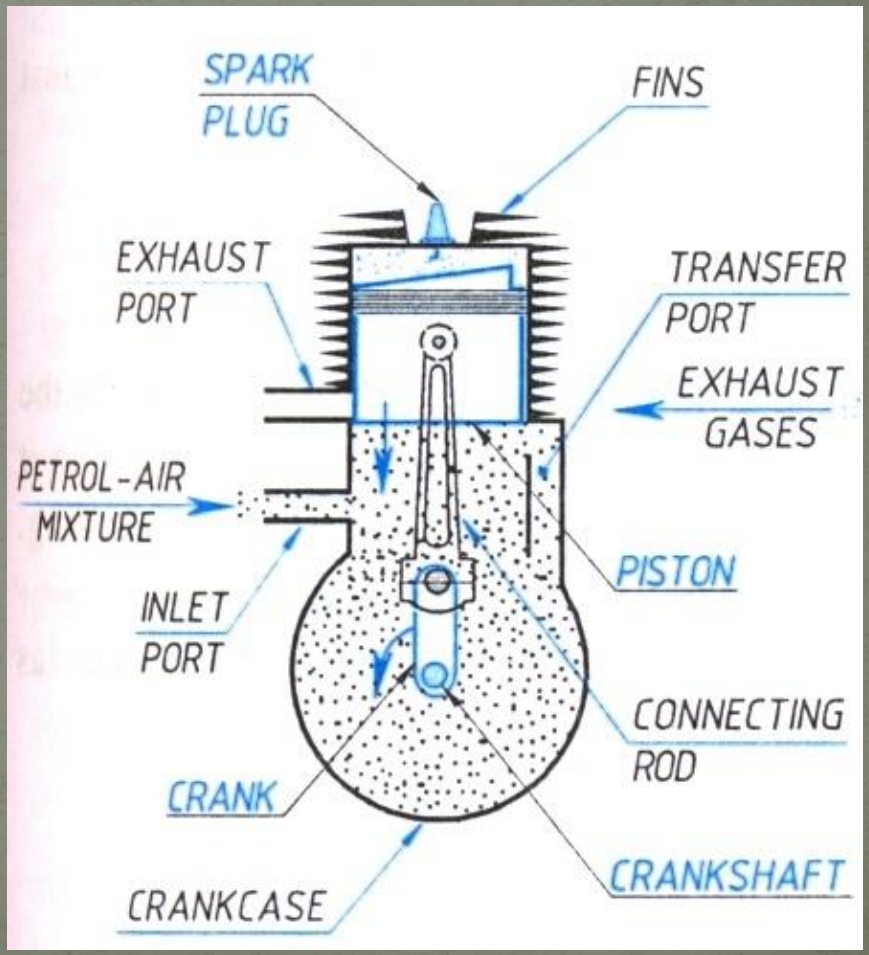


Parts

- Cylinder with one end fitted with cover and other end with a sealed crankcase.
- Ports are provided one below other on circumference of the cylinder.
- Lower one is the admission port or inlet port and upper port is the exhaust port.
- Transfer port diametrically opposite.

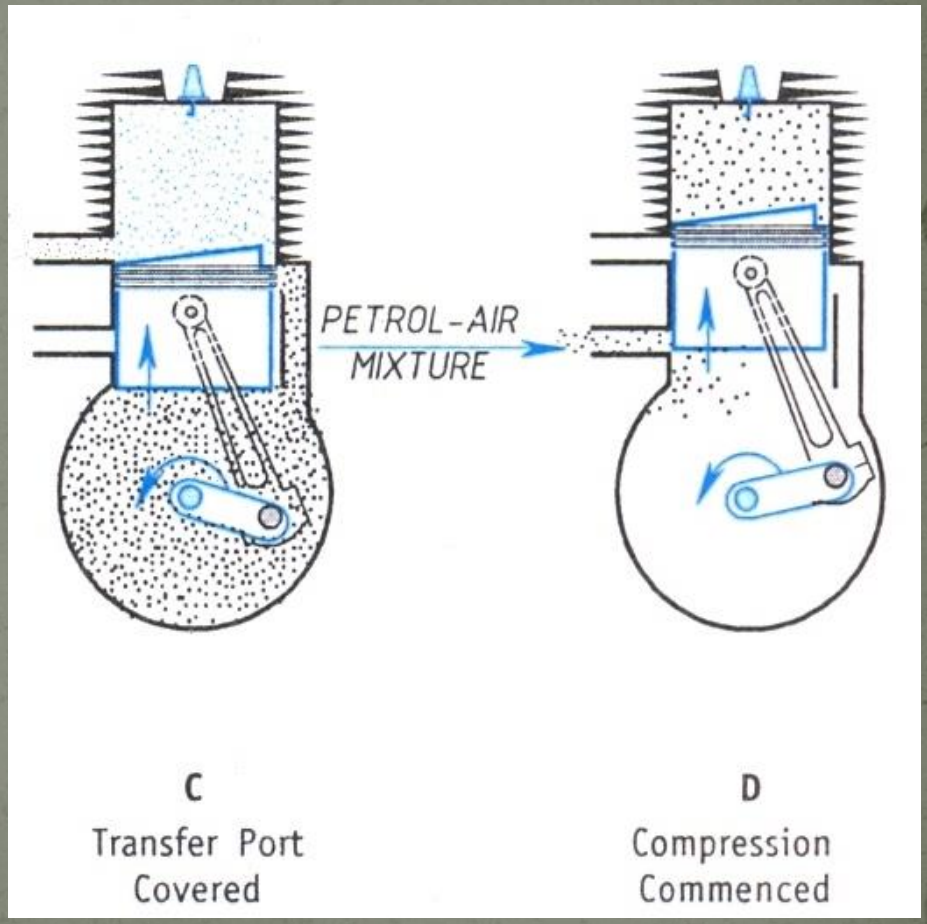


- Transfer port
  - *Function* – transfer of petrol air mixture from crankcase to cylinder.
- Spark plug, connecting rod, crank.

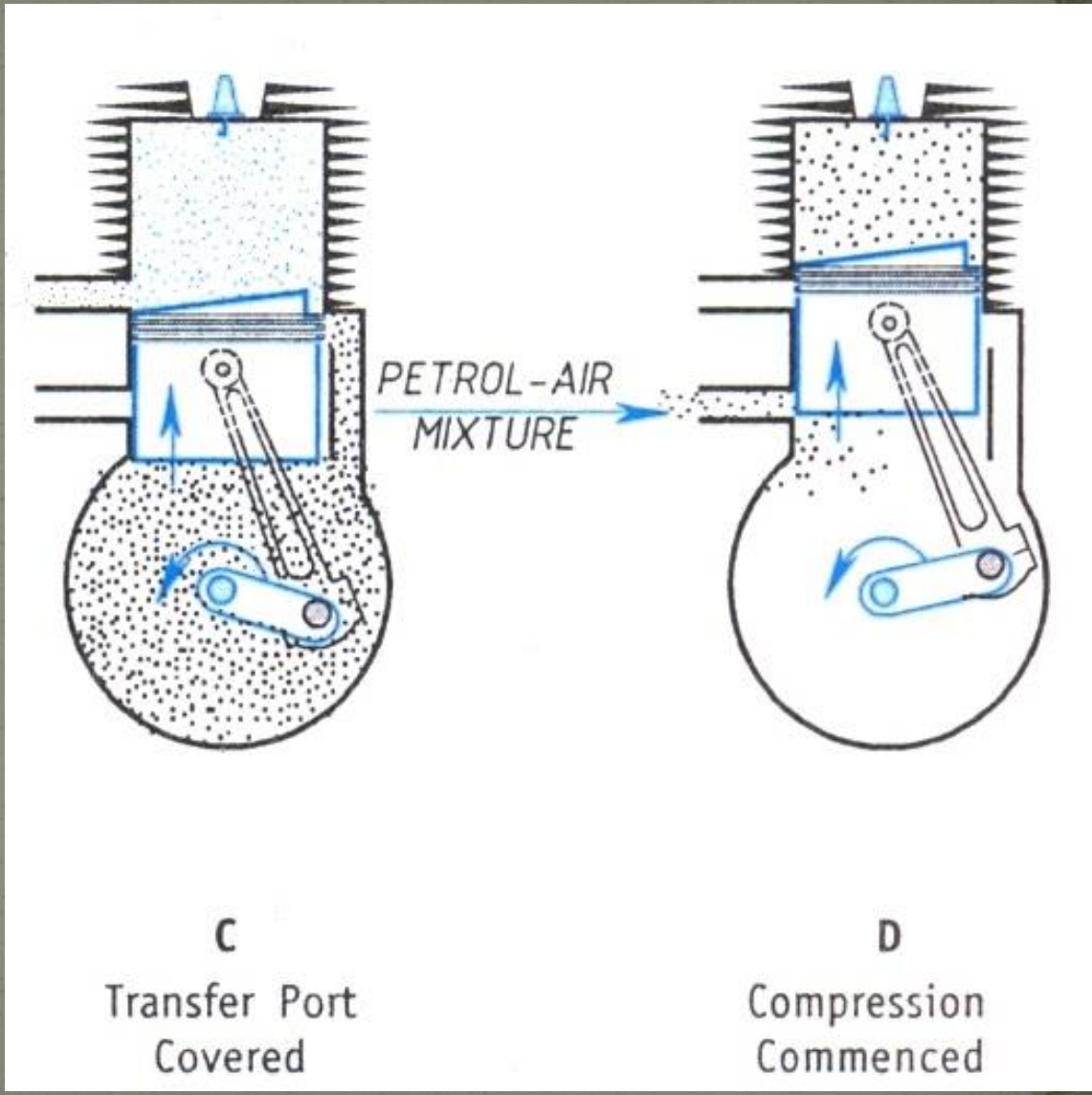


First stroke or upward stroke

- Piston moves from BDC to TDC.
- Air fuel mixture is drawn in through inlet.
- Supply of petrol air mixture is cut off in upward motion of piston.
- Further piston will compress the petrol air mixture in cylinder.

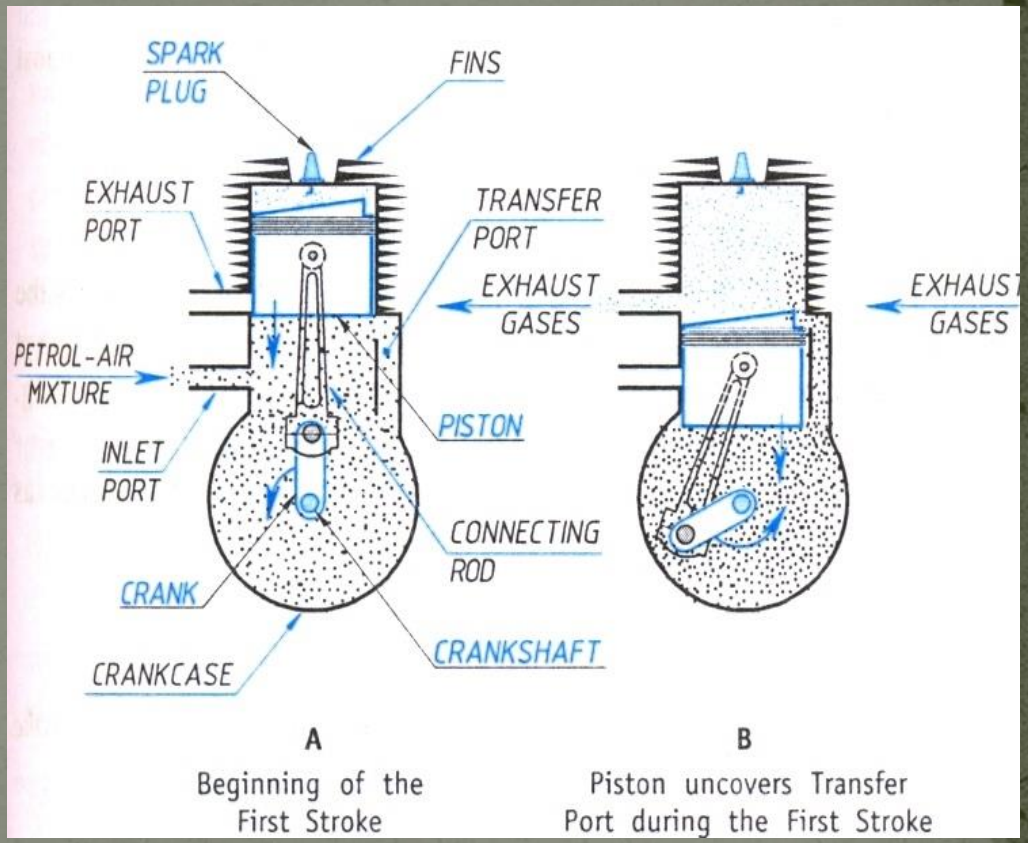


- At the end of the stroke spark plug ignites and combustion takes place.

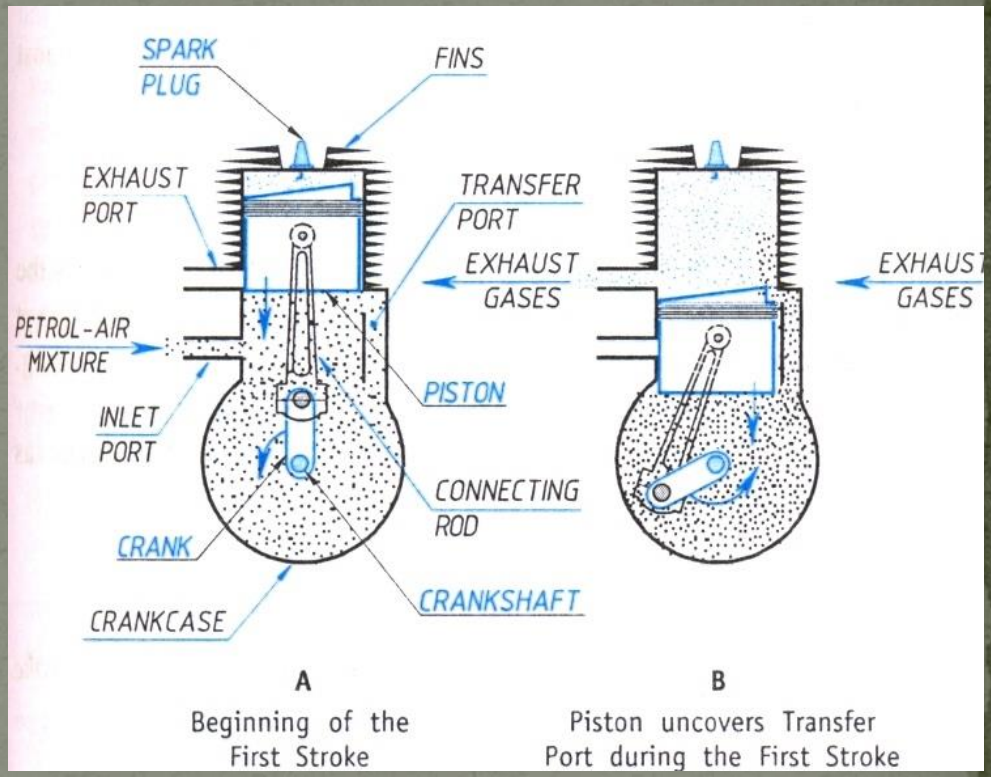


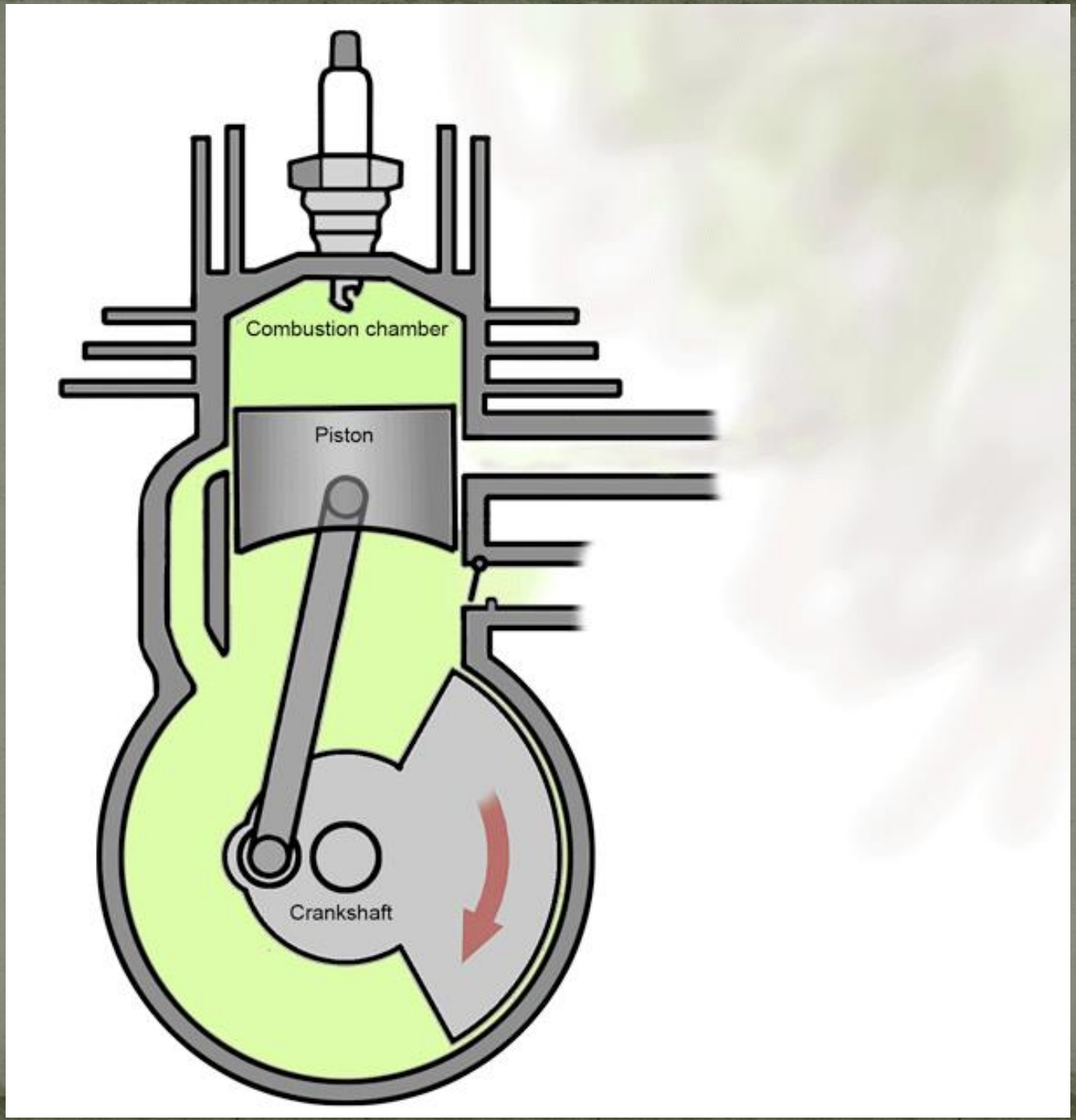
second stroke or downward stroke

- Piston moves from TDC to BDC.
- Piston performs the power stroke.
- Transfer port opens letting the fresh charge into cylinder.



- Due to this the burnt gases are expelled out of the cylinder. This process is called as *scavenging*.
- Crankshaft rotates by half the revolution.




Combustion chamber
Piston
Crankshaft

Scavenging Process

- In case of 2-stroke engines, there is no dedicated exhaust stroke. Scavenging is observed in its place.

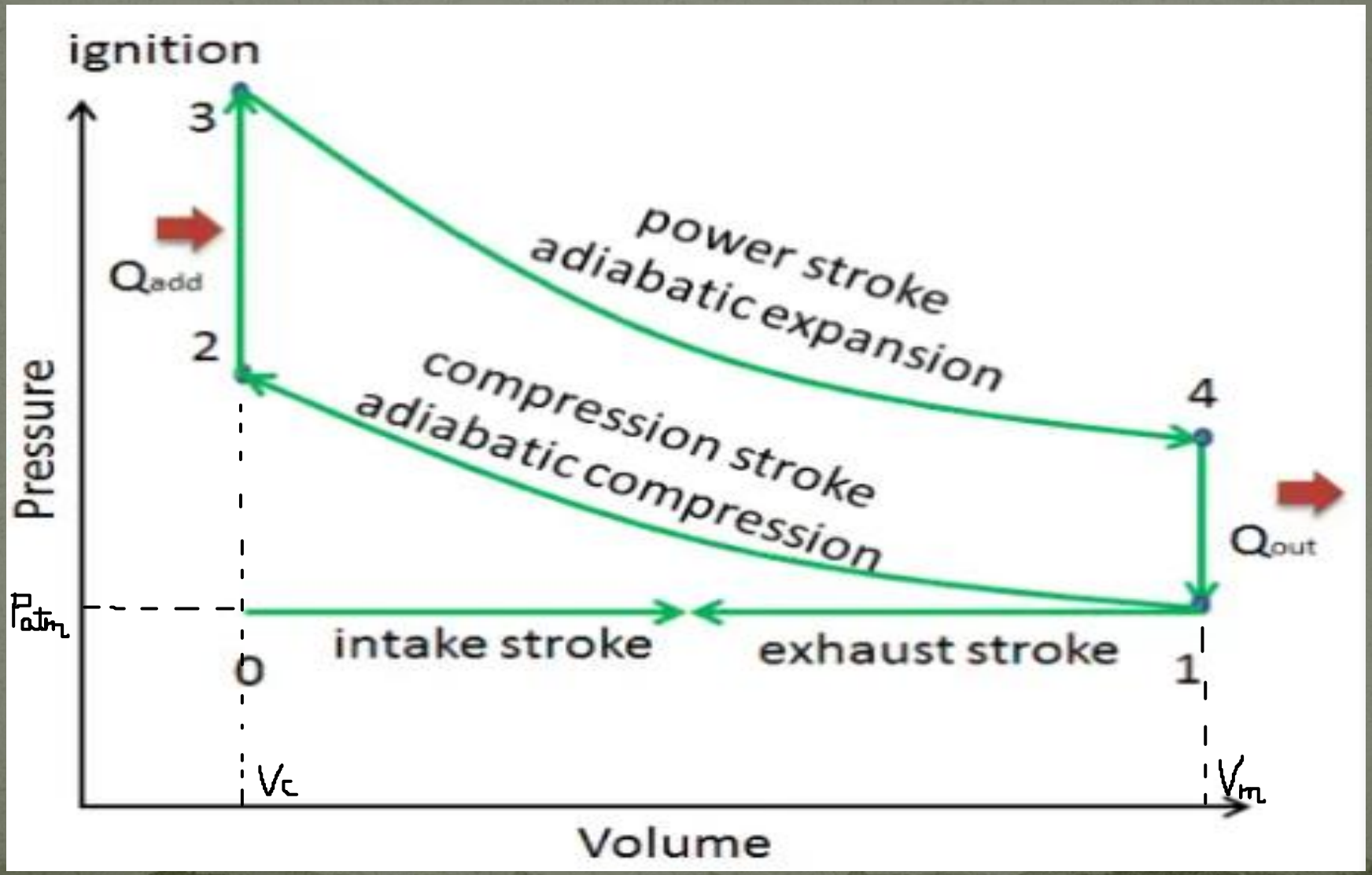
- It is the process in which the burnt gases inside the combustion chamber are pushed out by the fresh charge (fuel + Air) entering from the transfer port. This replacement of burnt gases by the fresh charge is called scavenging. A crown shaped piston (a piston with a deflector above it) helps in execution of scavenging.


OUTBOARDS
Two Stroke
Four Stroke

Criteria	S.I engine	C.I engine
Combustion process	Ignition takes place by a spark generated by spark plug.	Self ignition of the fuel take place due to high compression of air in chamber.
Compression ratio	8-12	16-22
Suction	Mixture of petrol and air in calculated ratio is drawn into cylinder.	Only pure air is drawn into cylinder during suction stroke.
Fuel	Petrol	Diesel
Thermodynamic cycle	Otto cycle	Diesel cycle
Weight of the engine	Less because of lower compression ratio, cylinder size is small.	High, engine size is large due to higher compression ratio.
Efficiency	Low because of lower compression ratio.	High because of high compression ratio.
Speed	High because of lighter engine.	Lower because of heavy engine.

Four-Stroke Engine	Two-Stroke Engine
The thermodynamic cycle is completed in four strokes of the piston or in two revolutions of the crankshaft. Thus, one power stroke is obtained in every two revolutions of the crankshaft.	The thermodynamic cycle is completed in two strokes of the piston or in one revolution of the crankshaft. Thus there is one power stroke for every revolution of the crankshaft.
Because of the above, turning moment is not so uniform and hence a heavier flywheel is needed.	Because of the above, turning moment is more uniform and hence a lighter flywheel can be used.
Again, because of one power stroke for two revolutions, power produced for same size of engine is less, or for the same power the engine is heavier and bulkier.	Because of one power stroke for every revolution, power produced for same size of engine is twice, or for the same power the engine is lighter and more compact.
Because of one power stroke in two revolutions lesser cooling and lubrication requirements. Lower rate of wear and tear.	Because of one power stroke in one revolution greater cooling and lubrication requirements. Higher rate of wear and tear.
Four-stroke engines have valves and valve actuating mechanisms for opening and closing of the intake and exhaust valves.	Two-stroke engines have no valves but only ports (some two-stroke engines are fitted with conventional exhaust valve or reed valve).
Because of comparatively higher weight and complicated valve mechanism, the initial cost of the engine is more.	Because of light weight and simplicity due to the absence of valve actuating mechanism, initial cost of the engine is less.
Higher volumetric efficiency due to more time for mixture intake.	Lower volumetric efficiency due to lesser time for mixture intake.
Thermal efficiency is higher; part load efficiency is better.	Thermal efficiency is lower; part load efficiency is poor.

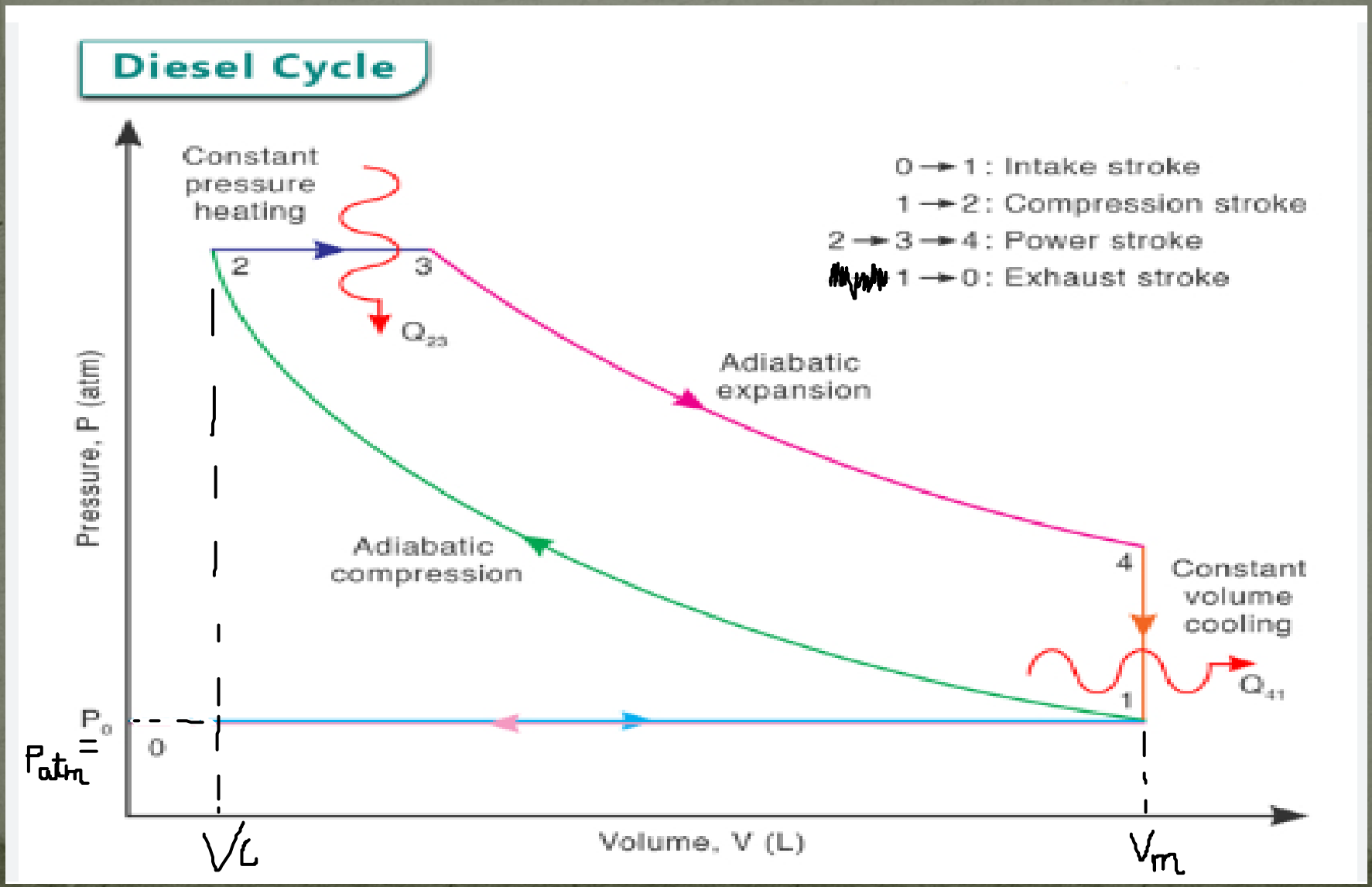
Otto Cycle PV diagram for SI engines



Otto Cycle PV diagram for SI engines

- 0-1 : Intake of fresh charge at constant pressure (1st stroke). Piston moves from TDC to BDC.
- 1-2 : rev. adiabatic compression (2nd stroke). Piston moves from BDC to TDC.
- 2-3 : Combustion of fuel+air due to spark. Constant volume heat addition, and rise in pressure.
- 3-4 : rev. adiabatic expansion (3rd stroke). Piston moves from TDC to BDC.
- 4-1 : Opening of exhaust valve and sudden pressure drop to atmospheric P (constant volume heat rejection).
- 1-0 : Exhaust stroke (4th stroke) at constant pressure. Piston moves from BDC to TDC.

Diesel Cycle PV diagram for CI engines



Diesel Cycle PV diagram for CI engines

- 0-1 : Intake of only air at constant pressure (1^{st} stroke). Piston moves from TDC to BDC.
- 1-2 : rev. adiabatic compression (2^{nd} stroke) of air. Piston moves from BDC to TDC.
- 2-3 : Admission of diesel in from of spray through fuel injector and its combustion. Constant pressure heating with increasing volume (3^{rd} stroke already started from point 2).
- 3-4 : rev. adiabatic expansion (3^{rd} stroke continued). Piston moves from TDC to BDC.
- 4-1 : Opening of exhaust valve and sudden pressure drop to atmospheric P (constant volume heat rejection or 'cooling').
- 1-0 : Exhaust stroke (4^{th} stroke) at constant pressure. Piston moves from BDC to TDC.