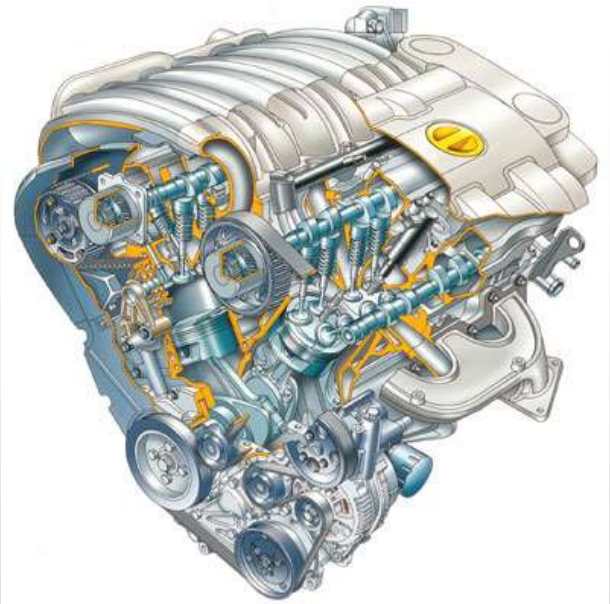
Internal Combustion Engines

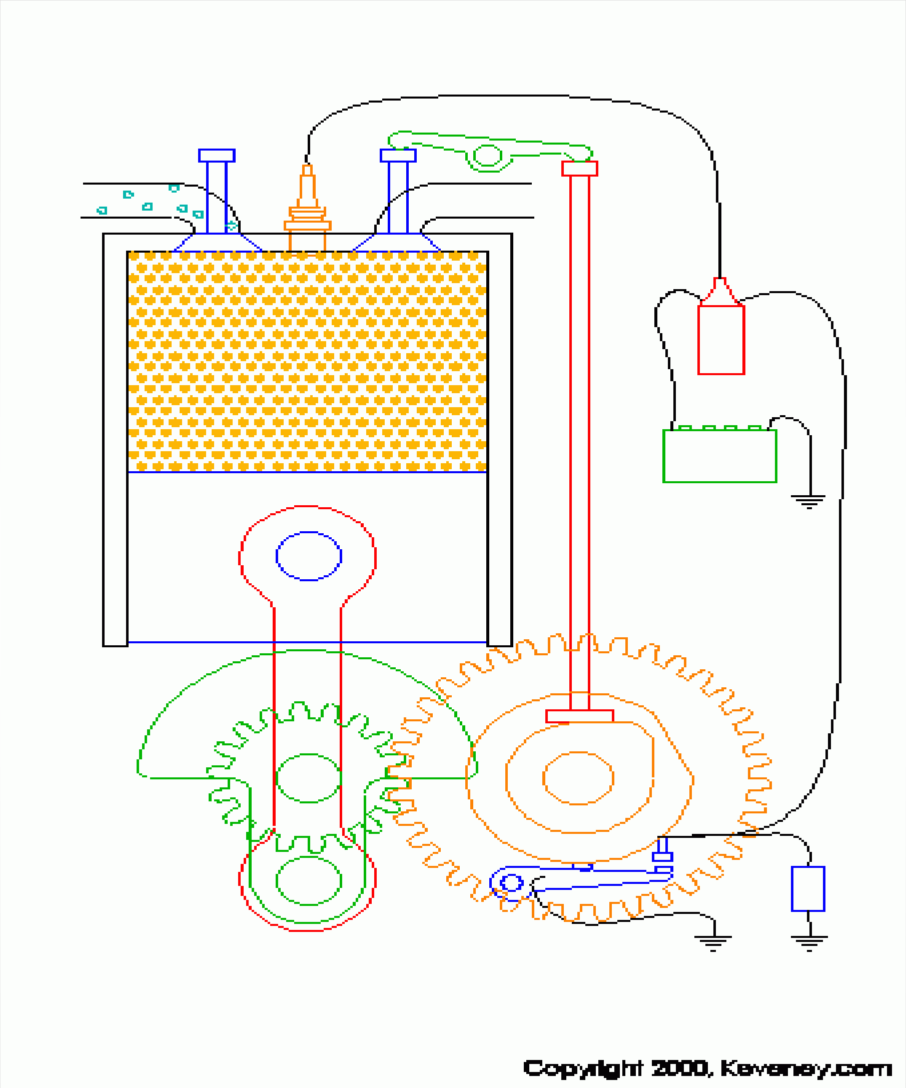


By Zeeshan

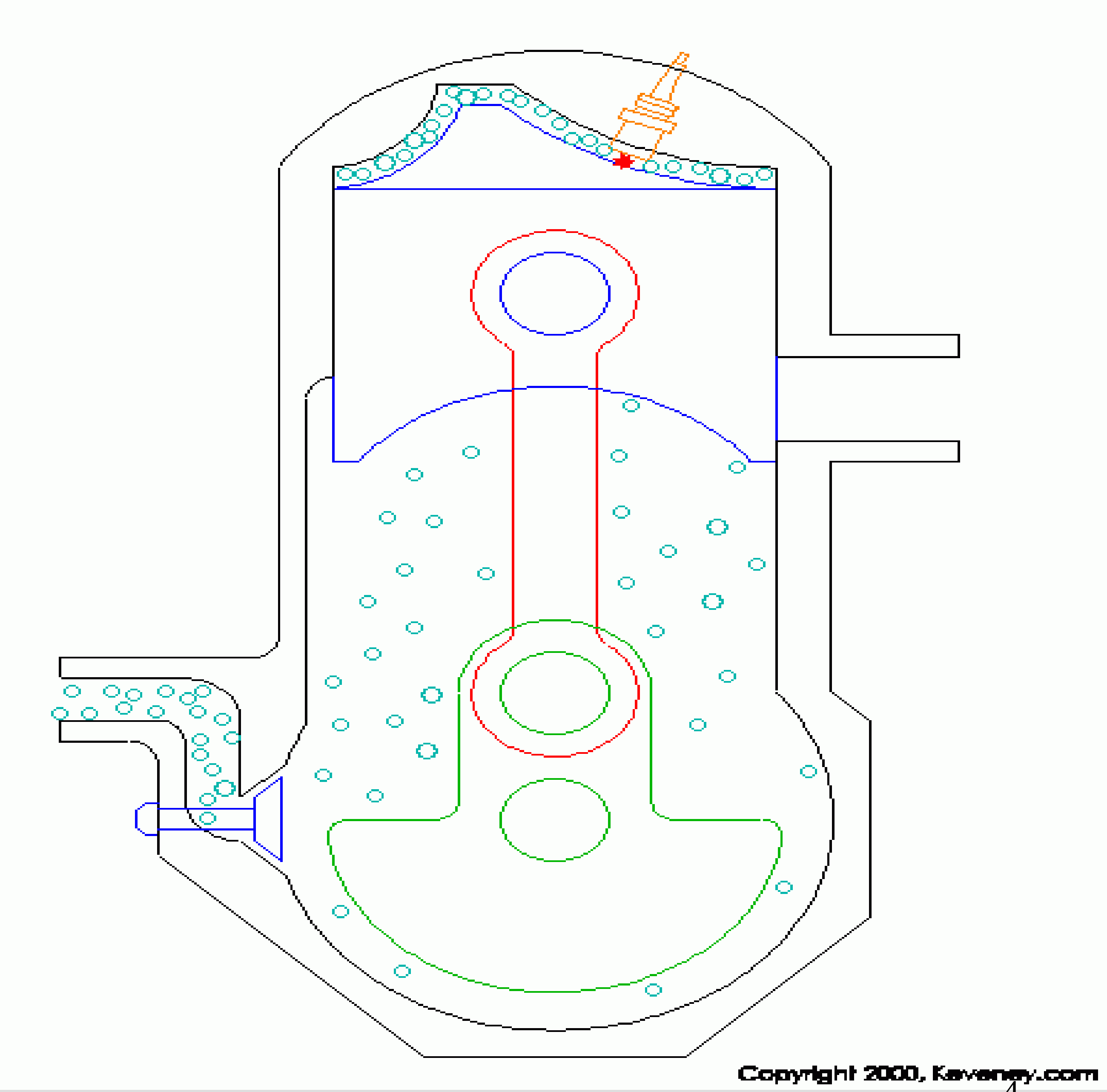
Internal Combustion Engines

- types of heat engines
  - external combustion
    - steam engines
    - turbines
    - Stirling engine
  - internal combustion
    - Otto engine
    - Diesel engine
    - Wankel engine

Working of a 4 Stroke SI Engine



Working of a 2 Stroke SI Engine



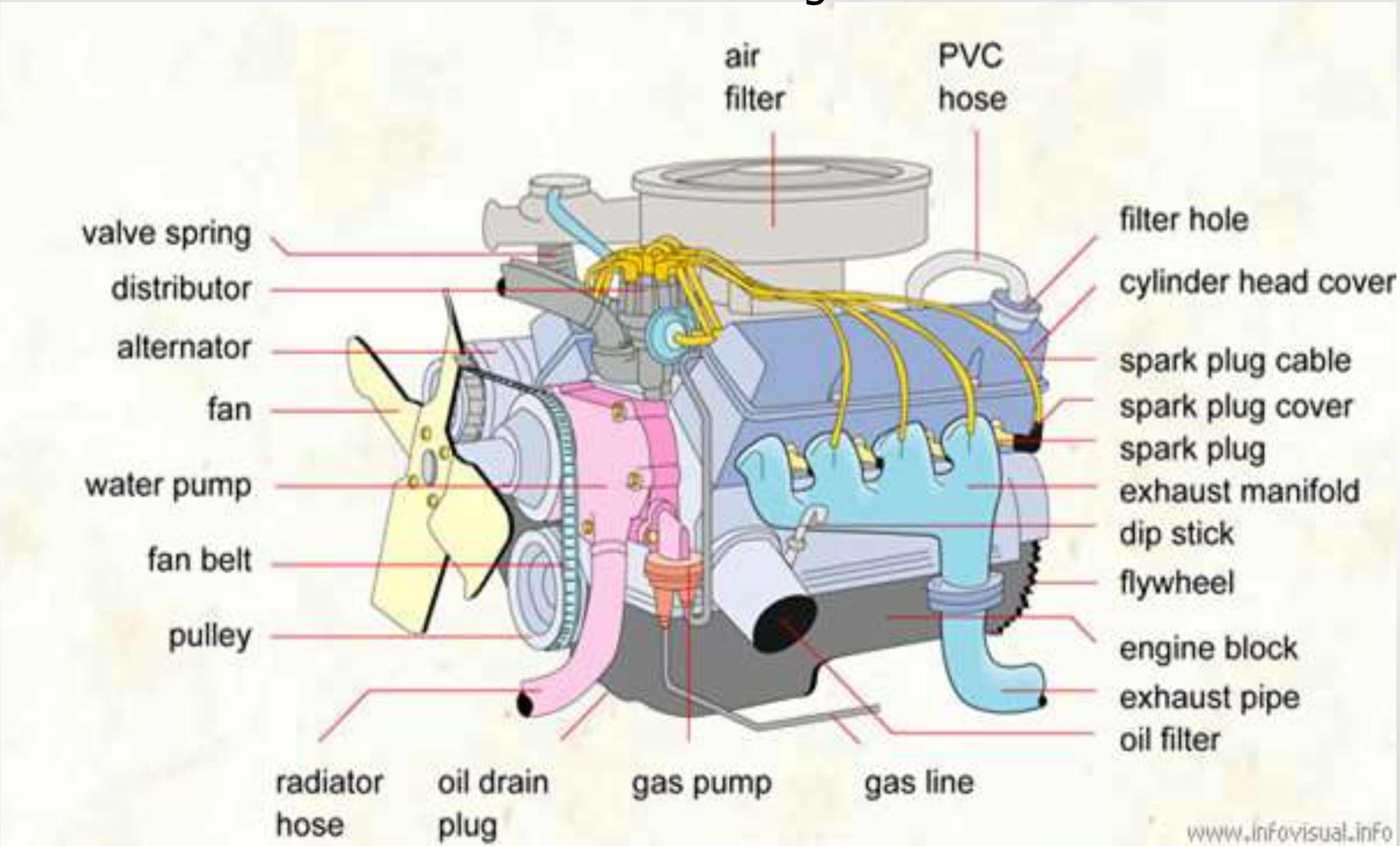
Internal Combustion Engines

The internal combustion engine is an engine in which the combustion of fuel-oxidizer mixture occurs in a confined space

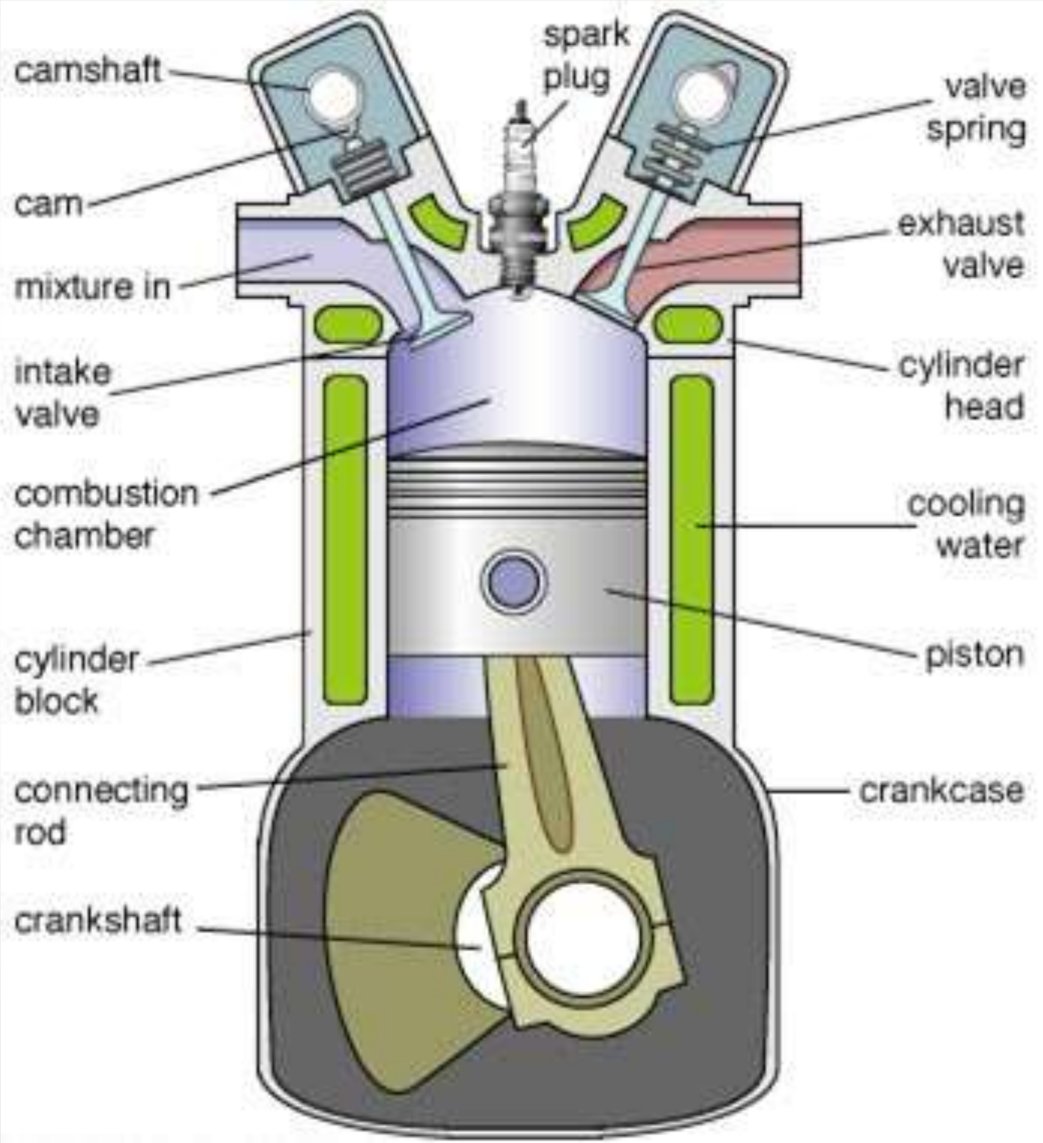
applied in:
automotive
rail transportation
power generation
ships
aviation
garden appliances

Internal Combustion Engines

Automobile Engine



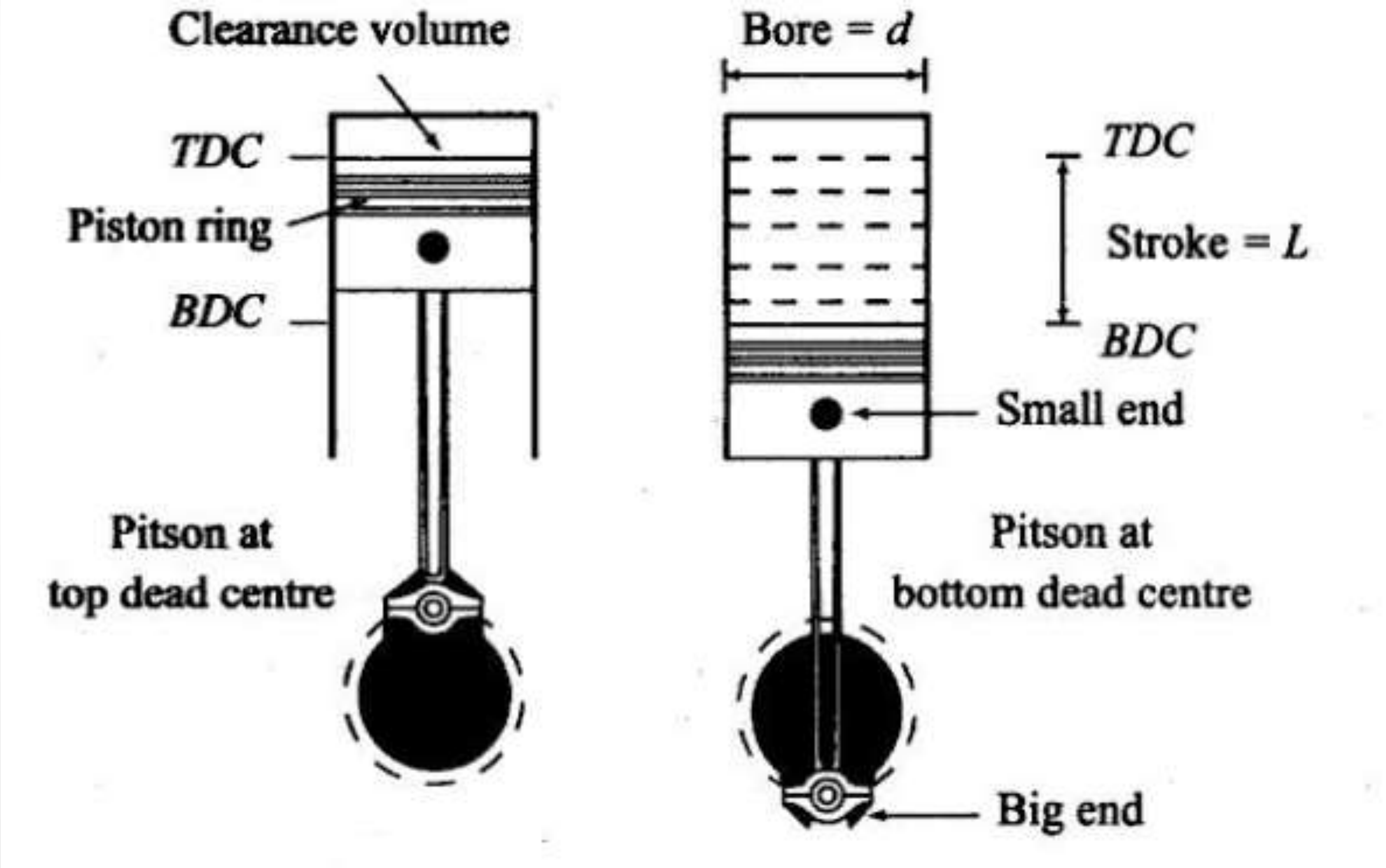
Internal Combustion Engines
Engine Components



Name of the engine parts, materials and manufacturing method

Name of the part	Material used	Method of manufacture
1. Cylinder	Cast iron, alloy steel	Casting
2. Cylinder head	Cast iron, aluminium alloy	Casting, forming
3. Piston	Cast iron, aluminium alloy	Casting, forging
4. Piston rings	Silicon cast iron	Casting
5. Wrist or piston (gudgeon) pins	Steel	Forging
6. Valves	Specially alloy steels	Forging
7. Connecting Rod	Steel	Forging
8. Crankshaft	Alloy steel, SG iron	Forging
9. Crankcase	Aluminium alloy, steel, cast iron	Casting
10. Cylinder liner	Cast iron, nickel alloy steel	Casting
11. Bearing	White metal, leaded bronze	Casting

Nomenclature



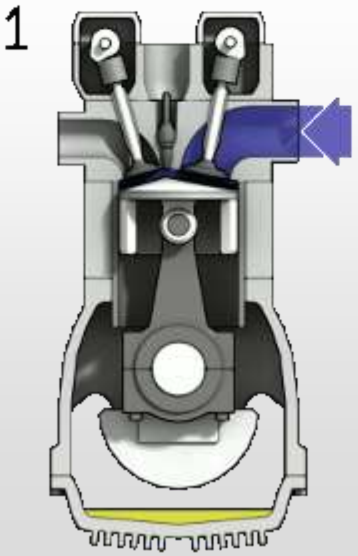
Gasoline Piston Engines

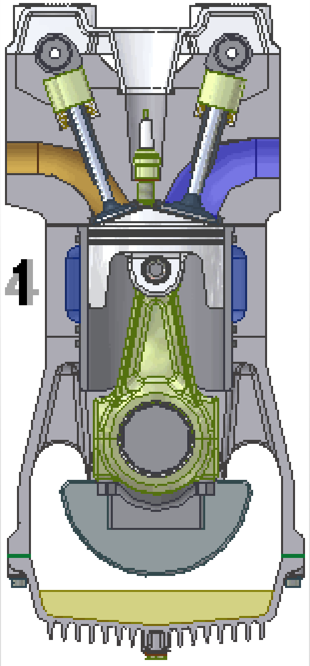
- Stroke – the movement of the piston from the top of the cylinder to the bottom.

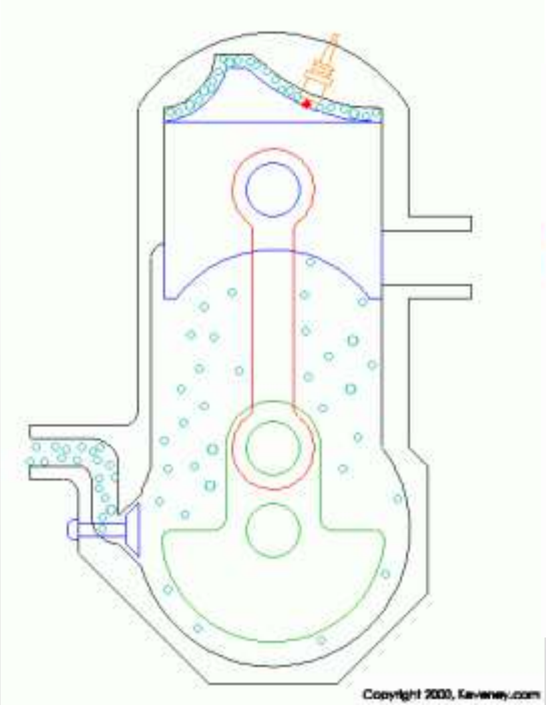
- Cycle – A complete set of piston movements that are needed to produce a power stroke.

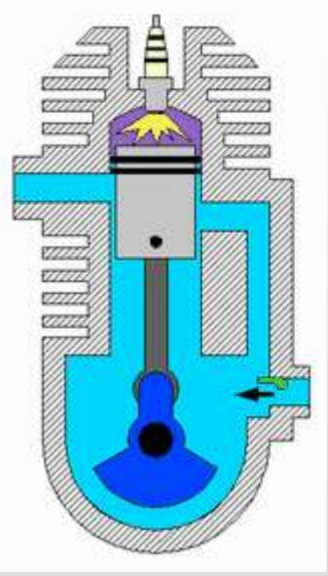
Gasoline Piston Engines

- There are two types of gasoline piston engines:
    1. Four Stroke Cycle
    2. Two Stroke Cycle







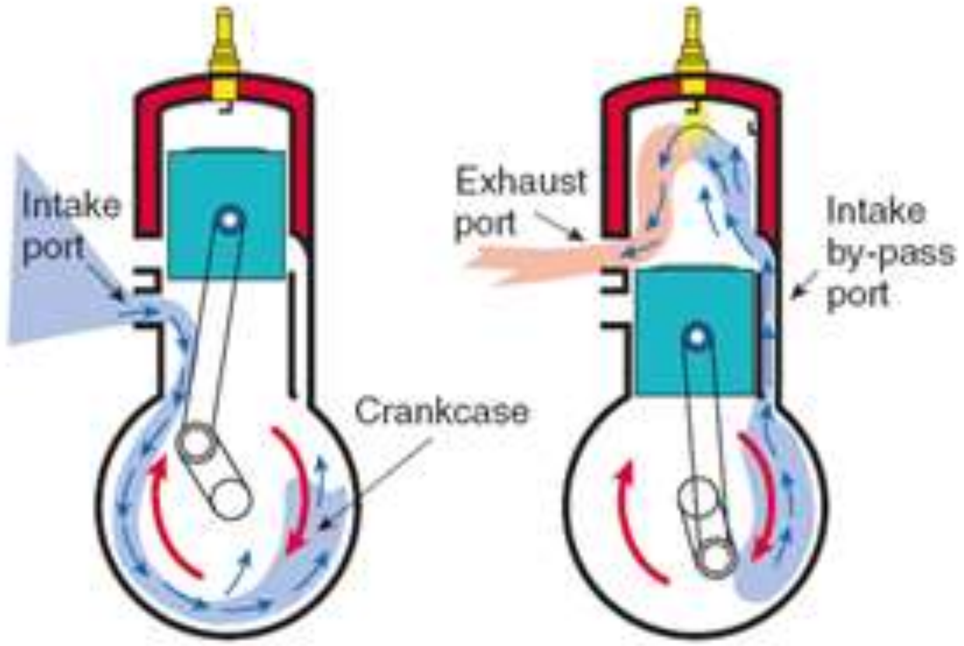


Gasoline Piston Engines

- Both operate with a piston moving up and down in a cylinder.

- The difference is in the number of strokes each piston makes per engine cycle.

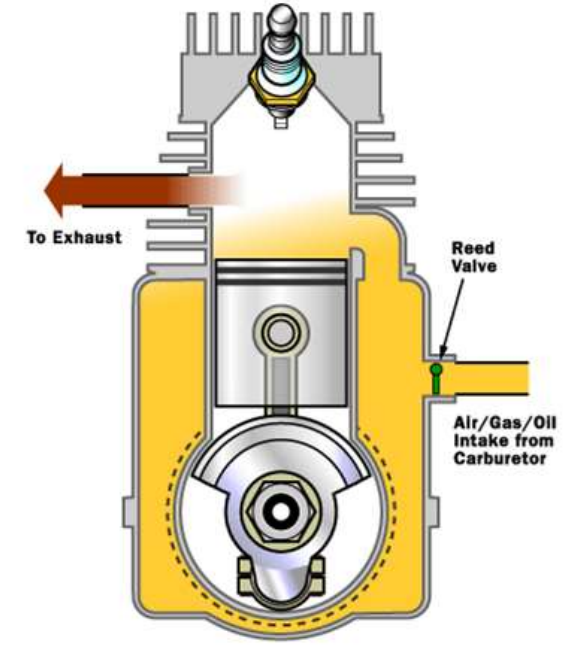
TWO STROKE ENGINE



Internal Combustion Engines
– two stroke -

1. Power / Exhaust

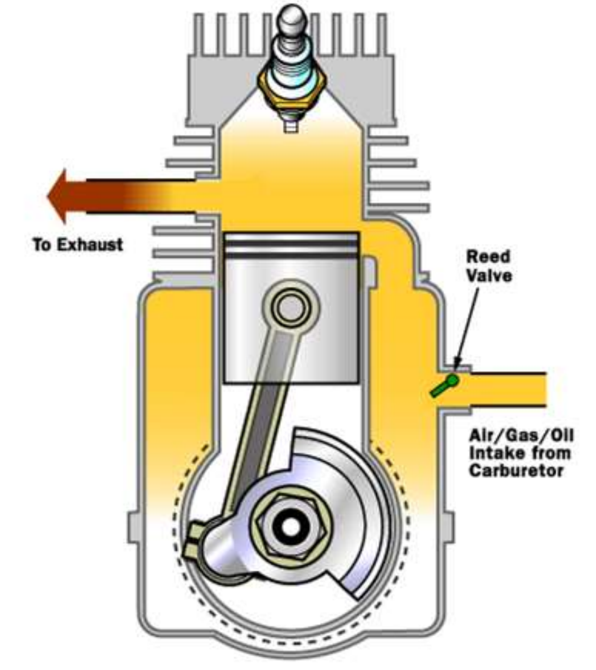
a. ignition
b. piston moves downward compressing fuel-air mixture in the crankcase
c. exhaust port opens



Fuel-intake position of a two-stroke engine

2. Intake / Compression

a. inlet port opens
b. compressed fuel-air mixture rushes into the cylinder
c. piston upward movement provides further compression

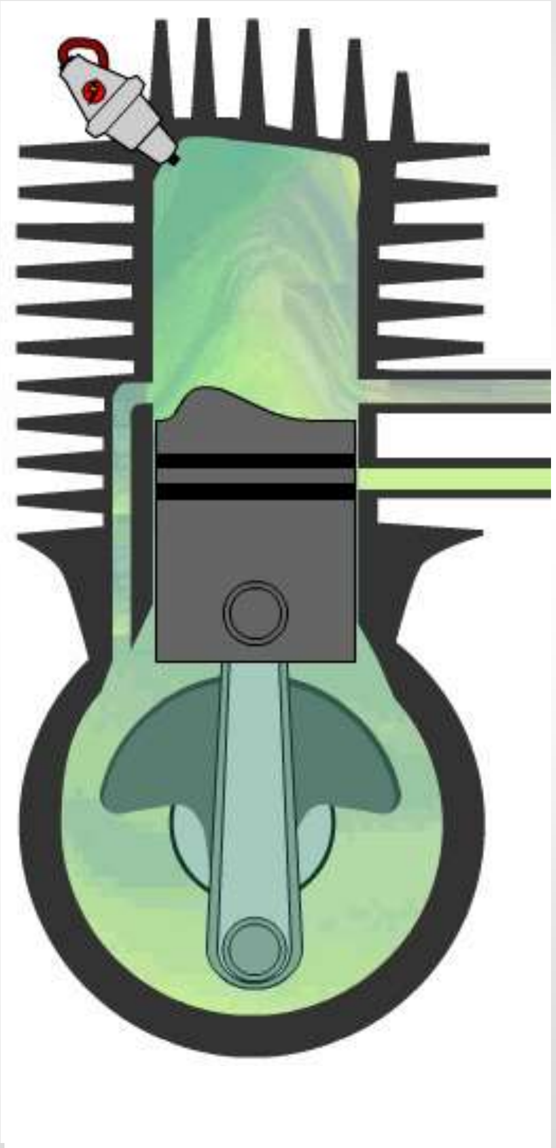


Compression action of a two-stroke engine

Internal Combustion Engines
– two stroke -

Advantages:
- lack of valves, which simplifies construction and lowers weight
- fire once every revolution, which gives a significant power boost
- can work in any orientation
- good power to weight ratio

Drawbacks:
- lack of a dedicated lubrication system makes the engine to wear faster.
- necessity of oil addition into the fuel
- low efficiency
- produce a lot of pollution



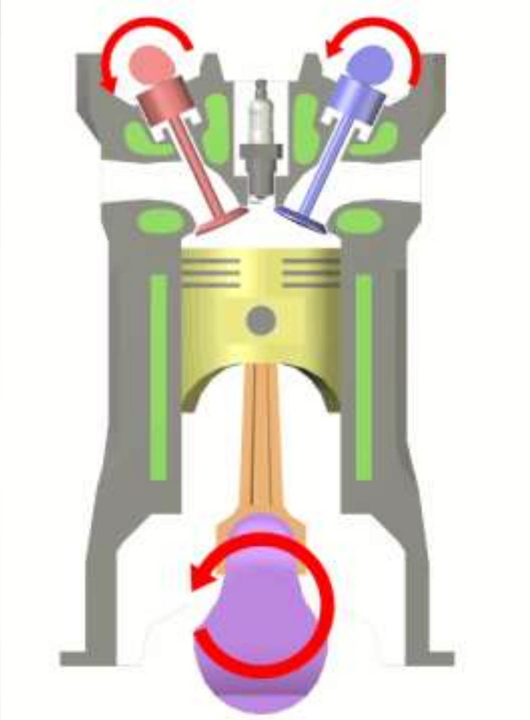
Four Stroke Engine
Brief History

- The principle of four stroke cycle engine was developed in 1862 by Beau de Rochas of France.
- The first four stroke cycle engine was built in 1876 by a German mechanical engineer called Nicholas Otto (O*tto cycle)*.

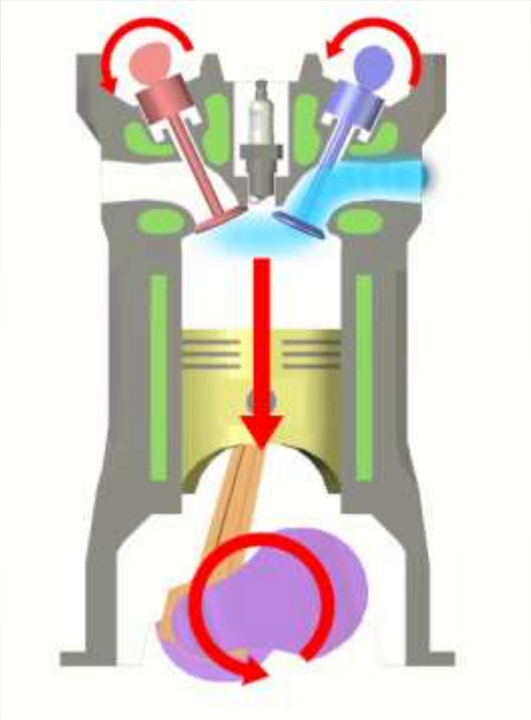
History

- In 1893 two American brothers named Duryea built and operated the first gasoline automobile.

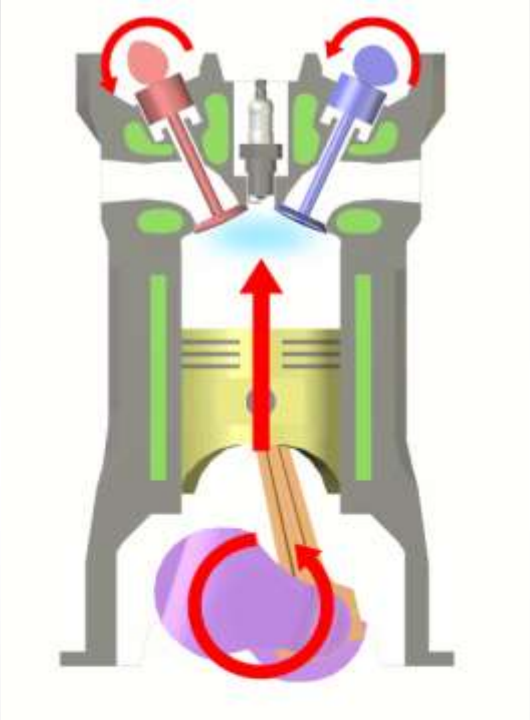
Internal Combustion Engines
– four stroke -



starting position



1. intake

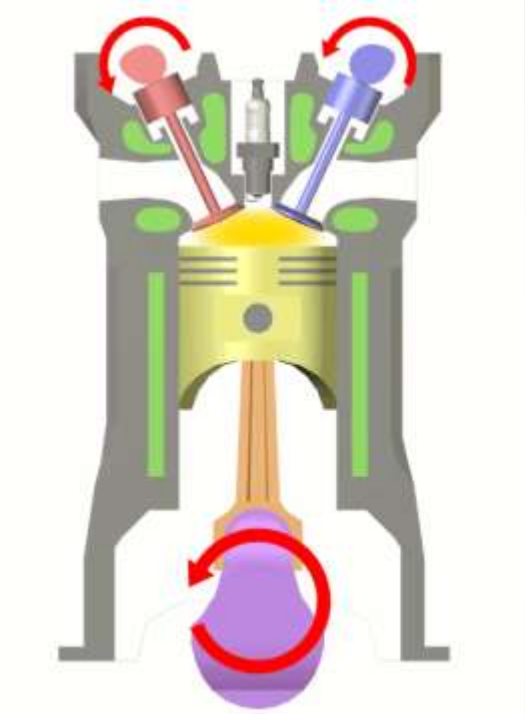


2. compression

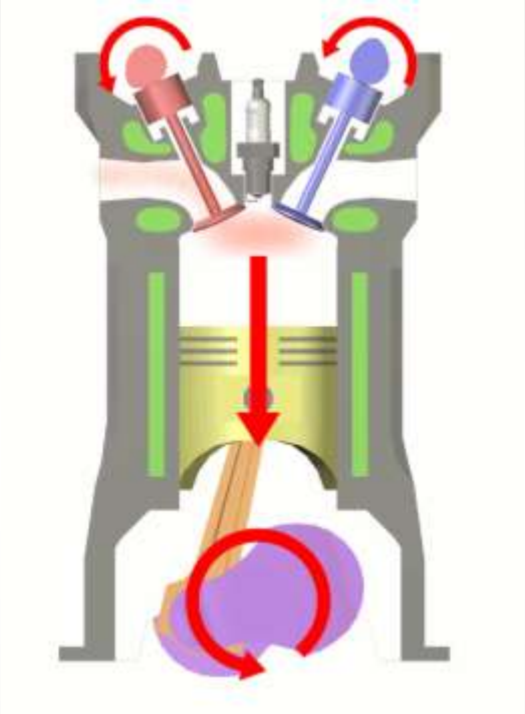
a. piston starts moving down
b. intake valve opens
c. air-fuel mixture gets in

a. piston moves up
b. both valves closed
c. air-fuel mixture gets compressed

Internal Combustion Engines
– four stroke -

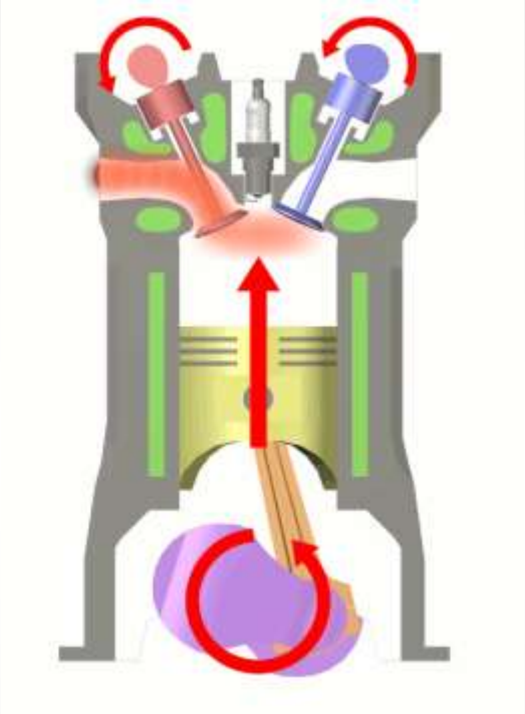


ignition



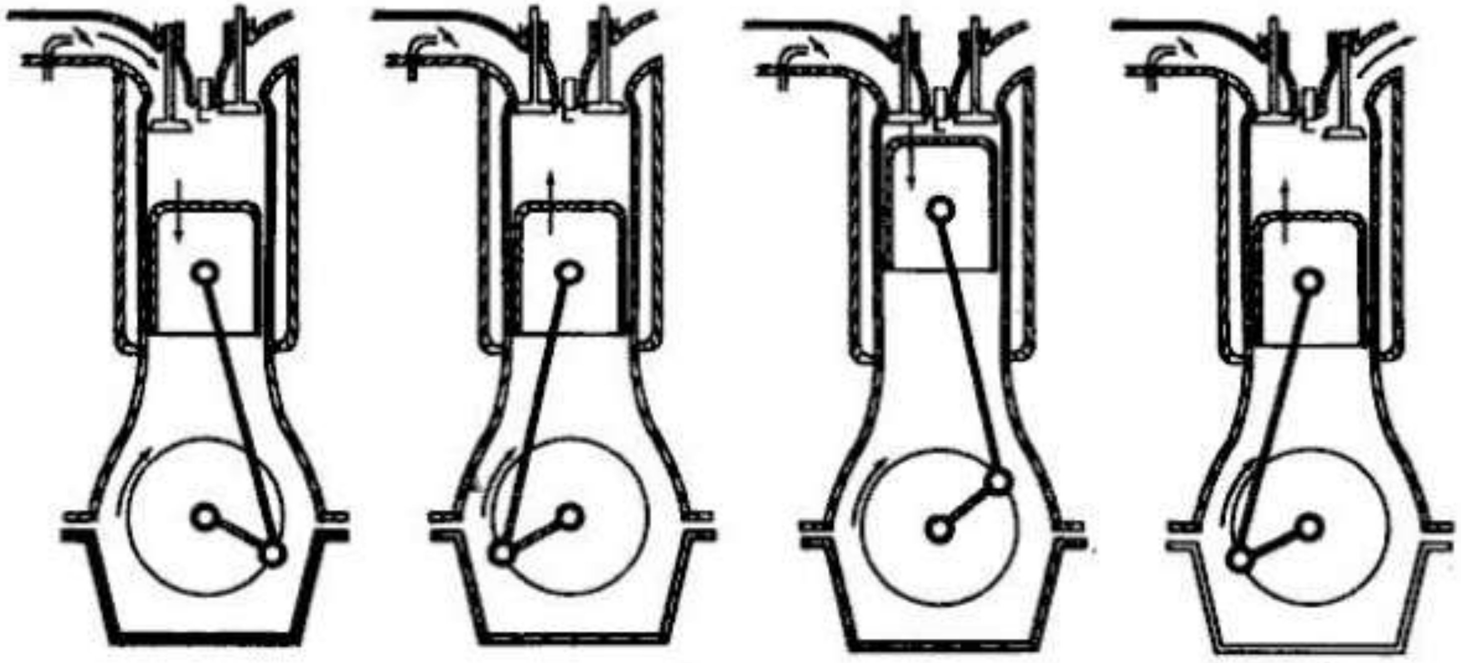
3. power

a. air-fuel mixture explodes driving the piston down



4. exhaust

a. piston moves up
b. exhaust valve opens
c. exhaust leaves the cylinder



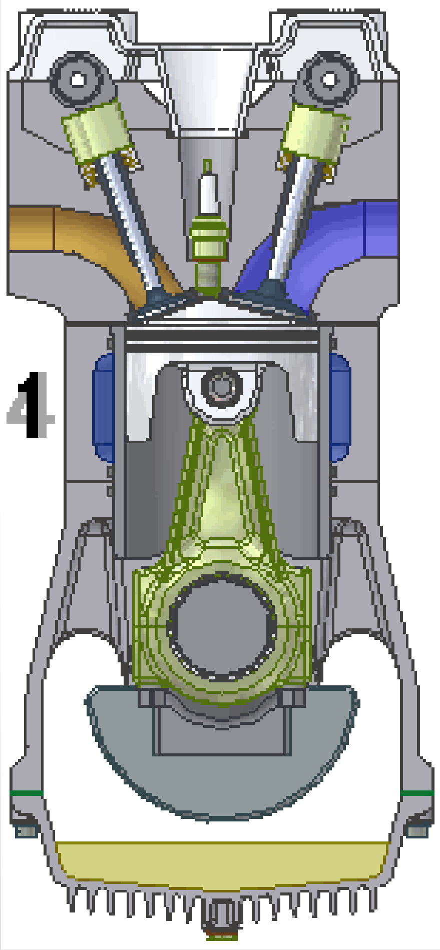
(a) Intake (b) Compression (c) Expansion (d) Exhaust

Name of Stroke	Pressure	Temp.
I. Suction or Intake stroke	$P < 1$ bar	25°C
II.Compression stroke	P 6-12 bar	$250^0 - 300^0C$
III. Expansion or Power Storke	$P = 30\text{-}40$ bar	$1800^0\text{-}2000^0C$
IV. Exhaust Stroke	$P = 4 - 5$ bar	$400^0 - 500^0C$

Internal Combustion Engines
– four stroke -

Advantages:
• dedicated lubrication system makes to engine more wear resistant
• better efficiency that 2-stroke engine
• no oil in the fuel – less pollution

Drawbacks:
• complicated construction
• should work in horizontal position due to lubrication



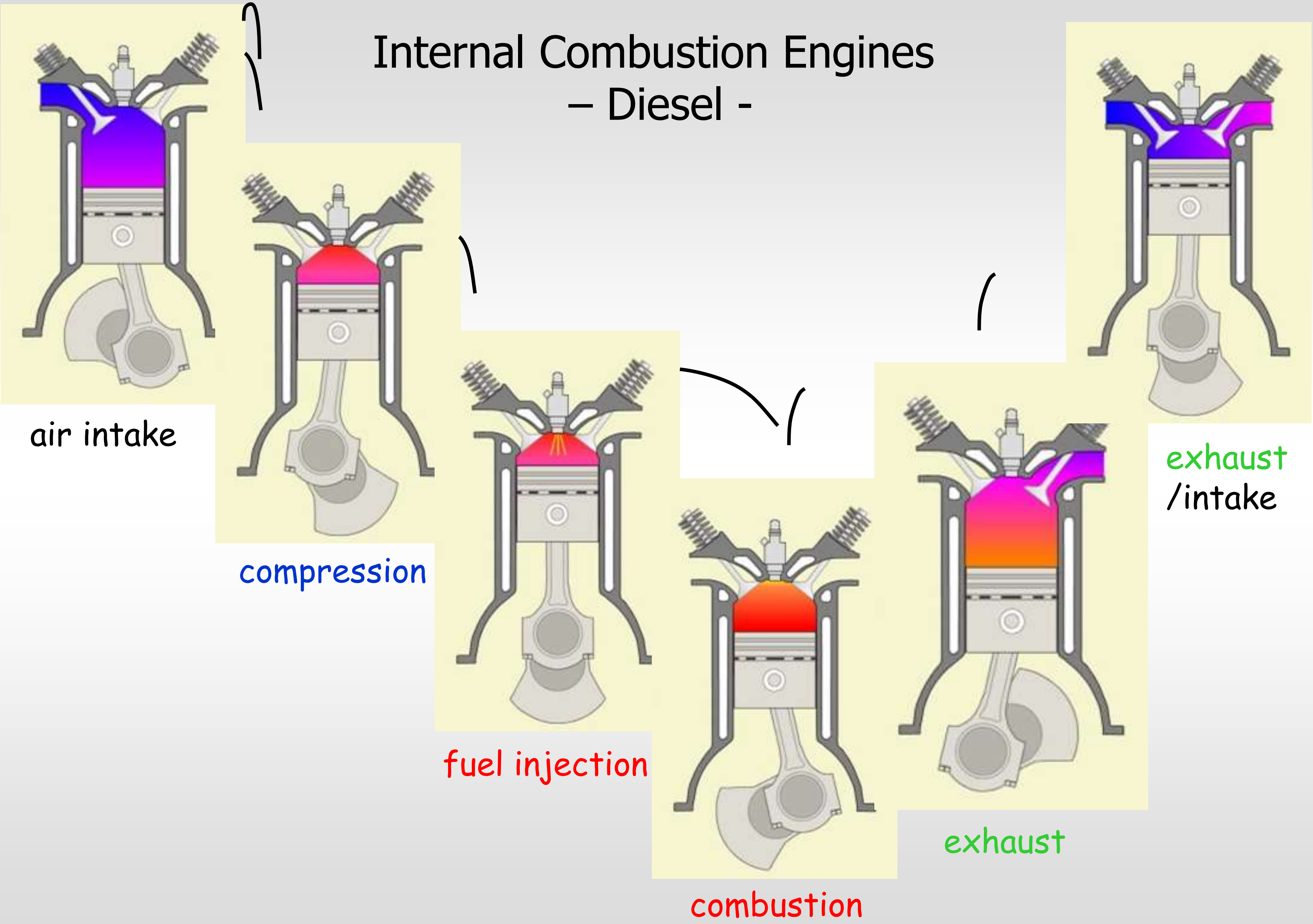
Diesel Engines

- This engine was invented in 1892 by a German mechanical engineer named Rudolph Diesel.
- At first this engine was known as the compression engine but later was named Diesel after its inventor.

Diesel Engines

- Diesels come in two stroke and four stroke versions and operate much like the gasoline driven engines.
- Diesels have a greater compression ratio than gasoline engines.
  - Diesel 16:1 – 23:1
  - Gasoline 6:1 – 12:1

Internal Combustion Engines
– Diesel -



Internal Combustion Engines
– Diesel -

Name of stroke　　Pressure　　Temp.

I. Suction stroke　$P < 1$ bar ;　$T = 25^0C$

II. Compression stroke　$P = 35\text{-}40$ bar; $T = 600^0 - 700^0C$

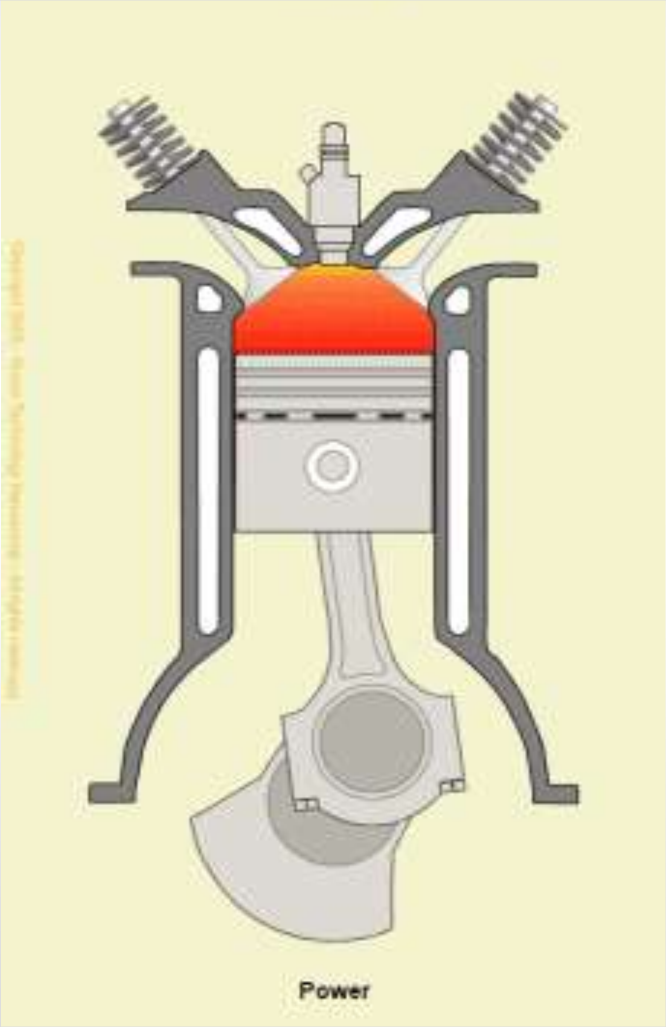
III. Expansion stroke　$P= 35\text{-}40$ bar; $T =$ $1800\text{-}2000\ ^0C$

<u>Injection pressure = 120 - 200 bar</u>

IV. Exhaust stroke　$P = 4 - 5$ bar; $T = 400^0\text{-}500^0C$

Internal Combustion Engines
– Diesel -

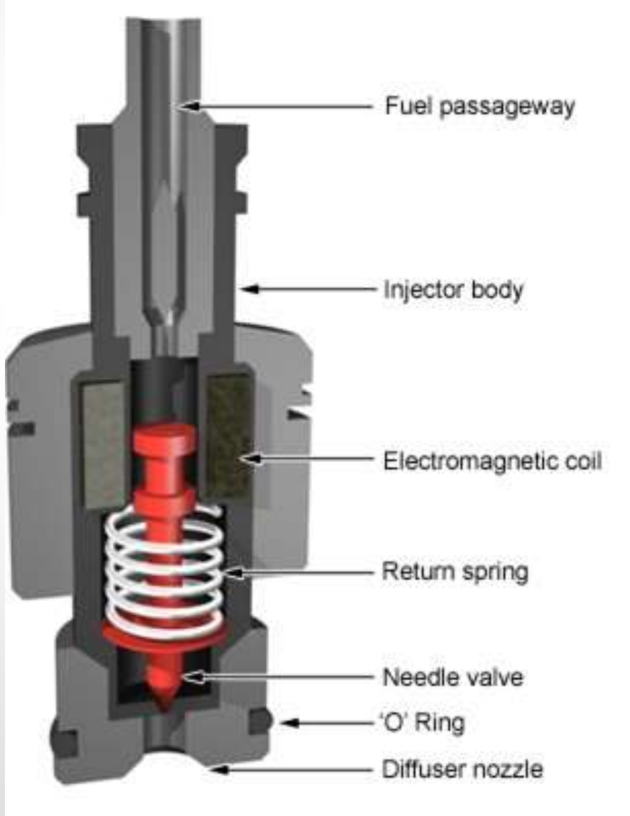
Advantages:
- self ignition (without electrical spark plug)
- better efficiency
- reliability
- higher durability
- supplied with worse fuels

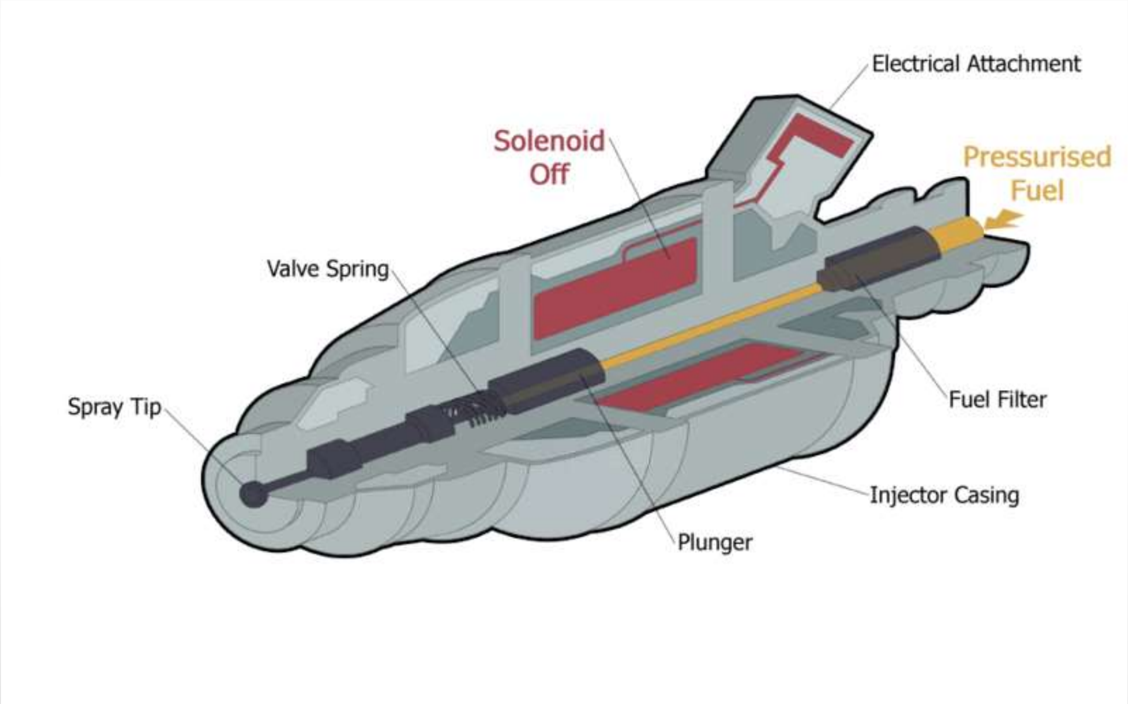


Drawbacks:
- more NO_x production
- more expensive production
- more weight
- louder
- lower revolutions

Internal Combustion Engines
– Diesel -

fuel injector

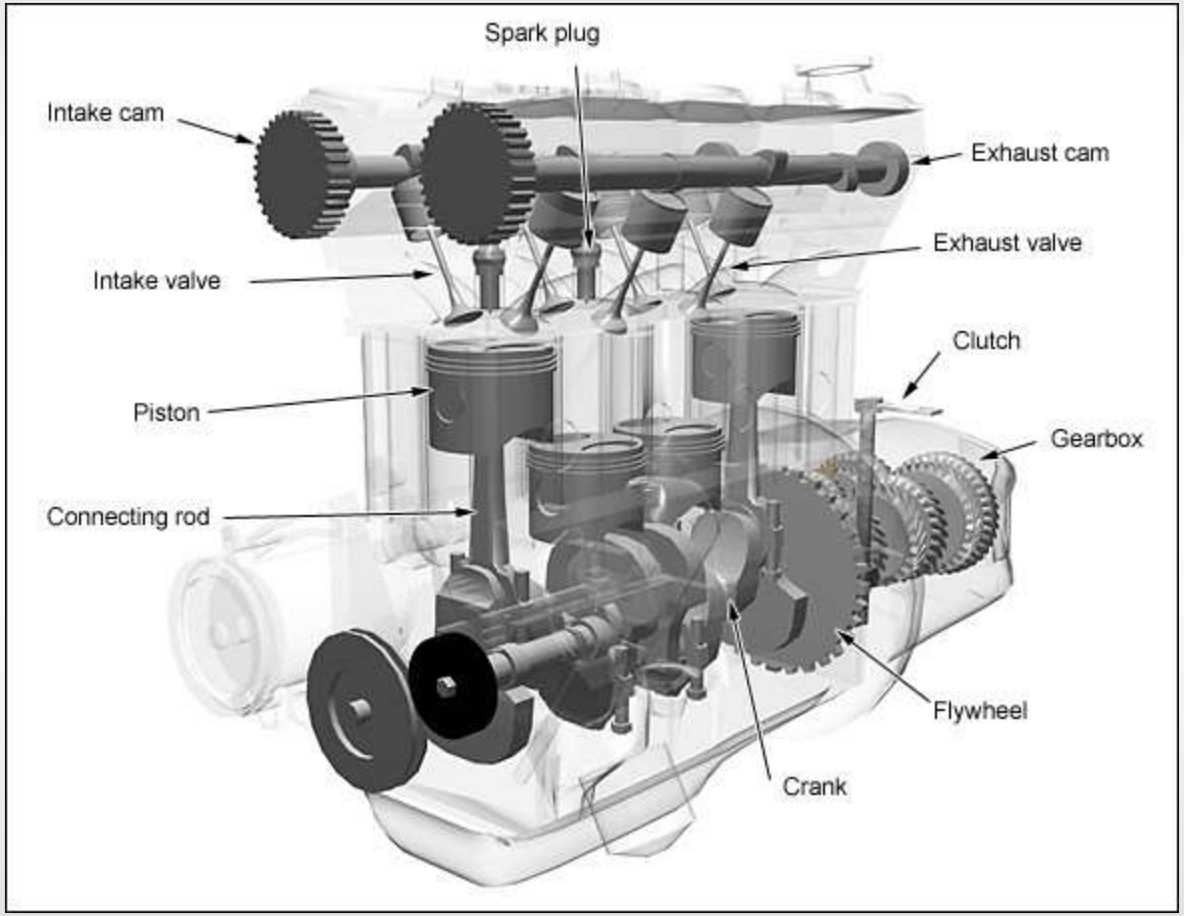




Diesel VS Gasoline Engines

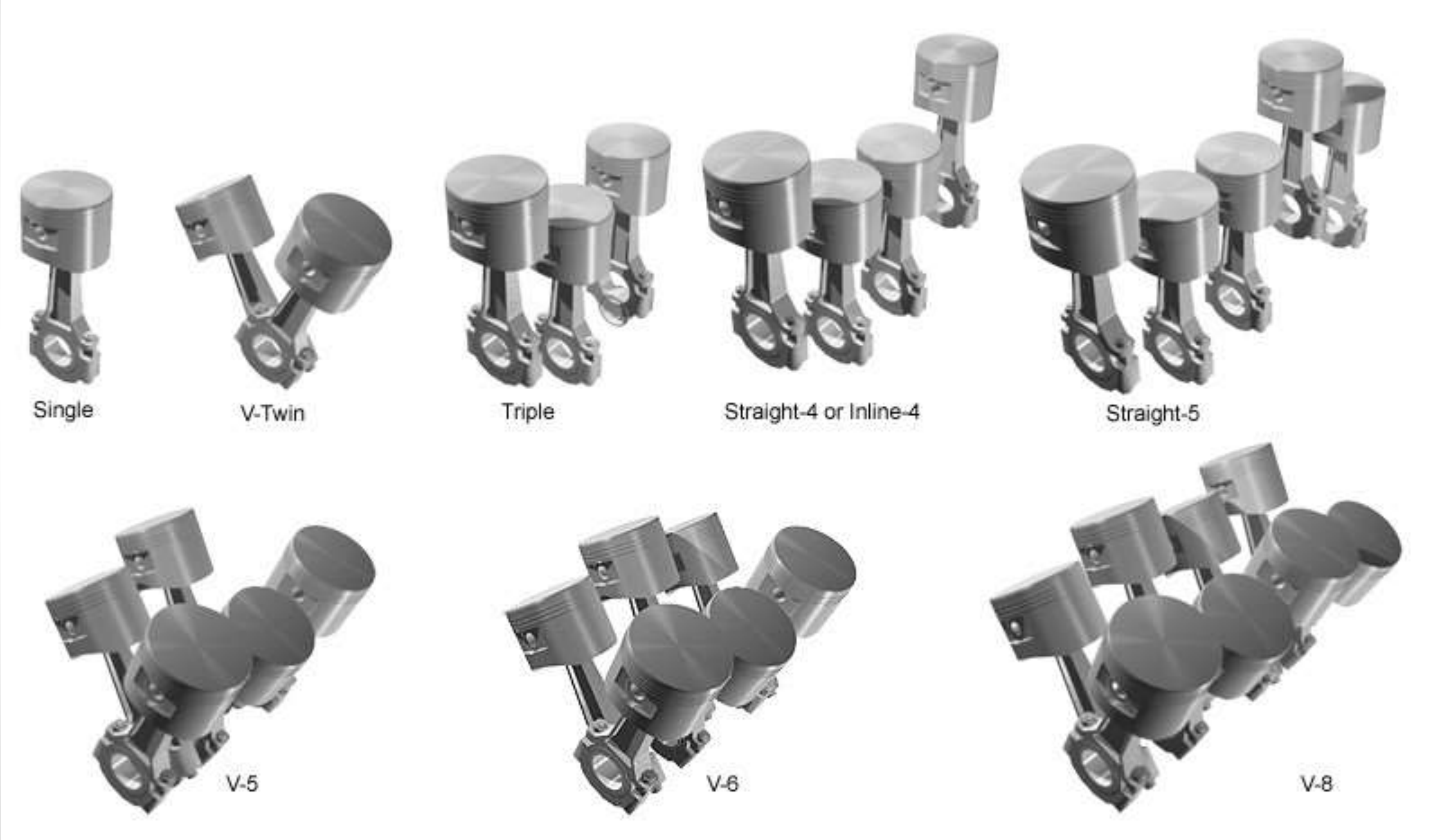
- Different type fuel (Diesel fuel).
- Diesel engines operate at a much higher compression ratio.
- Diesel engines do not use spark plugs.

Internal Combustion Engines
– multi-cylinder -

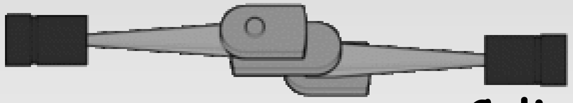


Internal Combustion Engines
– multi-cylinder -

Cylinder layouts

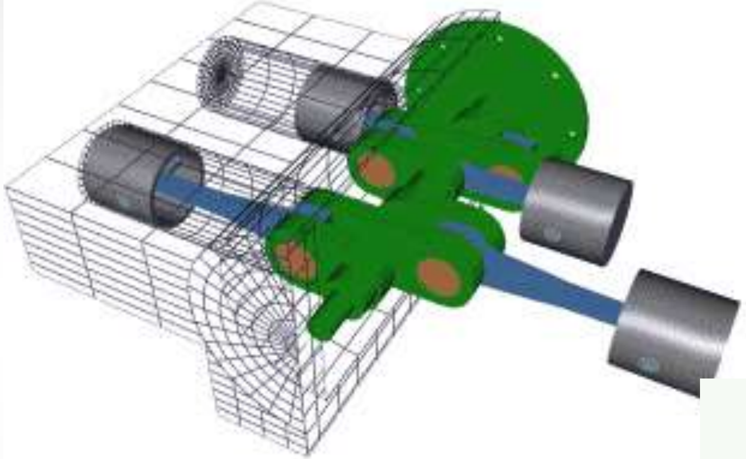


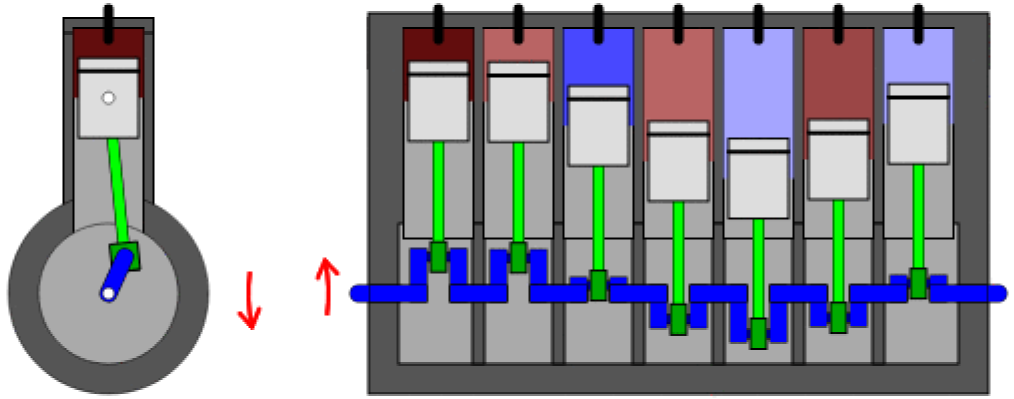
Internal Combustion Engines
– multi-cylinder -

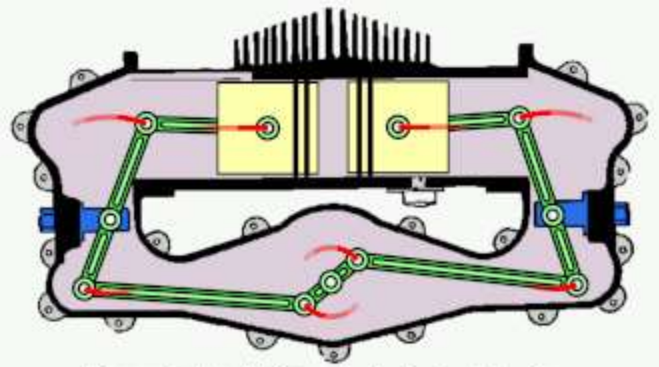


Cylinder layouts

flat

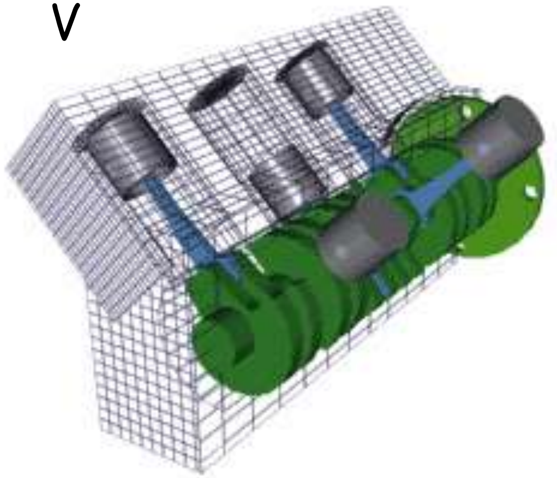




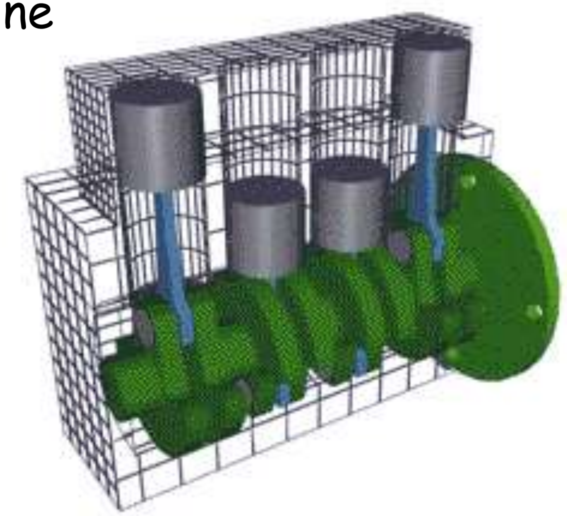


Diagrammatic sketch of the Simpson double acting two-stroke engine

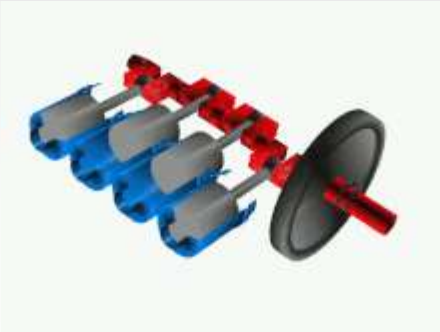
V

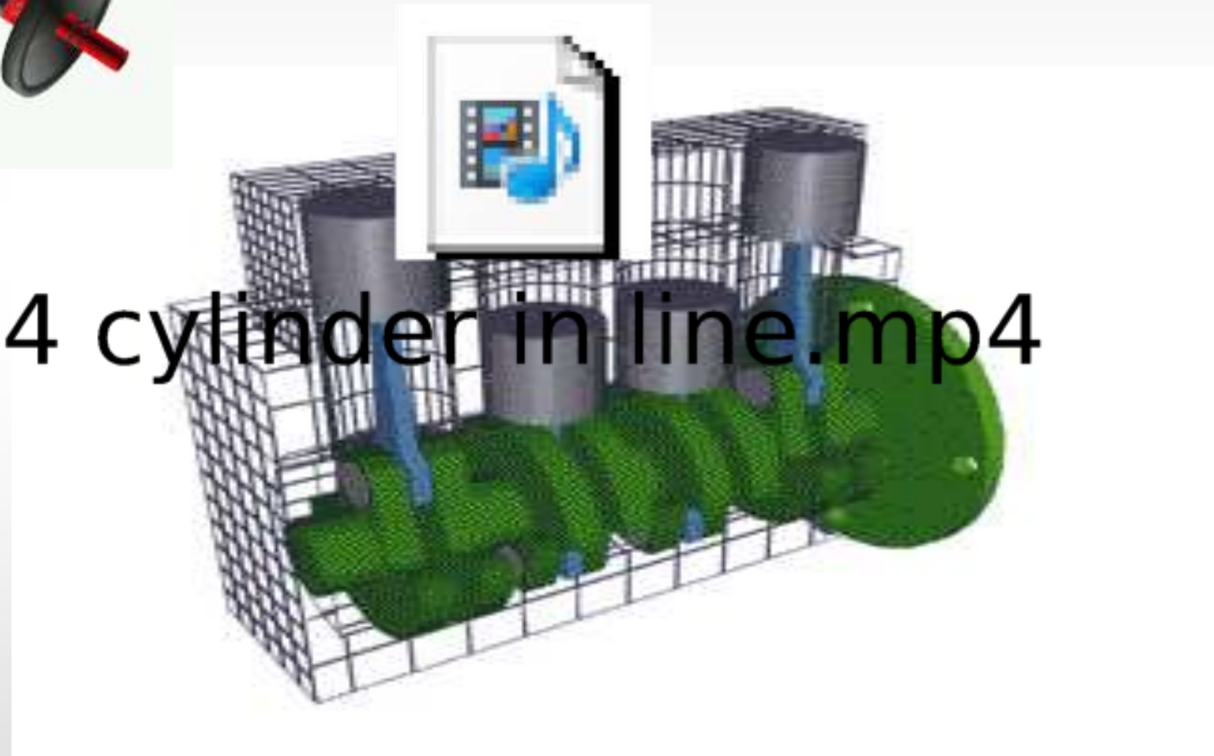


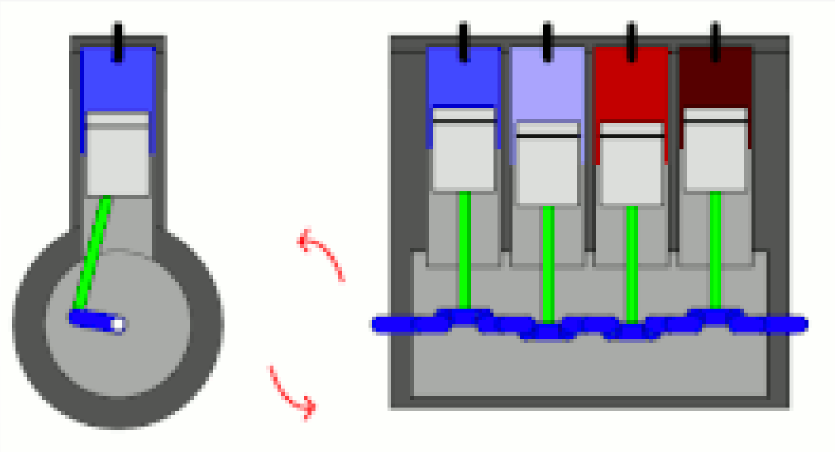
inline



Four cylinder engine(Inline)





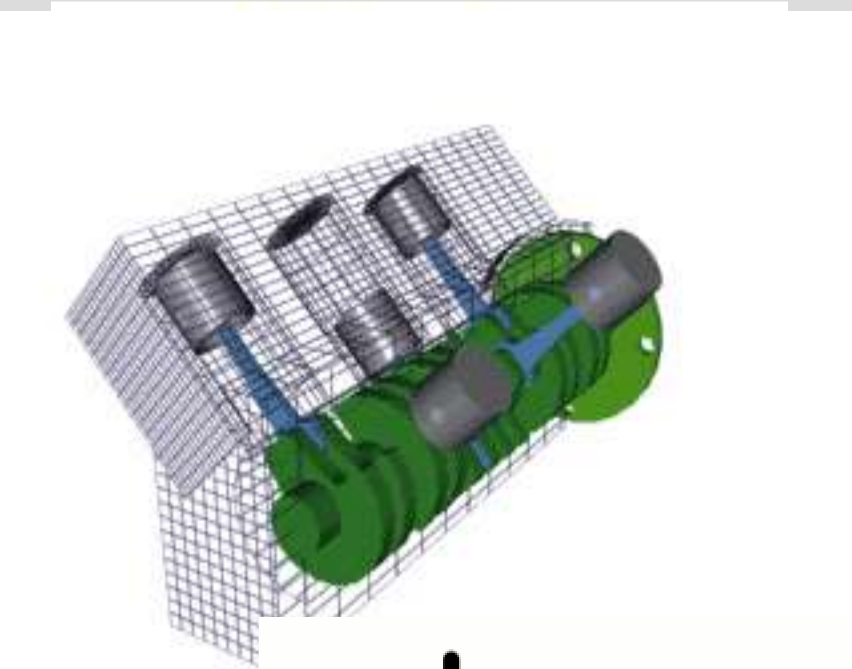


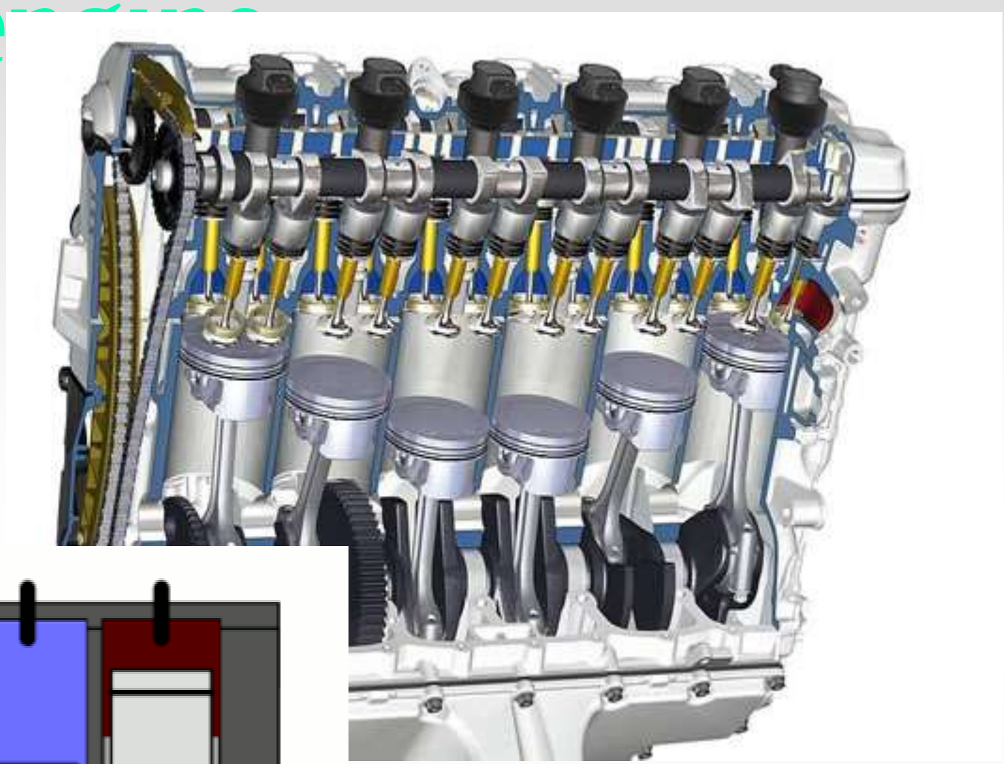
Four cylinder engine(V type)

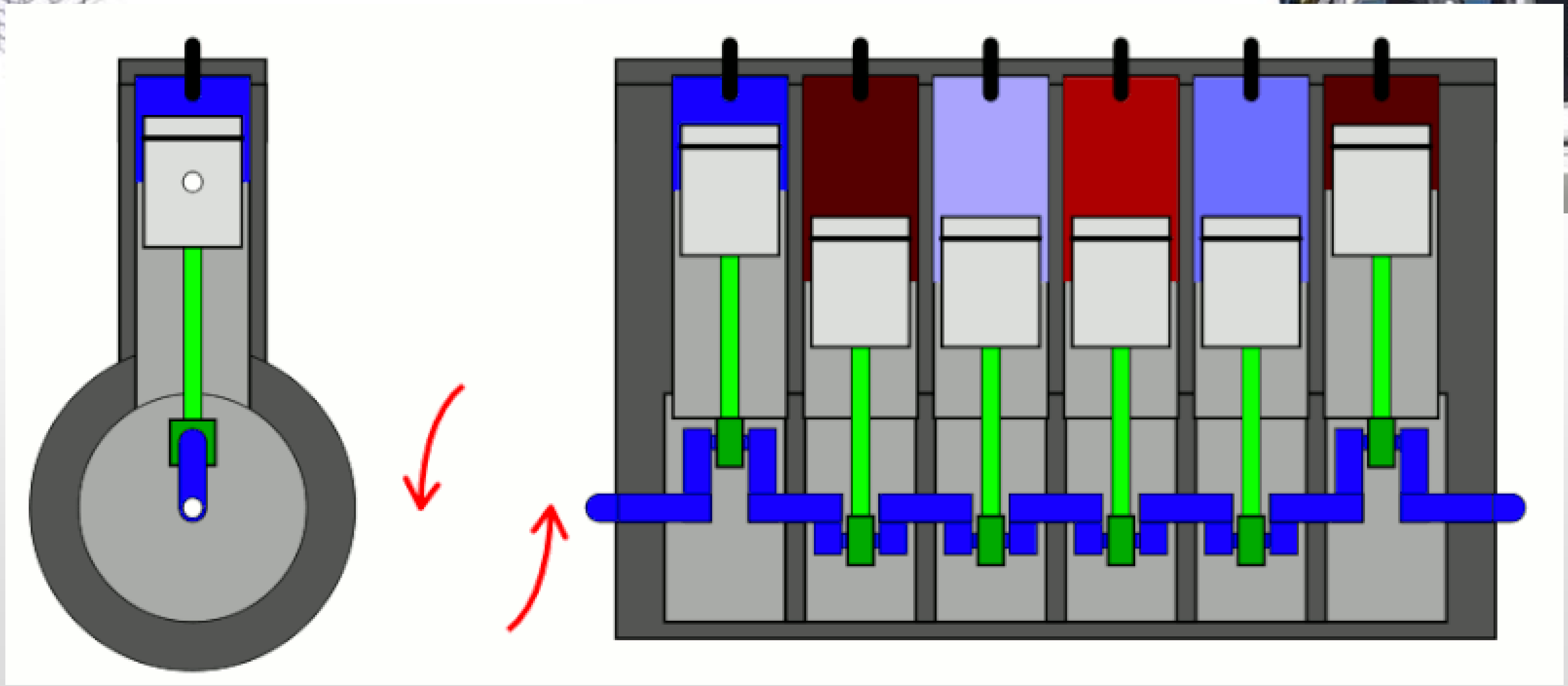
Five cylinder engine(Inline)

5 cylinder.mp4

Six cylinder e



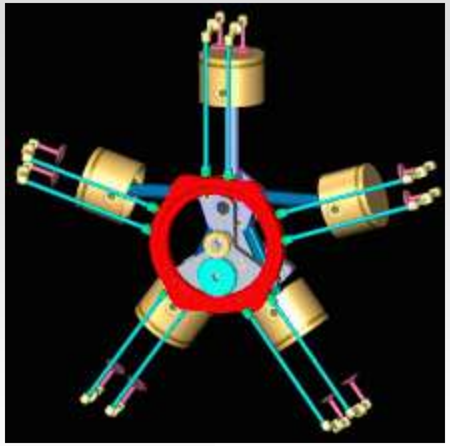




8 cylinder engine(V type)

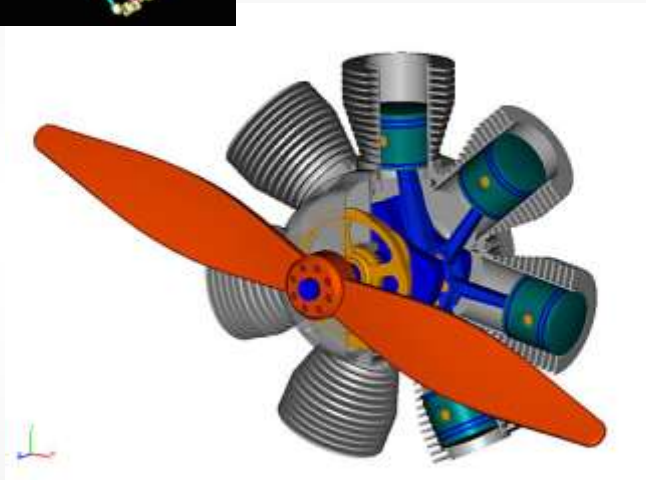
8 cylinder.mp4

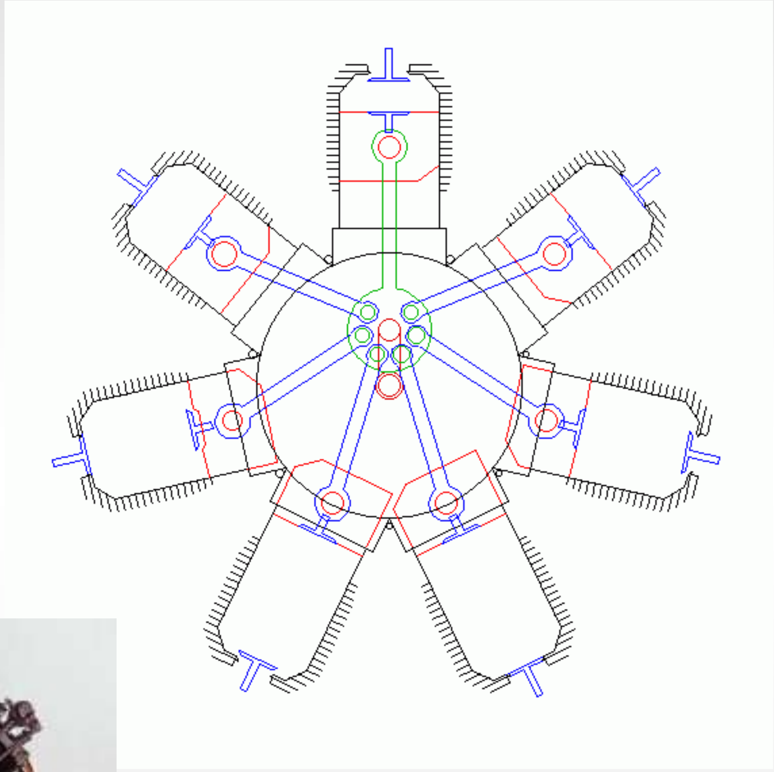
Internal Combustion Engines
– multi-cylinder -



Cylinder layouts

radial

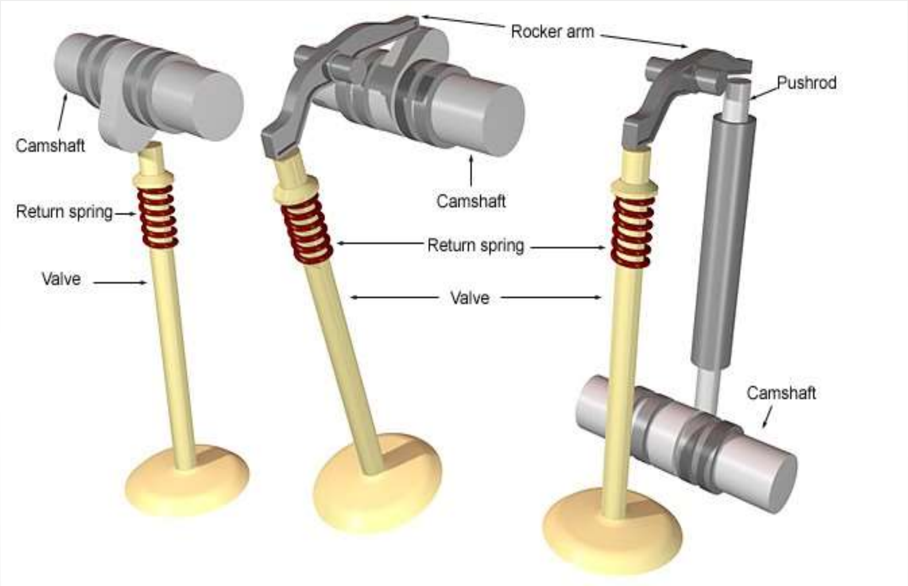


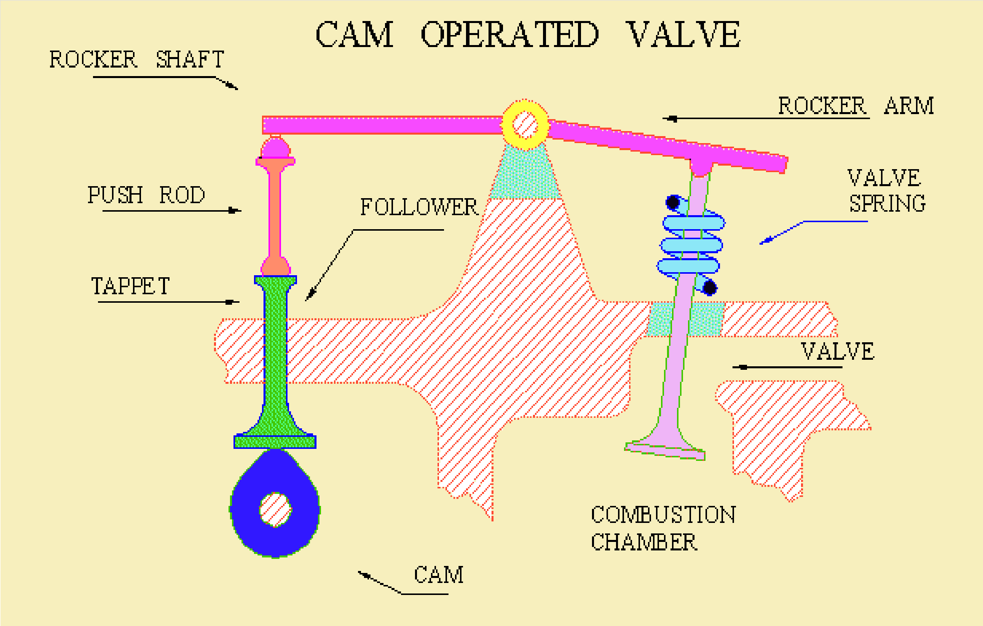


https://www.youtube.com/watch?v=Nk9Dl6RZxmQ

Internal Combustion Engines

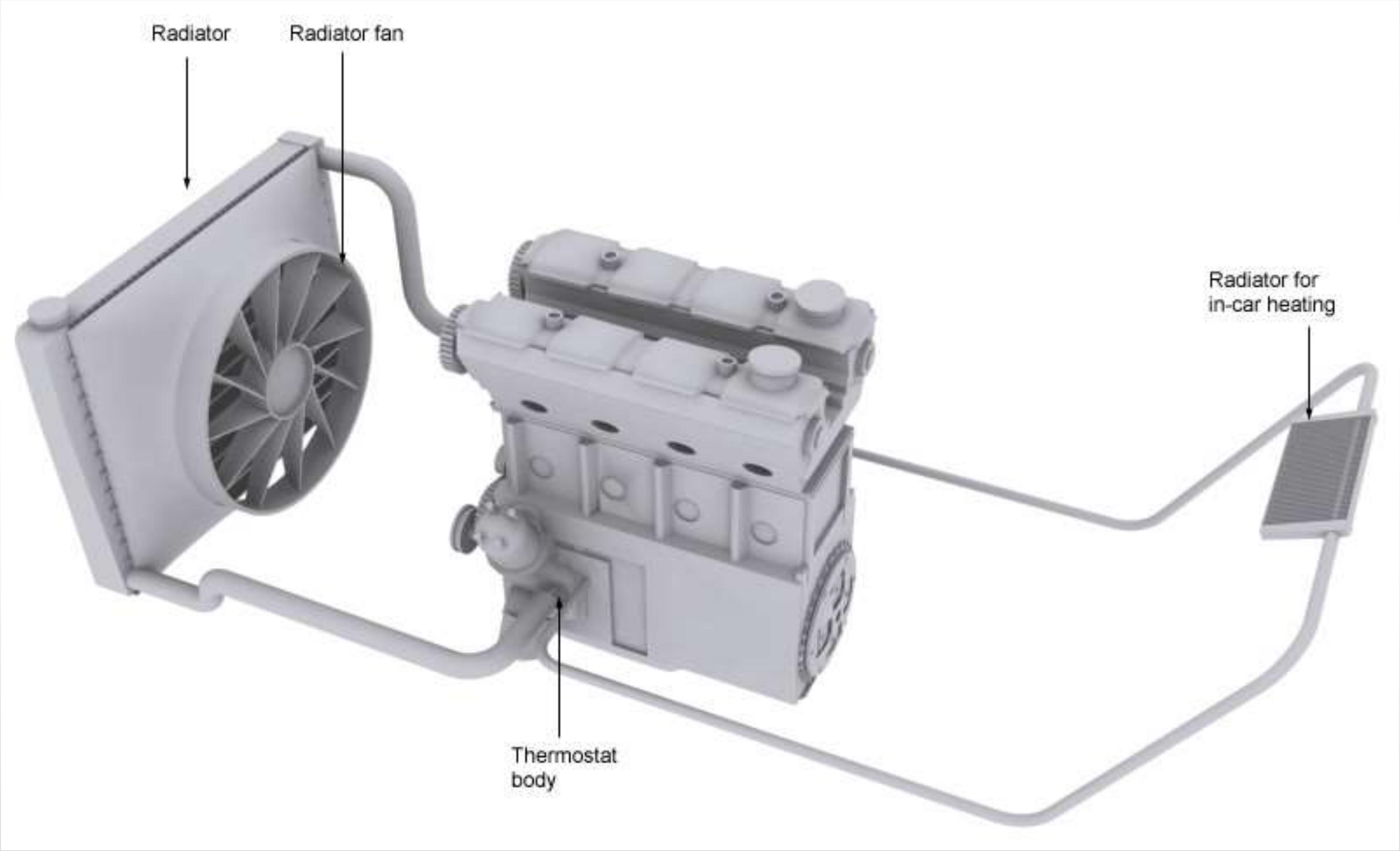
Valve operation



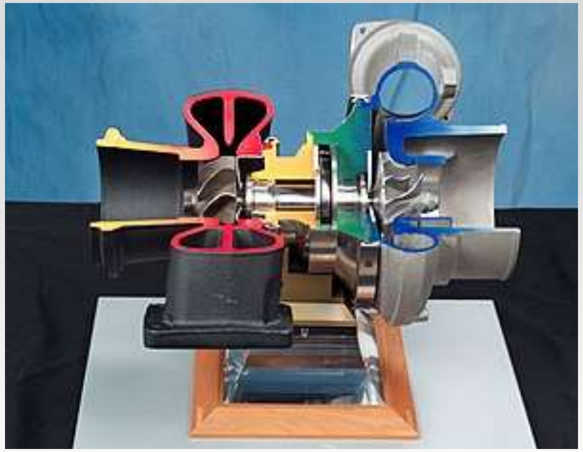


Internal Combustion Engines

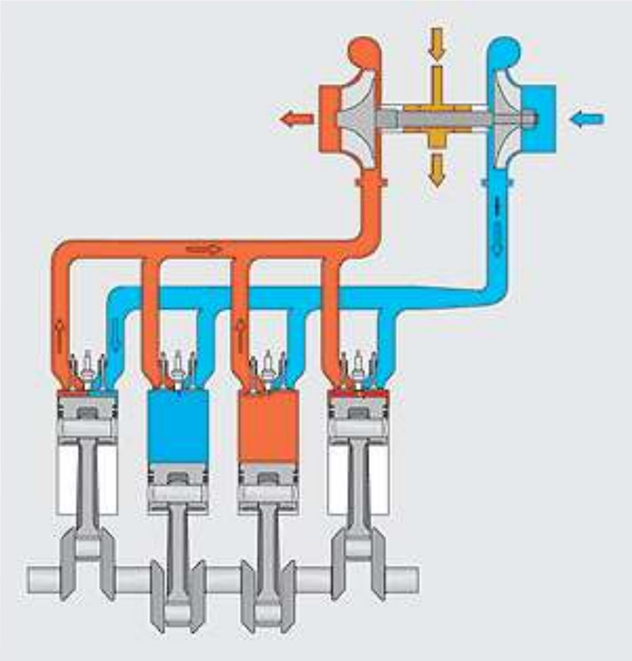
Engine cooling

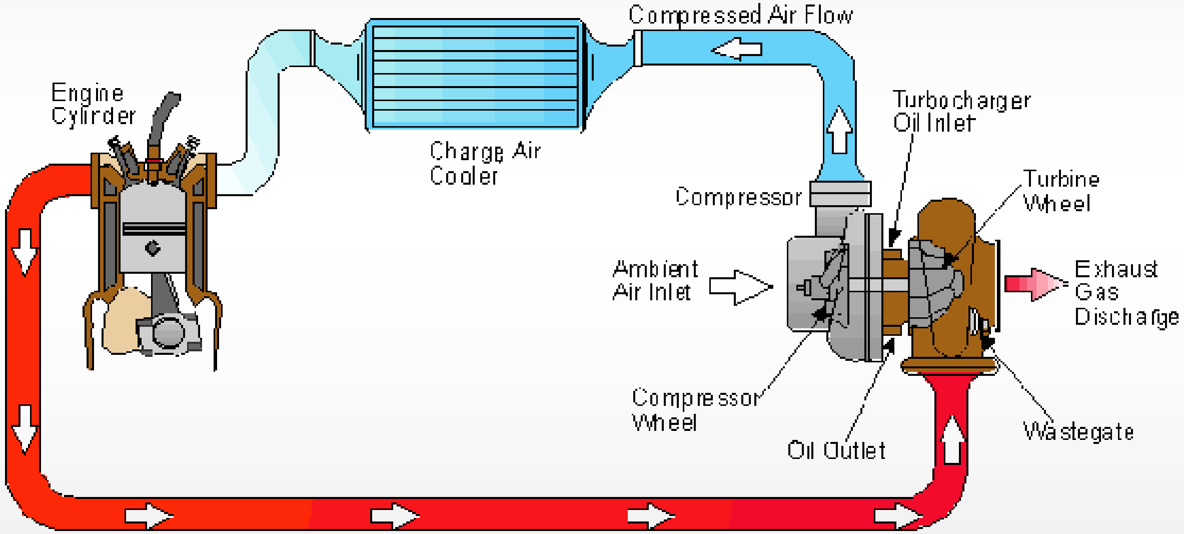


Internal Combustion Engines



Turbocharged
engine





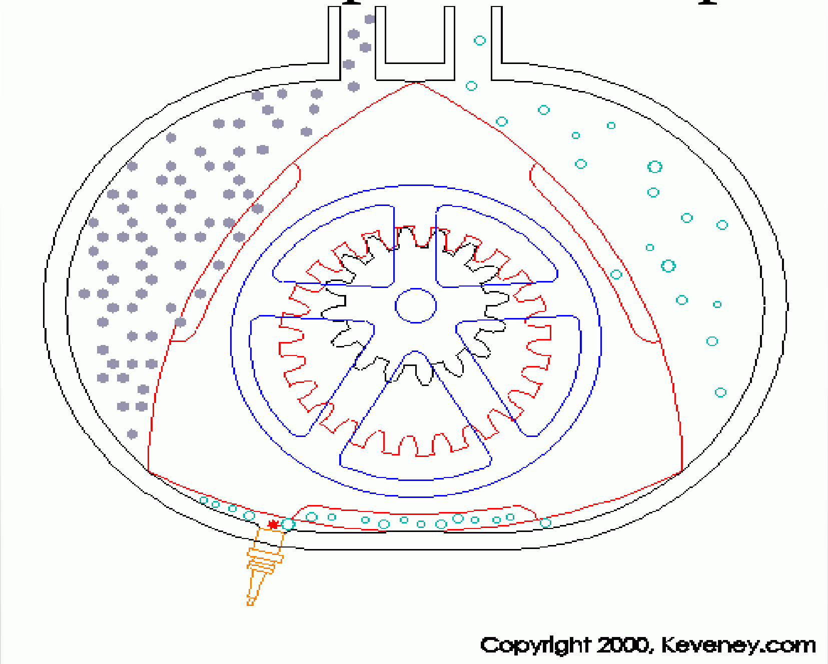
https://www.youtube.com/watch?v=DqWKNuTppmU

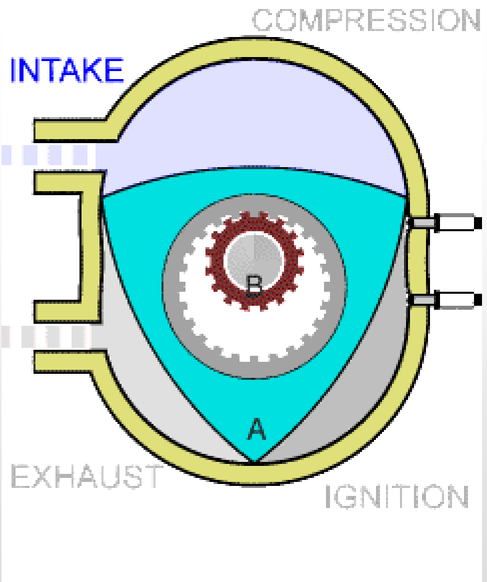
Rotary (Wankel) Engine

- Designed in 1958 by a German scientist named Felix Wankel.
- Wankel engines do not use pistons.

Wankel Engine

- The wankel engine uses a triangular shaped rotor housed in an oval shaped cylinder.
- As the rotor is rotated it moves around the cylinder producing the four basic functions to produce a power stroke.

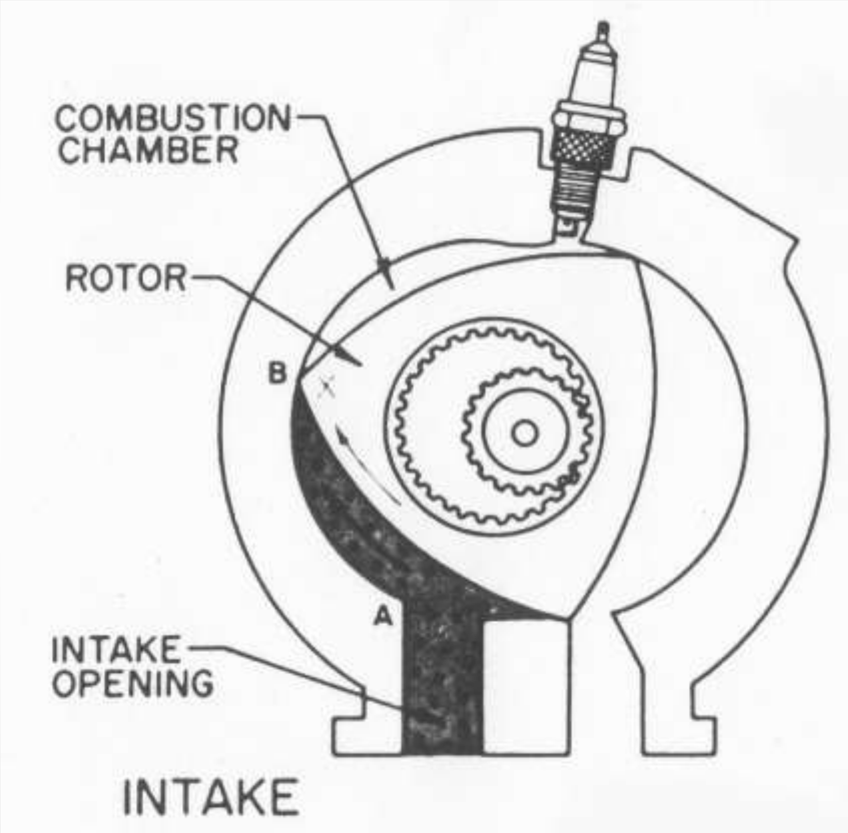




https://www.youtube.com/watch?v=TnpptL37evs

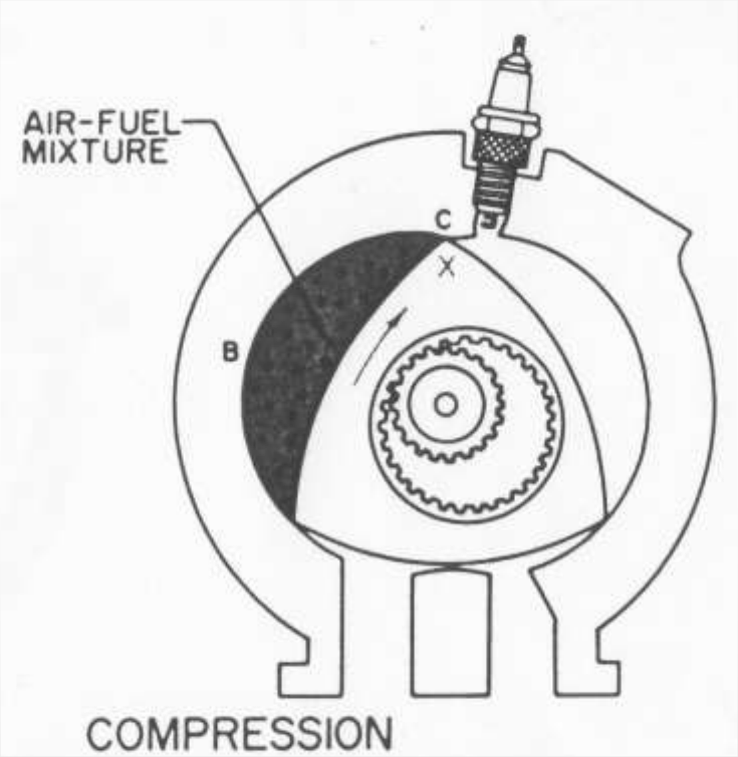
Wankel Engine Principles of Operation

- Intake Stroke
  - The production of power begins with the rotor at point A.
  - The intake port is uncovered allowing a new air/fuel mixture to enter the combustion chamber.



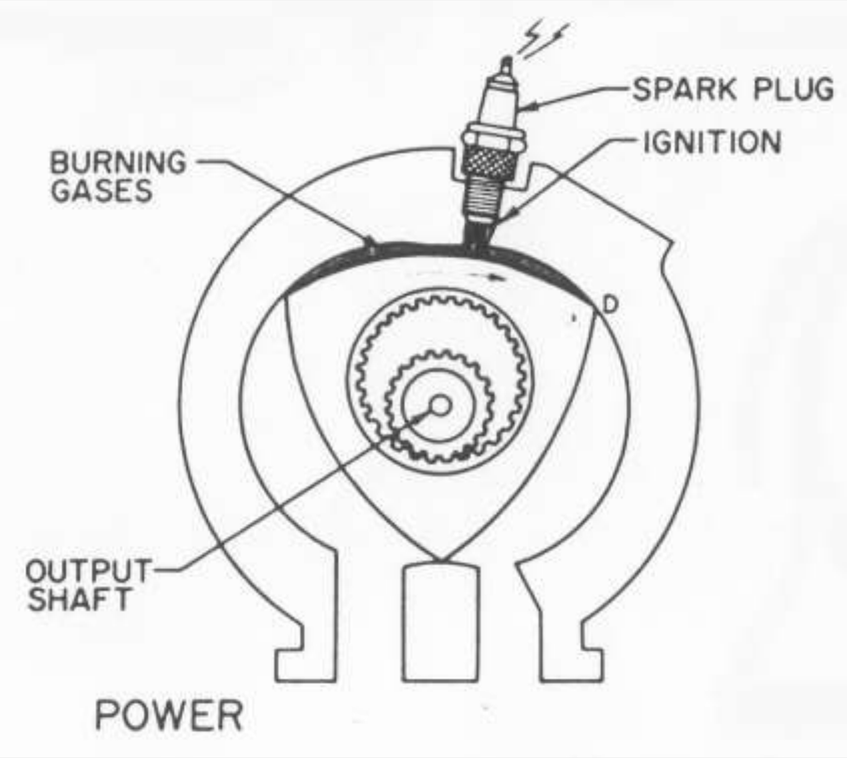
Wankel Engine Principles of Operation

- Compression Stroke
  - As the rotor rotates the combustion chamber is reduced in size compressing the mixture.



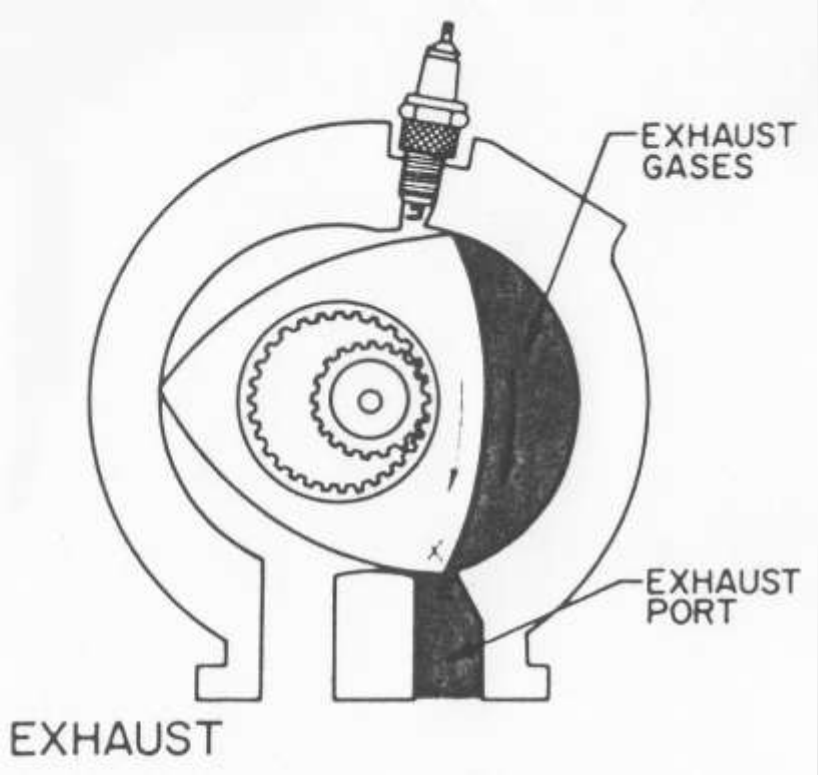
Wankel Engine Principles of Operation

- Power Stroke
  - At the highest point of compression the air/fuel is ignited.
  - The hot expanding gases push on the rotor causing it to rotate.



Wankel Engine Principles of Operation

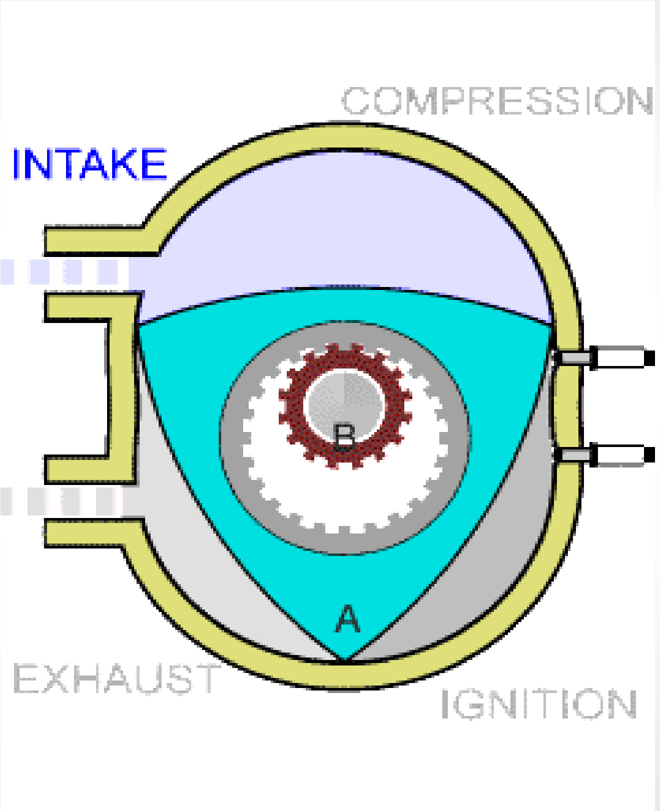
- Exhaust Stroke
  - The continued rotation of the rotor uncovers the exhaust port allowing the exhaust gas to escape.
  - The cycle then repeats when a new air/fuel mixture is permitted to enter the combustion chamber.



Internal Combustion Engines

Wankel rotary engine

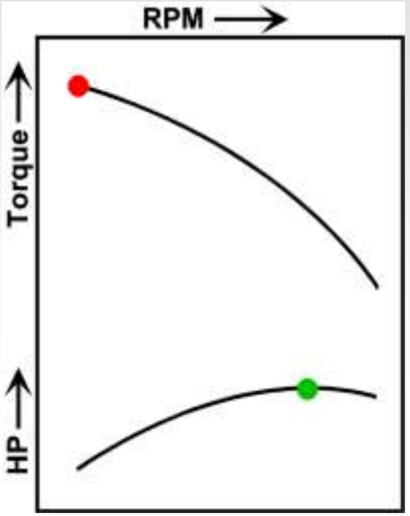
Advantages:
- higher power output
- no reciprocating mass
- simpler and lighter constructionLess vibration than piston driven engines.
- A two rotary engine is as powerful as a six cylinder piston engine..
- Power output can be increased by adding additional rotors to the engine



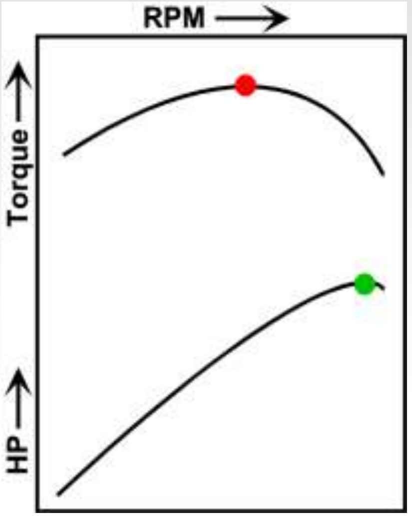
Drawbacks:
- increased wear of rubbing parts
- higher fuel consumption
- requirement for better materials
- Sealing the rotor in the odd shaped cylinder is very difficult requiring costly maintenance.
- Construction cost are high for this engine.

Internal Combustion Engines

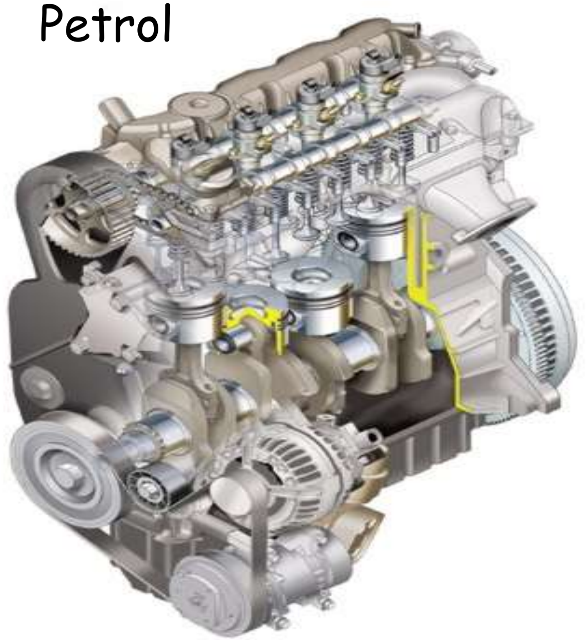
Engine characteristic

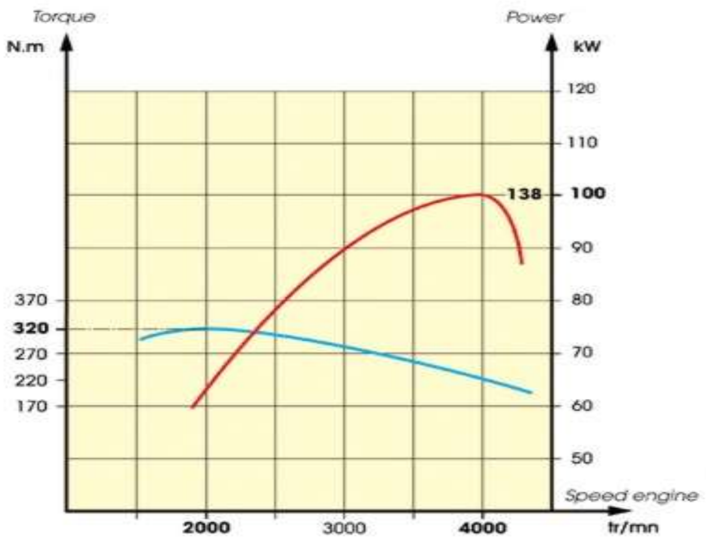


Diesel



Petrol

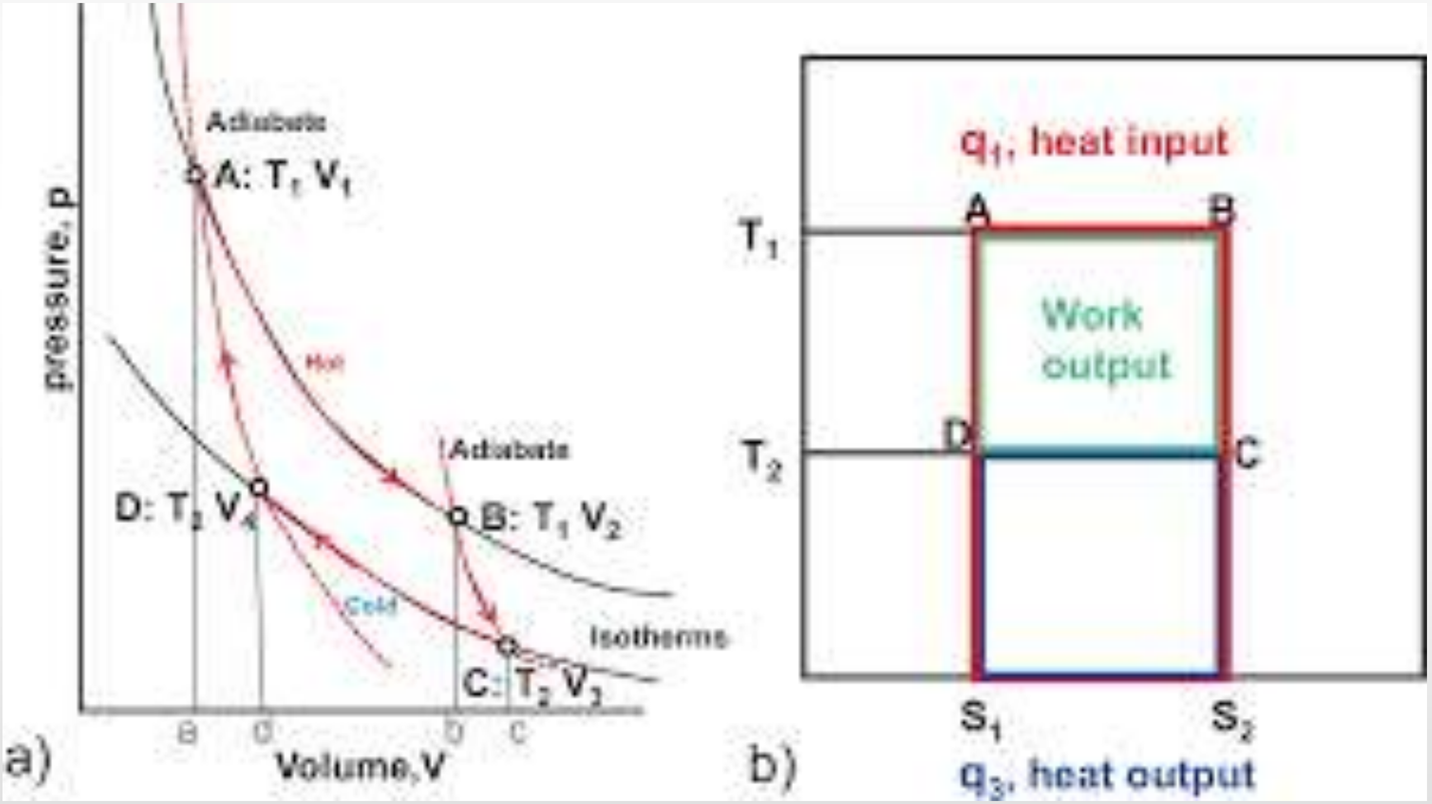




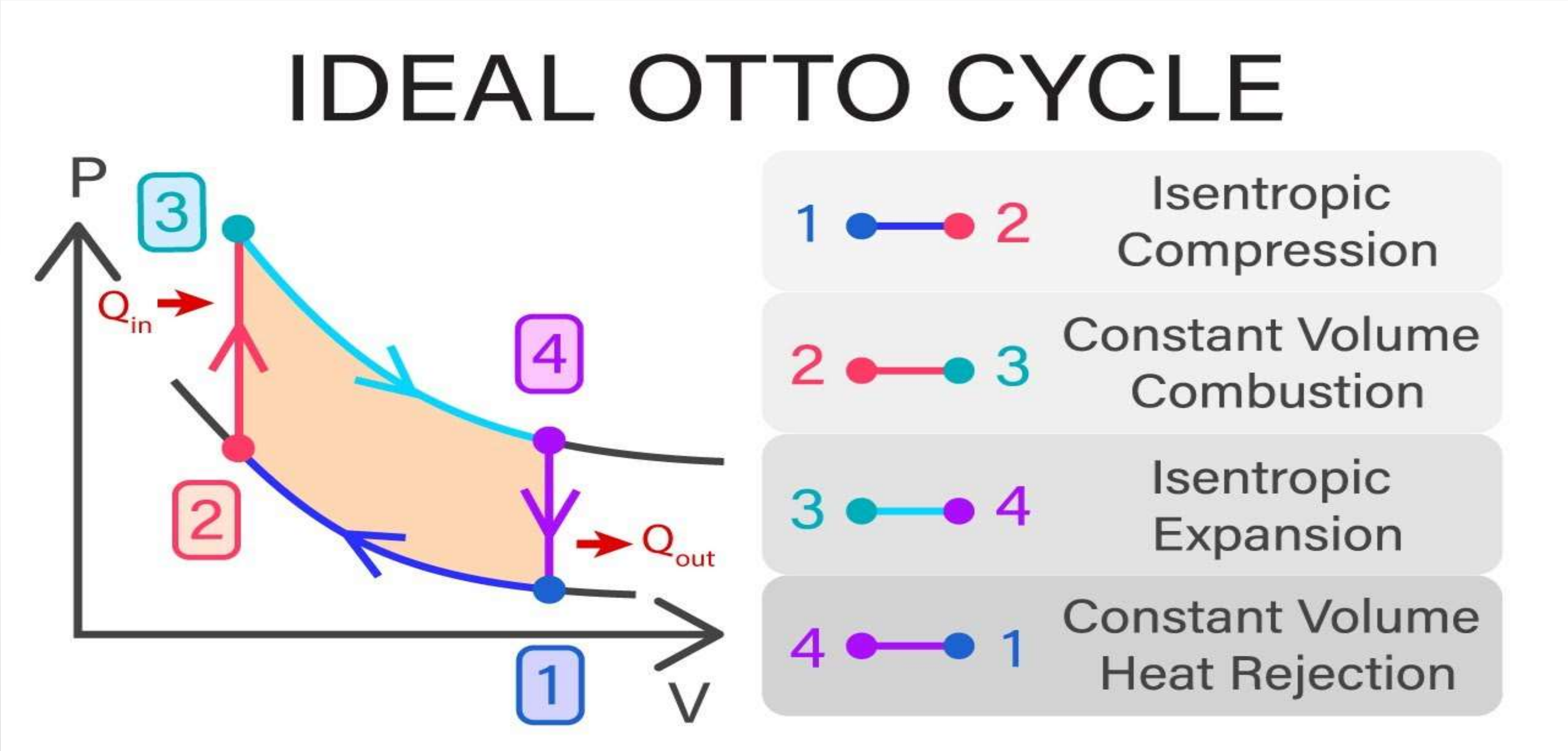
Assumptions for analysis of IC engines

- Working medium perfect gas follows pV=mRT.
- No change in mass.
- Reversible processes.
- Heat supplied from constant high temp. source not from chemical reactions during cycle.
- Some heat rejected to low temp. sink.
- No heat loss to surroundings.
- Working medium has constant specific heats.

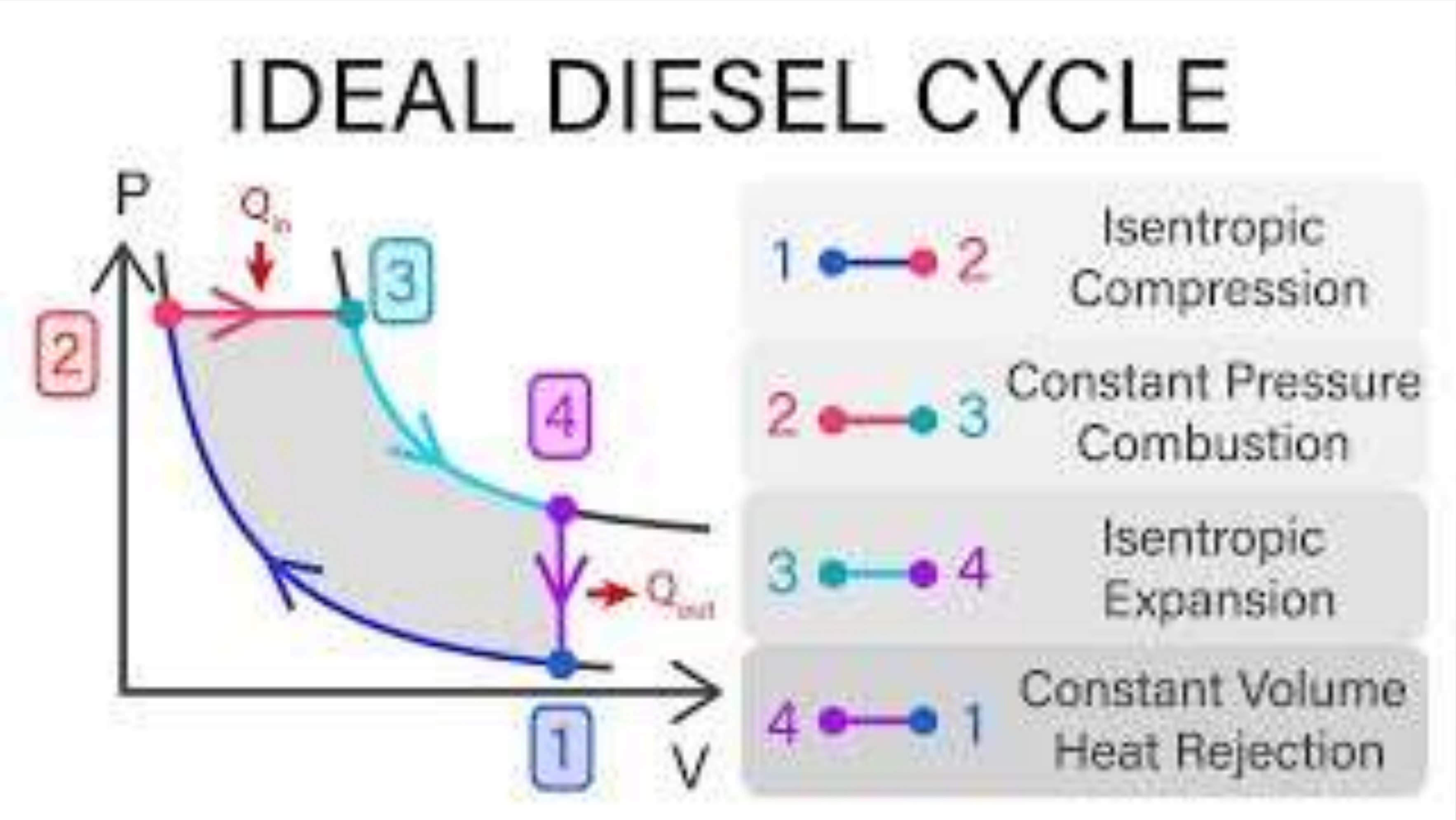
Carnot cycle



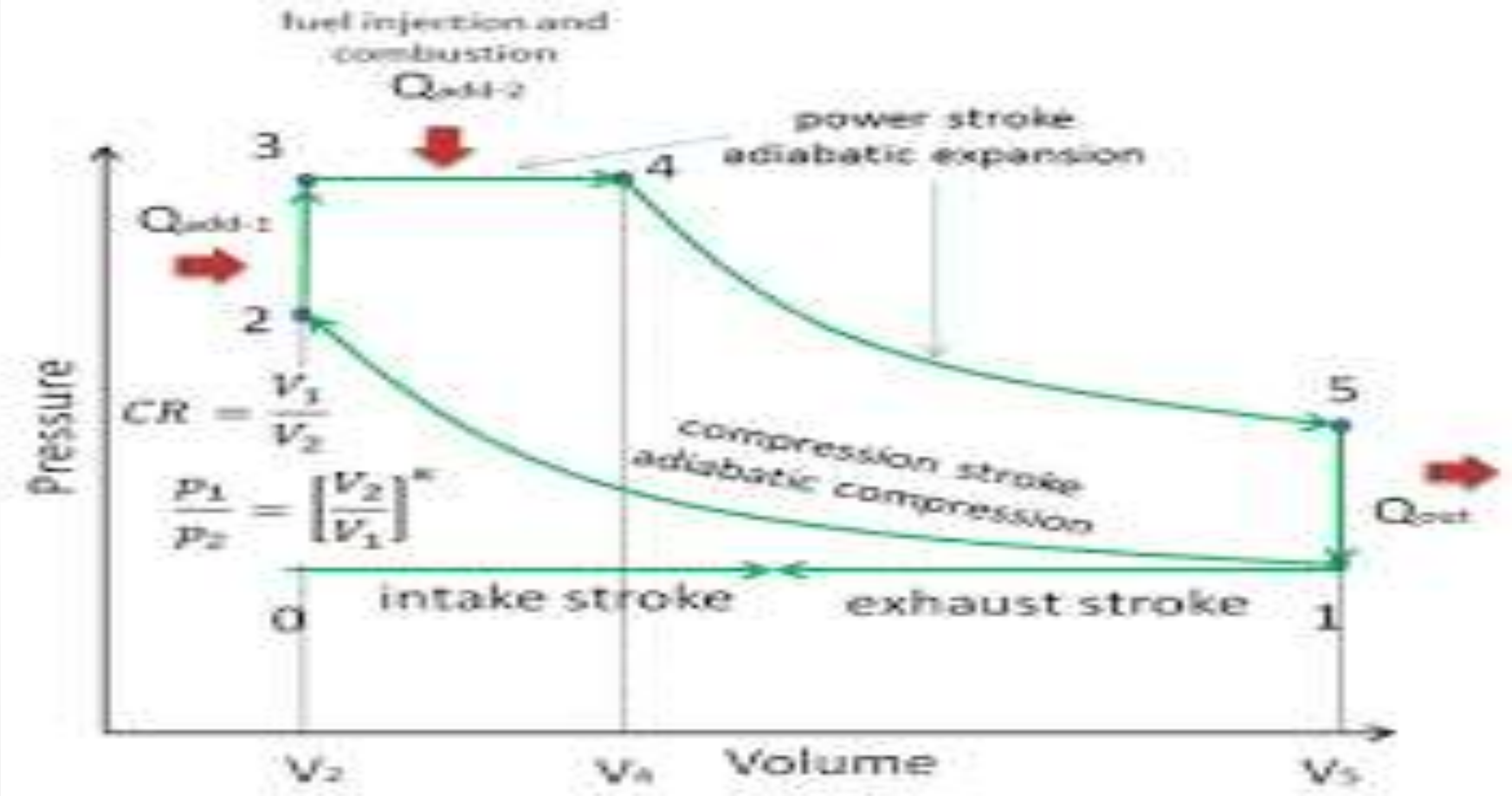
Otto Cycle


IDEAL OTTO CYCLE
P
V
3
4
2
1
Q_{in}
Q_{out}
1 — 2 Isentropic Compression
2 — 3 Constant Volume Combustion
3 — 4 Isentropic Expansion
4 — 1 Constant Volume Heat Rejection

Diesel cycle



Dual cycle



fuel injection and combustion
Q_{add-2}
power stroke
adiabatic expansion
3
4
Q_{add-1}
2
Pressure
$CR = \frac{V_1}{V_2}$
$\frac{p_1}{p_2} = \left[\frac{V_2}{V_1}\right]^{\kappa}$
5
compression stroke
adiabatic compression
Q_{out}
intake stroke
exhaust stroke
0
1
V_2
V_4
Volume
V_5

Engine performance parameters

i. Indicated thermal efficiency
ii. Brake thermal efficiency
iii. Mechanical efficiency
iv. Volumetric efficiency
v. Mean effective pressure
vi. Mean piston speed
vii. Specific power output
viii. Specific fuel consumption
ix. Fuel-Air ratio or Air-fuel ratio
x. Calorific value of fuel

11. Specific output

- Specific output = $\frac{B.P.}{A}$

B.P.=Brake Power
A=Area of cross section of the cylinder,m2

10. Volumetric efficiency:-

- $\eta_{vol} = \frac{\text{Actual volume of charge/air sucked at atm. Condition}}{\text{Swept volume}}$

Performance Parameters

- Mechanical efficiency

$$\eta_m = \frac{bp\ (kJ/s)}{ip(kJ/s)}$$

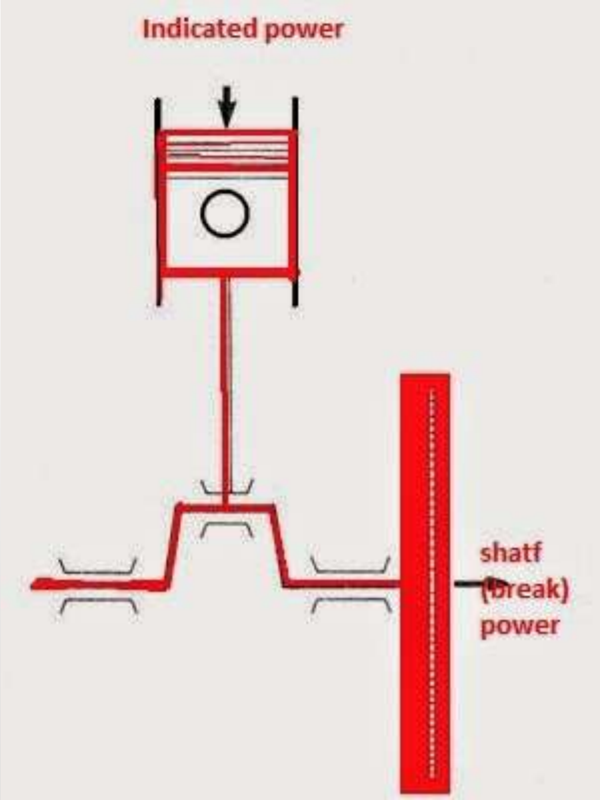
$$f_p = ip - bp$$

- Indicated Thermal efficiency

$$\eta_{ith} = \frac{ip\ (kJ/s)}{energy\ in\ fuel\ per\ second(kJ/s)}$$

- Break Thermal efficiency

$$\eta_{bth} = \frac{bp\ (kJ/s)}{energy\ in\ fuel\ per\ second(kJ/s)}$$



Mean Piston Speed:

$$\bar{S}_p = 2LN$$

Indicated Mean Effective Pressure or Mean Indicated Pressure (MIP)

It is the pressure which on acting upon the piston, performs the same work as the actual pressure in the operating cycle. It is the ratio of work done during the working stroke to the swept volume. It is determined graphically from a diagram or calculated from engine parameters.

Few Practice Questions

1. What are the main components of IC Engines?
2. What is difference between SI and CI engine?
3. What is difference between 4S and 2S engine?
4. Draw the schematic diagram of 4S Petrol engine.
5. Explain with neat figure swept volume and compression ratio?
6. Describe the working of 4S and 2S engine.
7. What are the advantages and disadvantages of rotary engine
8. State and explain IP, BP and FP?
9. State and explain with formula brake thermal, mechanical and volumetric efficiency
10. Write a short note on IC Engine from Energy and environment point of view.