



Lecture ( 4a )

# Internal Combustion Engine

## Introduction

## Definition:

The internal combustion (IC) engine is a heat engine that converts chemical energy in a fuel into mechanical energy

المحرك الحراري هو الآلة التي تتحول بواسطتها الطاقة الحرارية الناتجة عن إحتراق الوقود (سواء كان هذا الوقود صلباً أو سائلاً أو غازياً) إلى شغل ميكانيكي يمكن الاستفادة منه في إدارة الآلات المستخدمة سواء في الصناعة أو في النقل .



# Engine Classifications

# Engine Classifications

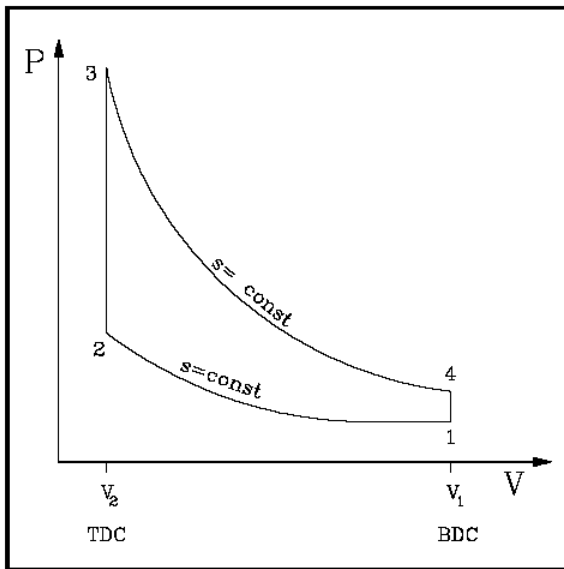
There are many ways to classify engines, all of which make sense in different situations.

## 1. By Application

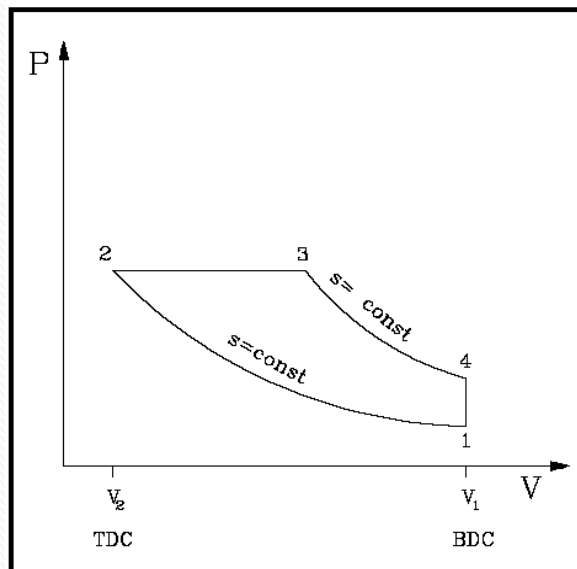
**Automotive:** -Car, truck, motorcycle, locomotive, marine, aircraft, etc.

**Stationary:** -Power generation, emergency power, utility, pumping, etc.

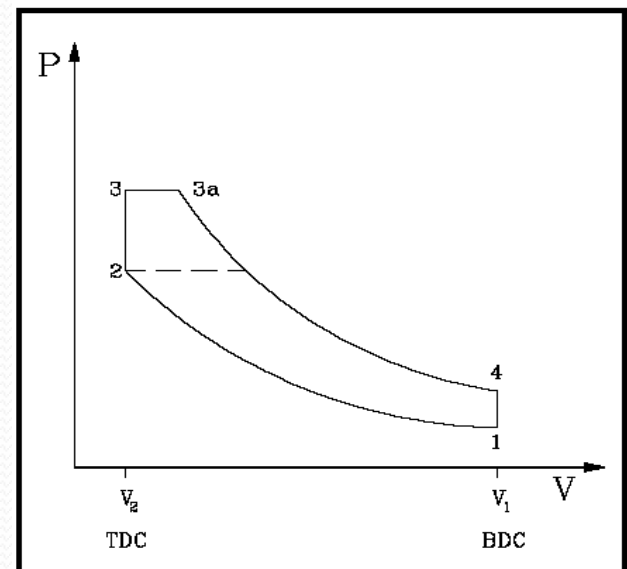
## 2. By Working Cycle



Otto Cycle



Diesel Cycle



Dual Cycle

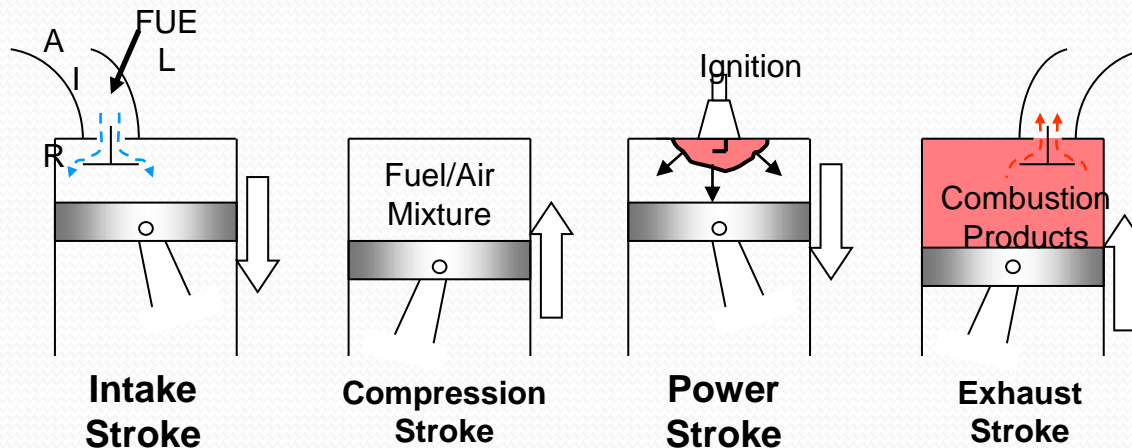


## 3. By Number of strokes

Four stroke, two stroke

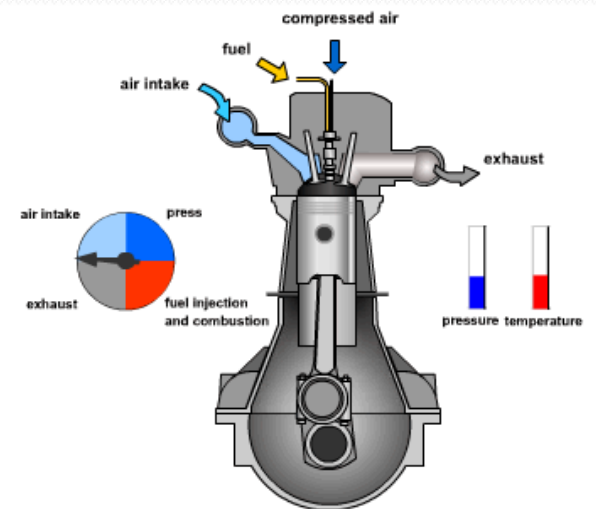
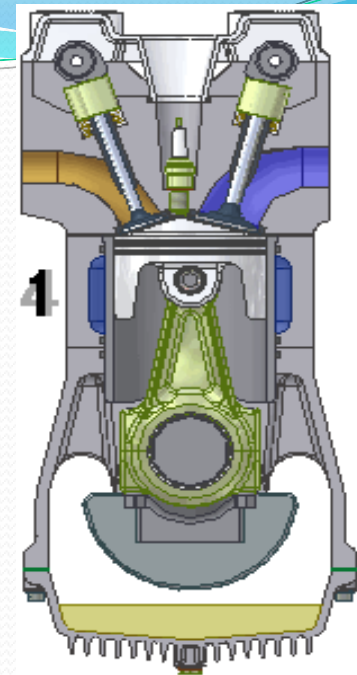
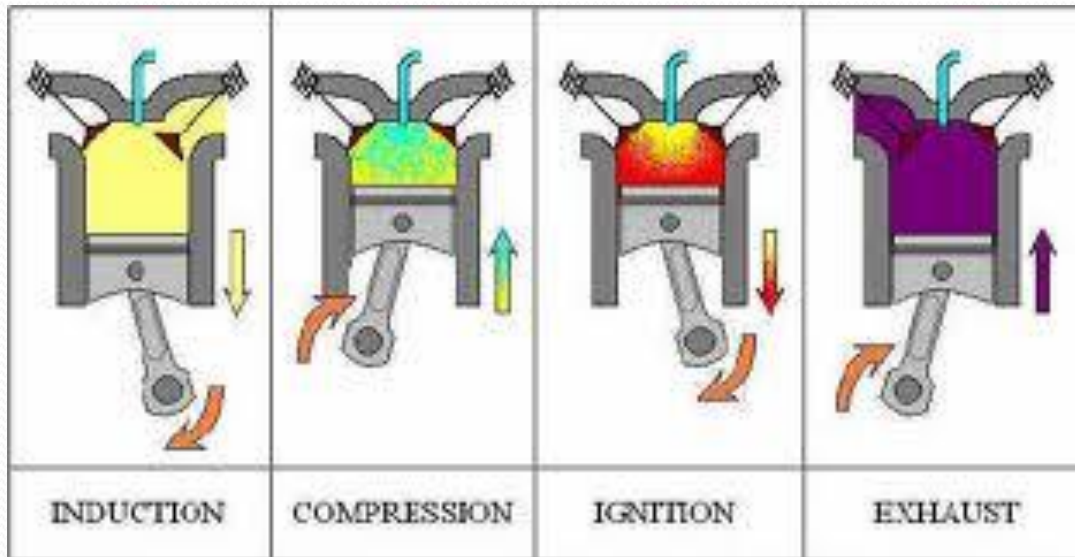
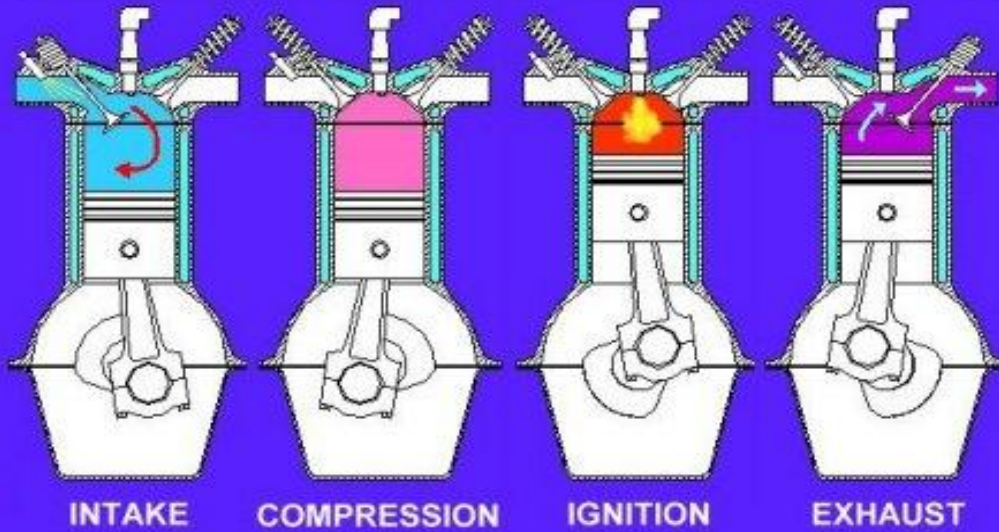
### Four stroke Spark Ignition (SI) Engine

- Stroke 1: Fuel-air mixture introduced into cylinder through intake valve (**suction or intake stroke**)
- Stroke 2: Fuel-air mixture compressed (**compression stroke**)
- Stroke 3: Combustion (roughly constant volume) occurs and product gases expand doing work (**expansion stroke**)
- Stroke 4: Product gases pushed out of the cylinder through the exhaust valve (**exhaust stroke**)



# Engine Classifications

## THE FOUR STROKE CYCLE

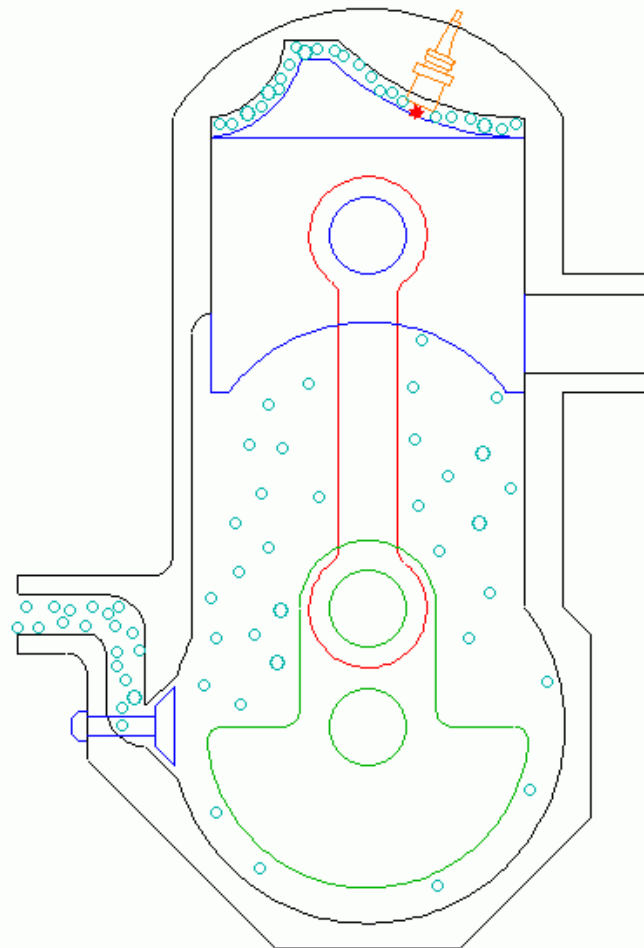
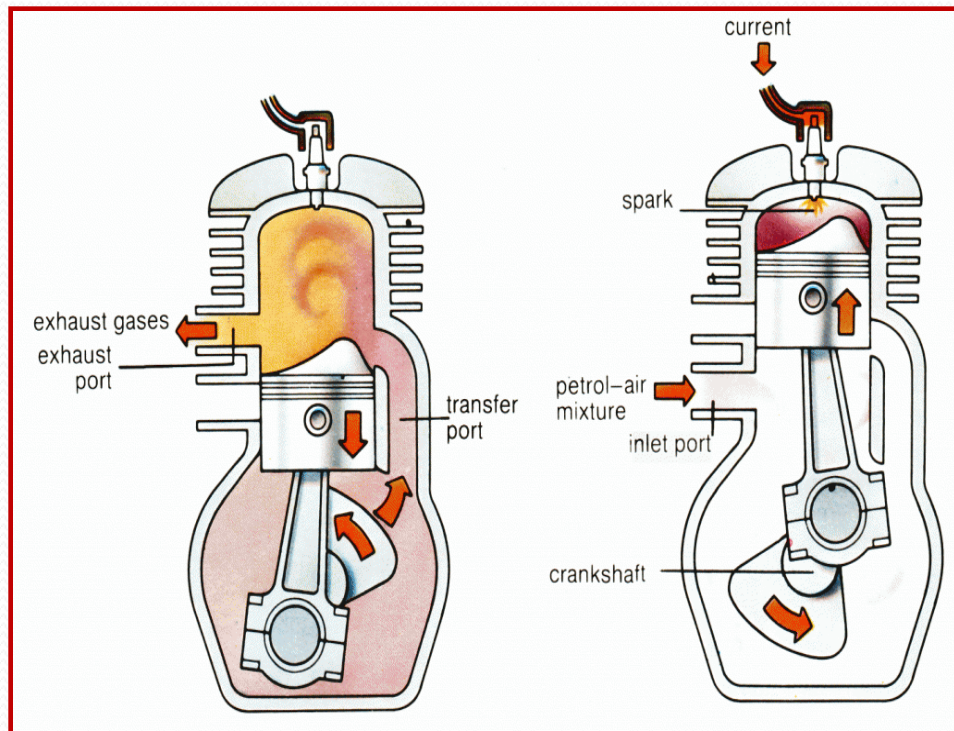


# Two stroke Spark Ignition (SI) Engine

This cycle is completed in two strokes of piston rather than four strokes.

<b>Stroke</b>	<b>Piston Direction</b>	<b>Actions Occurring during This Stroke</b>	<b>Explanation</b>
<b>Stroke 1</b>	<b>Piston travels up the cylinder barrel</b>	<b>Induction &amp; Compression</b>	<b>As the Piston travels up the barrel, fresh fuel/air mix is sucked into the crankcase (bottom of the engine) &amp; the fuel/air mix in the cylinder (top of the engine) is compressed ready for ignition</b>
<b>Stroke 2</b>	<b>Piston travels down the cylinder barrel</b>	<b>Ignition &amp; Exhaust</b>	<b>The spark plug ignites the fuel/air mix in the cylinder, the resulting explosion pushes the piston back down to the bottom of the cylinder, as the piston travels down, the transfer port openings are exposed &amp; the fresh fuel/air mix is sucked from the crankcase into the cylinder. As the fresh fuel/air mix is drawn into the cylinder, it forces the spent exhaust gases out through the exhaust port.</b>

# Engine Classifications





# Engine Classifications

## 4. By cylinder Arrangement:

(a) Single Cylinder.

(b) In-Line.

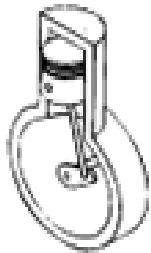
(c) V Engine.

(d) Opposed Cylinder Engine

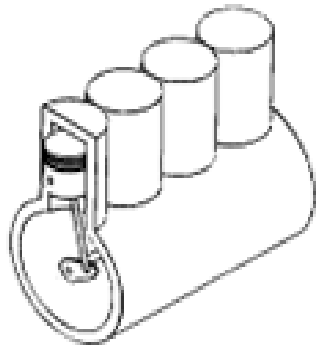
(e) W Engine.

(f) Opposed Piston Engine

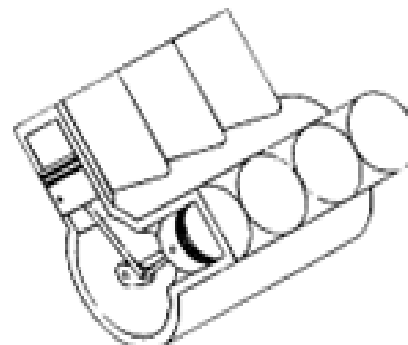
(g) Radial Engine.



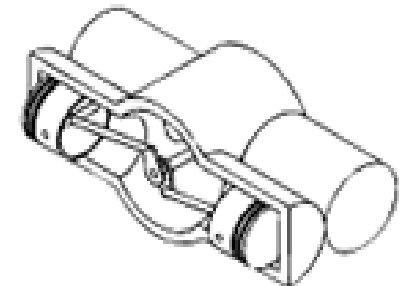
(a)



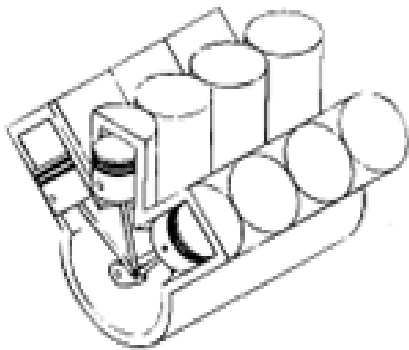
(b)



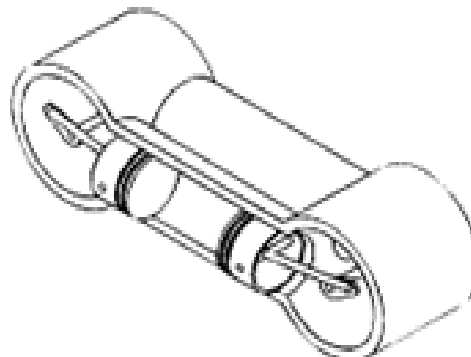
(c)



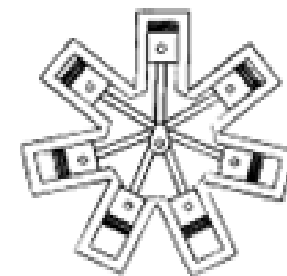
(d)



(e)



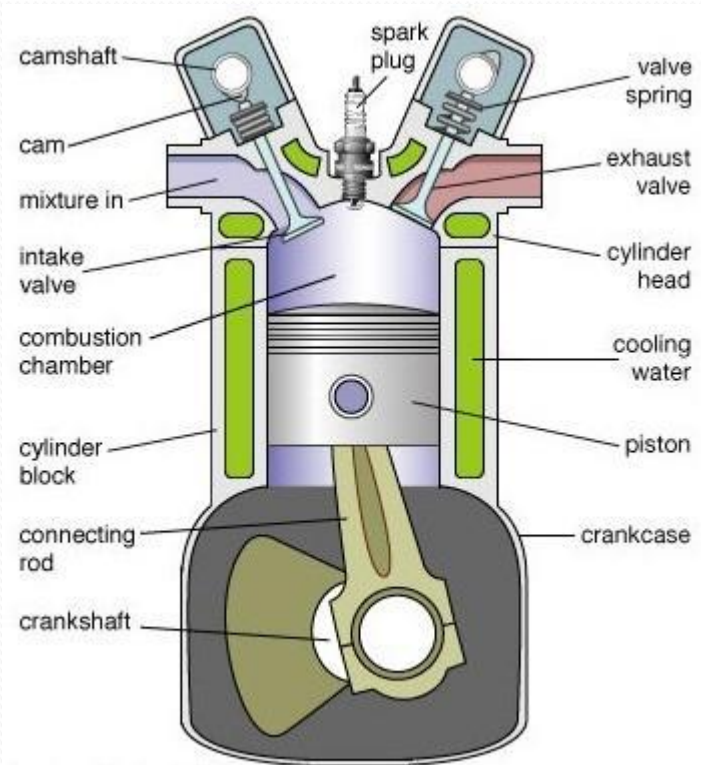
(f)



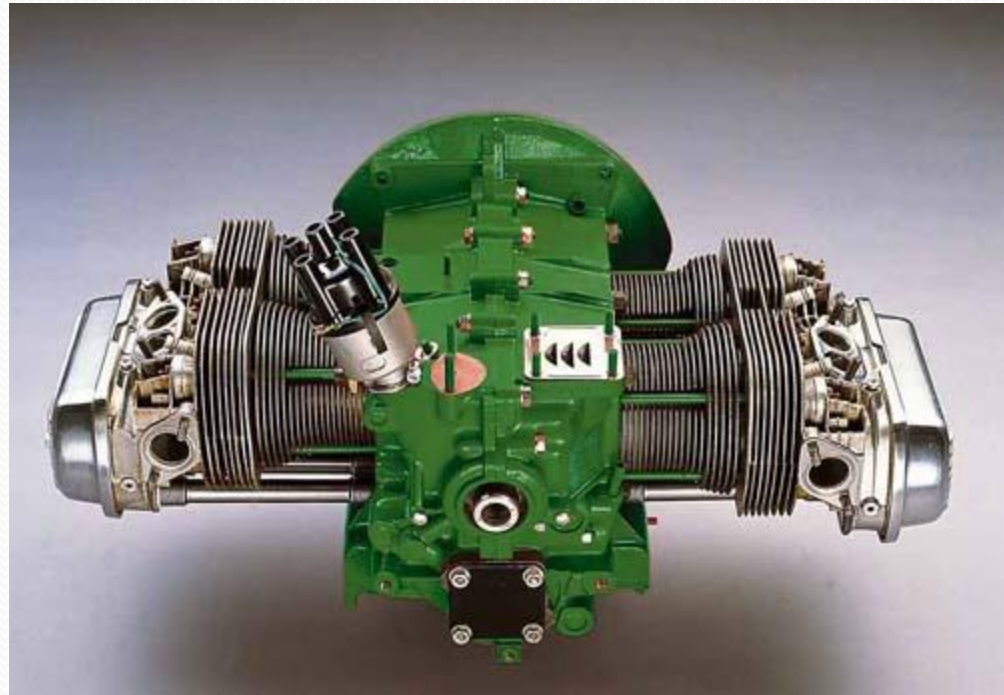
(g)

# Engine Classifications

## 5.By Cooling System:



**Water Cooled Engine**



**Air Cooled Engine**

### 6. By method for charging the cylinder

#### 1- For Fuel

- a- Carbureted.
- b- Injected.

#### 2- For Air

**1- Naturally Aspirated.** No intake air pressure boost system.

**2-Supercharged.** Intake air pressure increased with the compressor driven off of the engine cranks

**3-Turbocharged.** Intake air pressure increased with the turbine-compressor driven by the engine exhaust

**4- Crankcase Compressed.** Two-stroke cycle engine which uses the crankcase as the intake air compressor. Limited development work has also been done on design and construction of four-stroke cycle engines with crankcase compression.

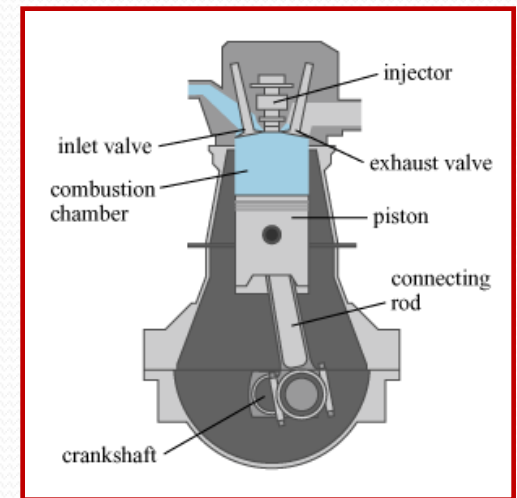
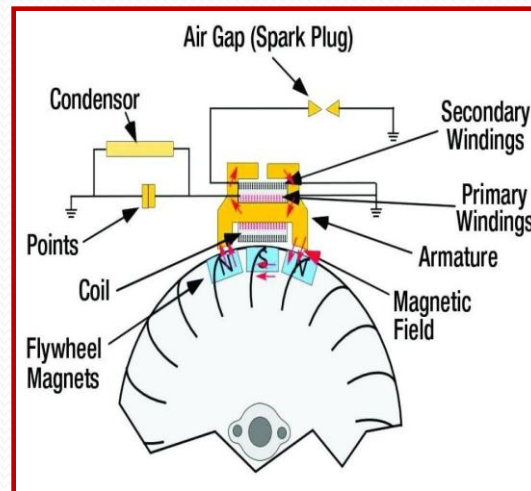
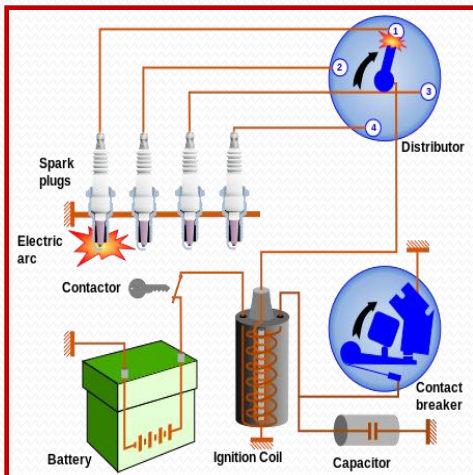
## 7. By Fuel type

Gasoline (petrol), diesel (Diesel oil), natural gas, propane, LPG, ethanol, methanol, residual oil, hydrogen, dual fuel, bi-fuel

## 8. By Ignition method

A- Spark ignition, (single or multiple spark plugs, single strike or multi-strike system, etc)

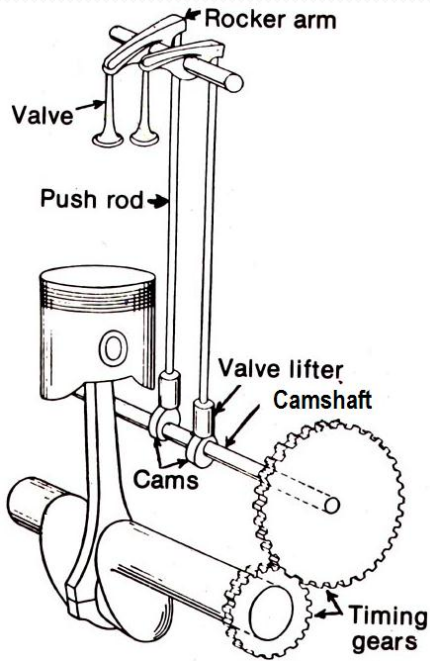
B- Compression ignition -glow plug or spark assist



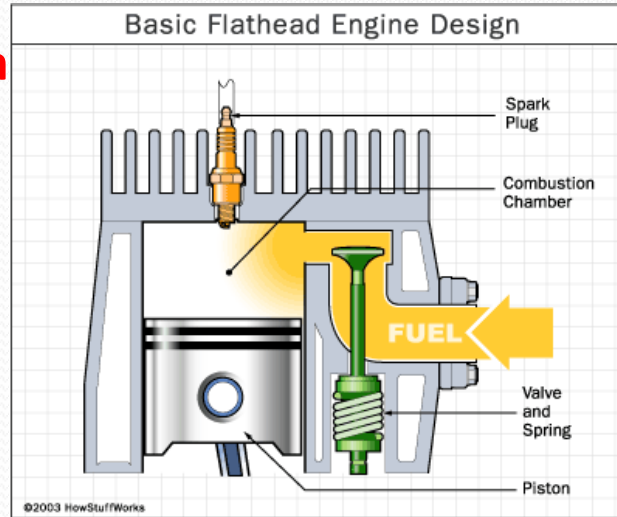


# Engine Classifications

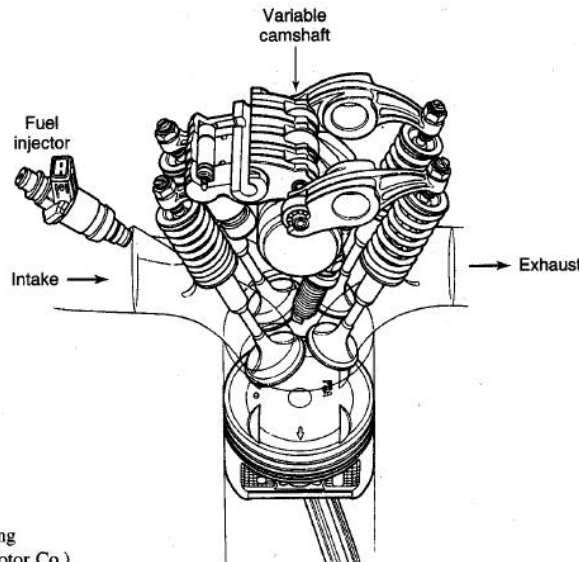
## 9. By Valve type, location and operating method



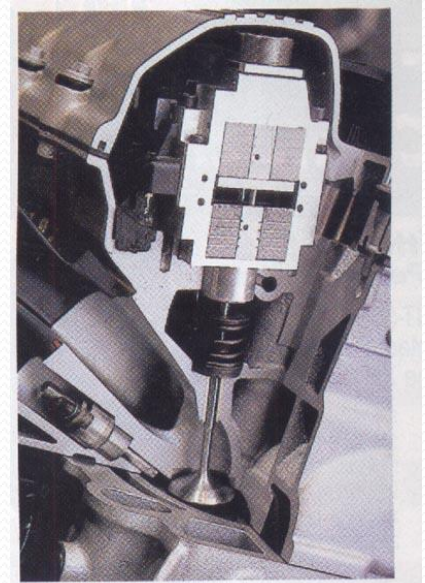
**Overhead Valve**



**Side valve**



**Honda Variable valve Timing and lift Electronic Control (VTEC)**

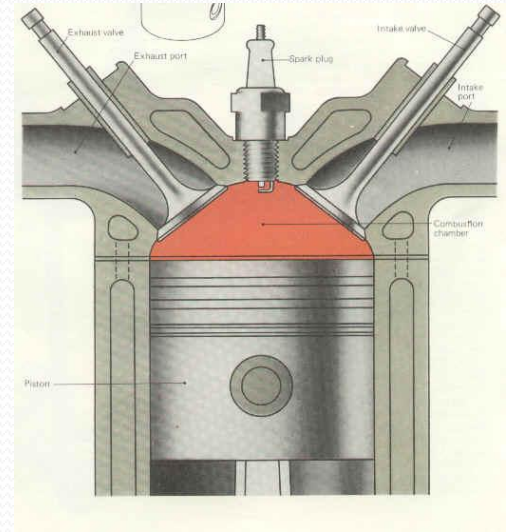
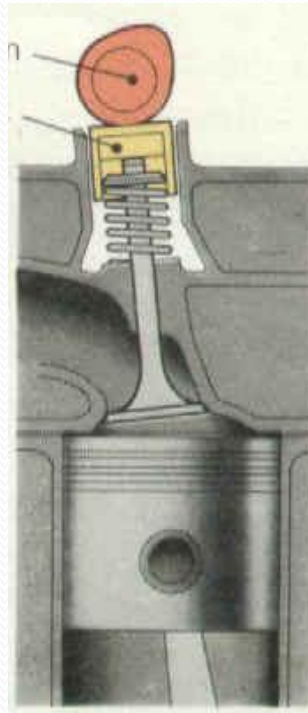
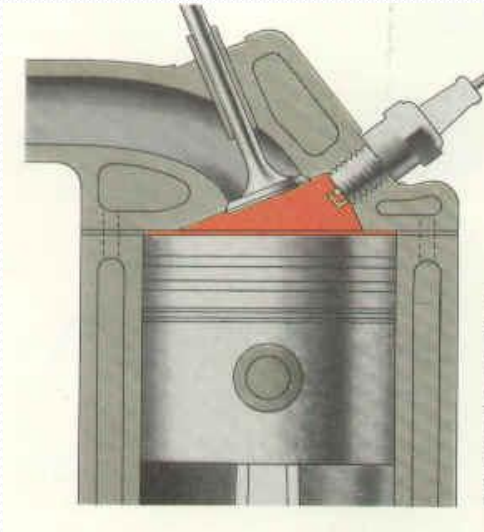


Electronically operated valves could replace cams in the future. This cutaway of a BMW prototype engine shows the powerful solenoid above each valve that controls its movement.

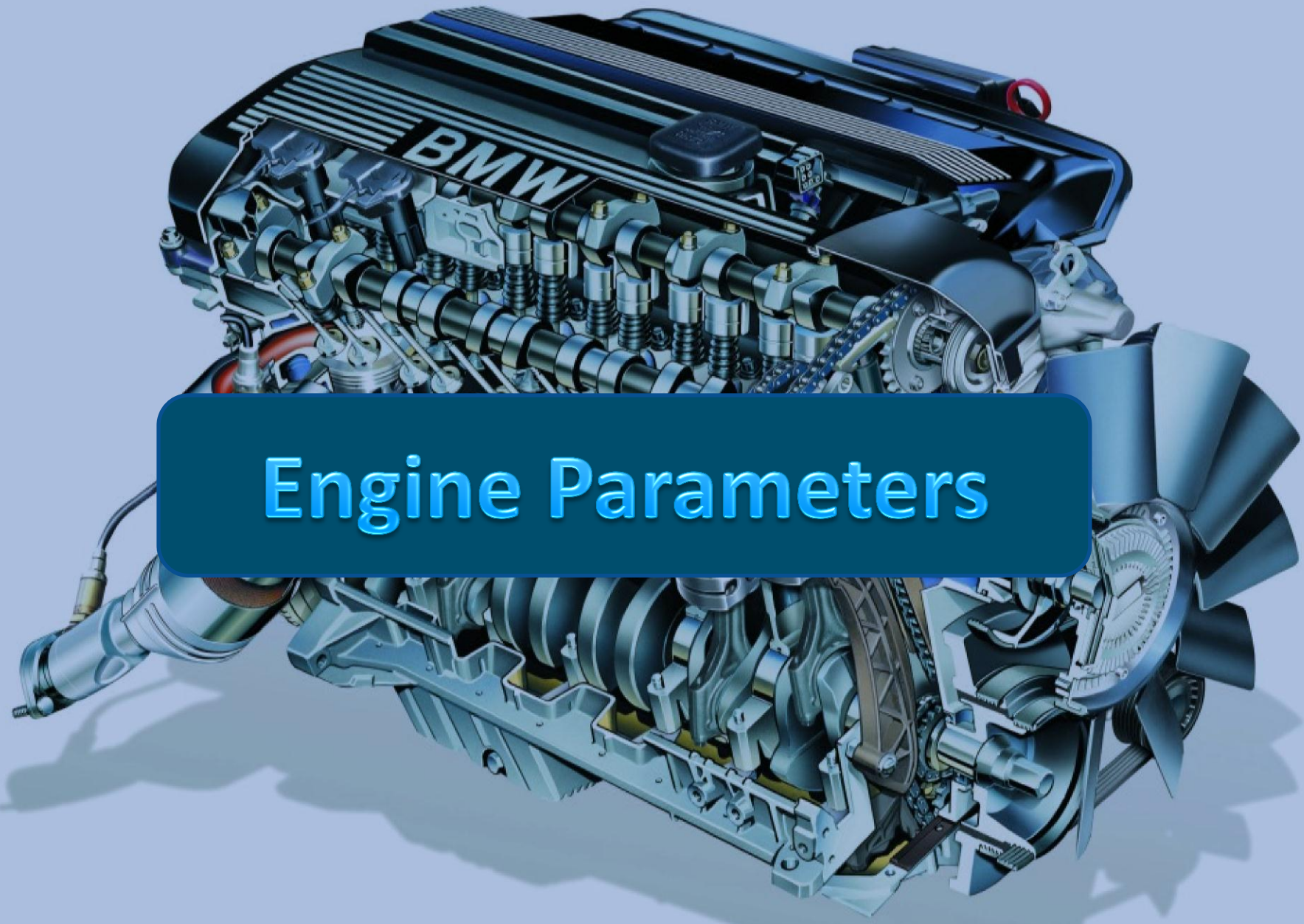
**Solenoid Operated Valve**

## 10. By Combustion chamber design

- open chamber -wedge, disk, hemisphere, pent-roof, bowl-in-piston, etc
- divided chamber – pre-chamber, torch chamber, swirl chamber, etc.

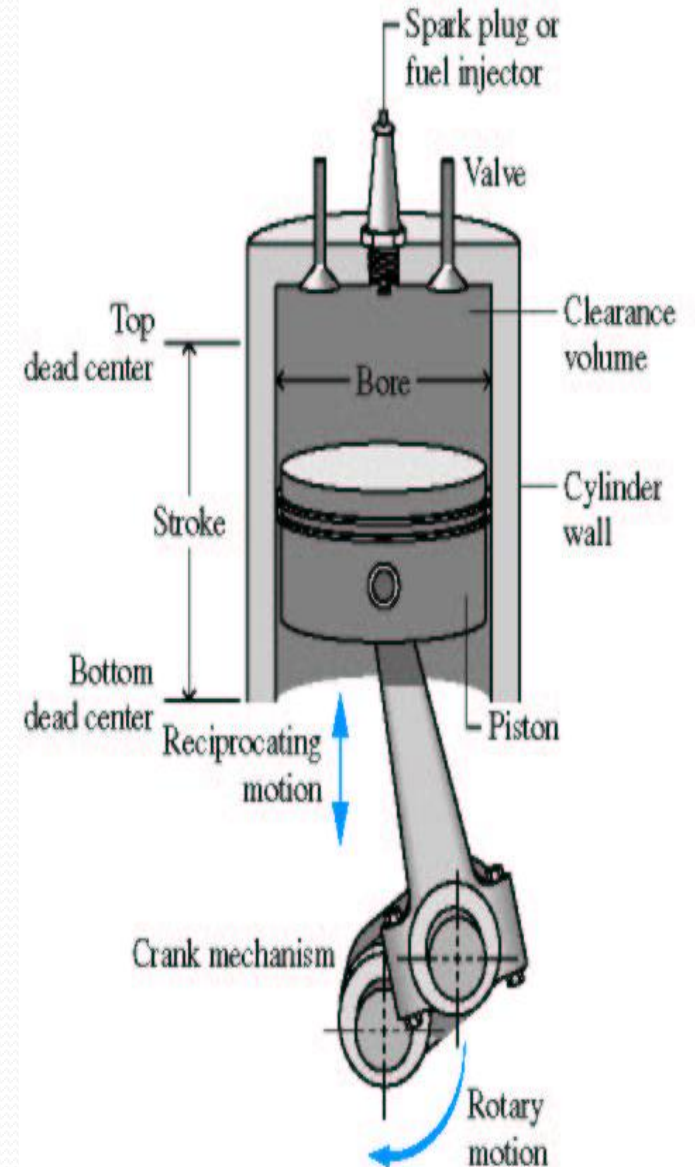
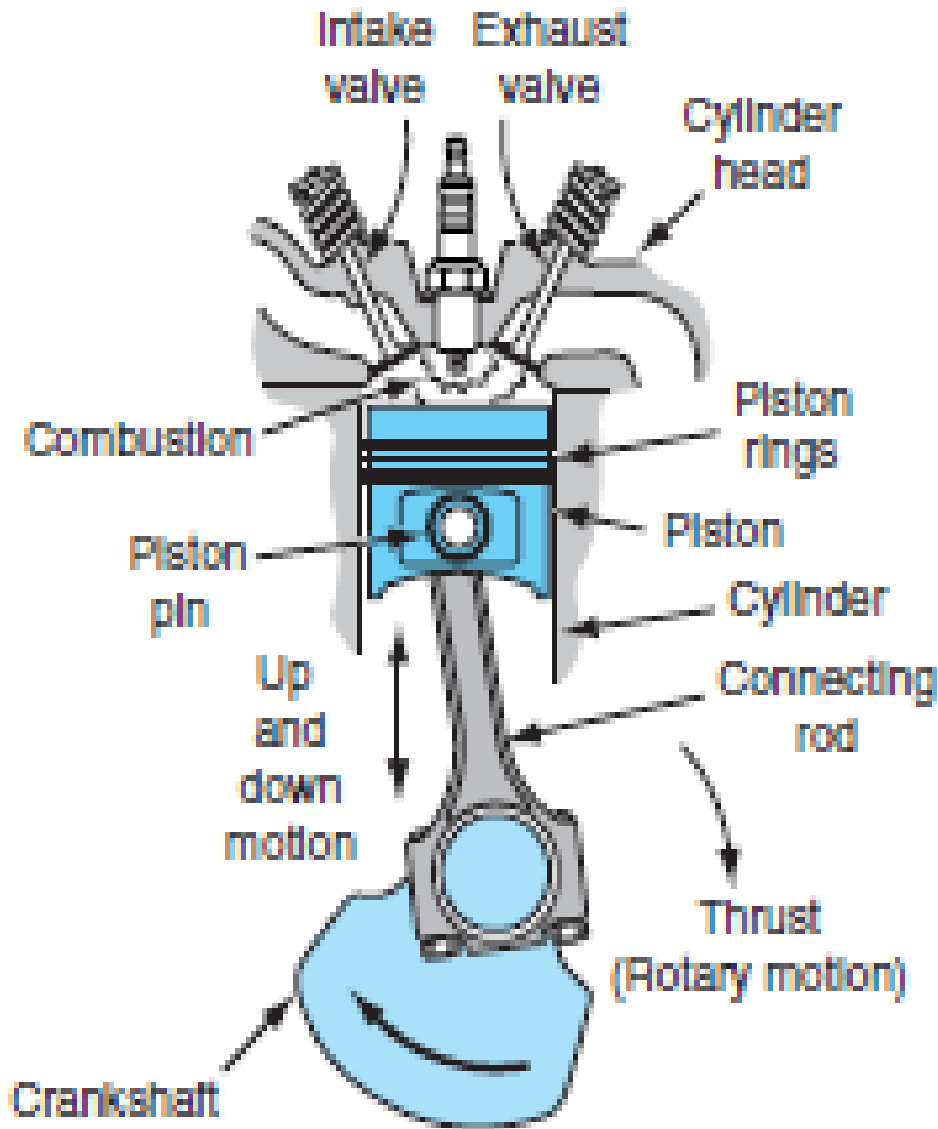






# Engine Parameters

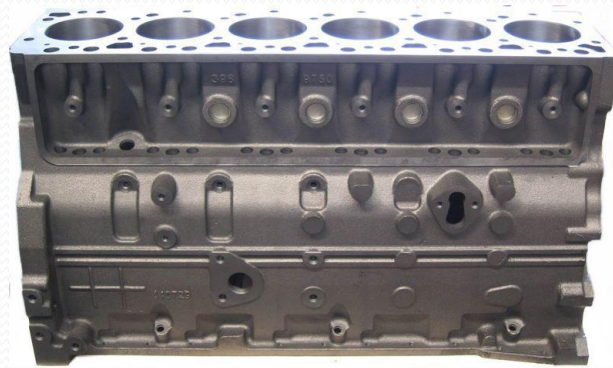
# Engine Parameters



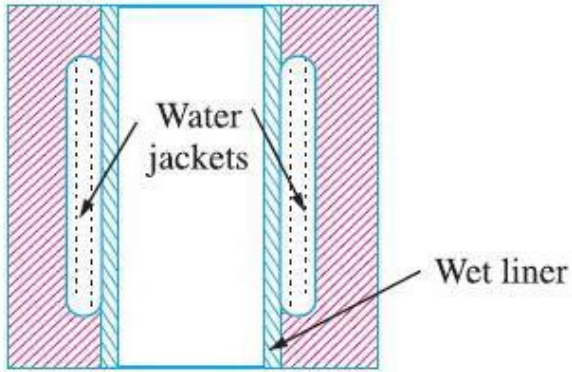


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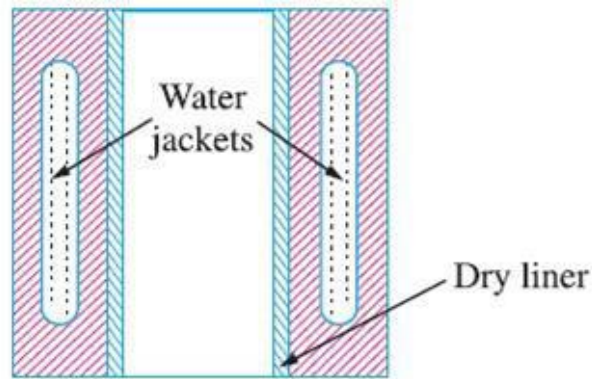
## Cylinder Block:



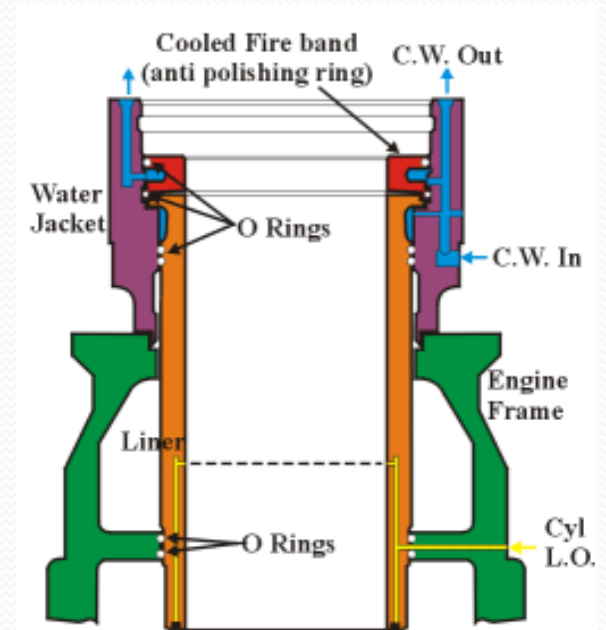
## Cylinders:



(b) Wet liner.

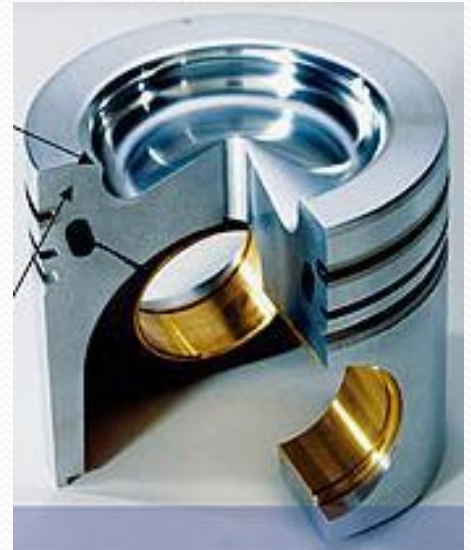


(a) Dry liner.

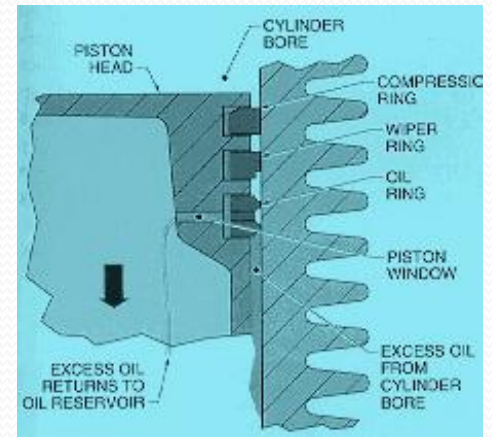
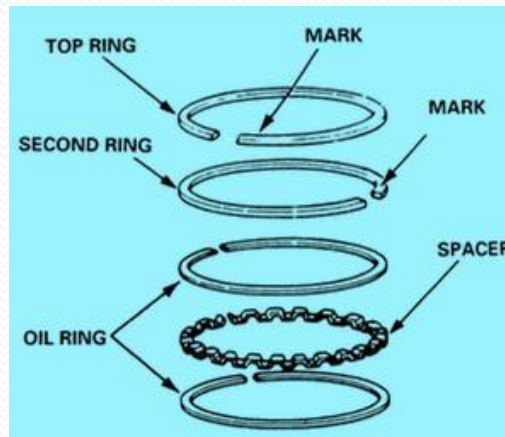


# Engine Parameters

**Piston:**

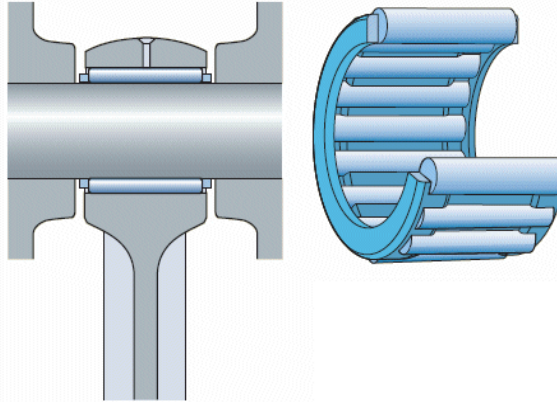
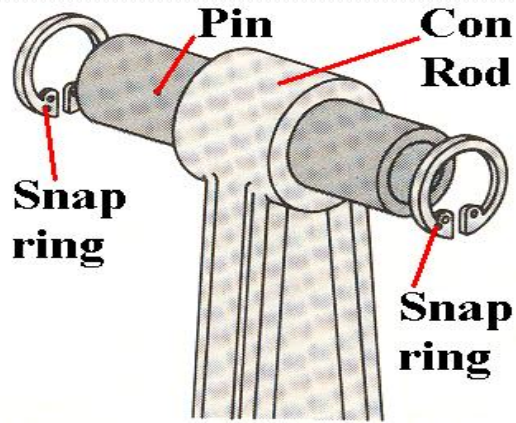


**Piston Rings:**

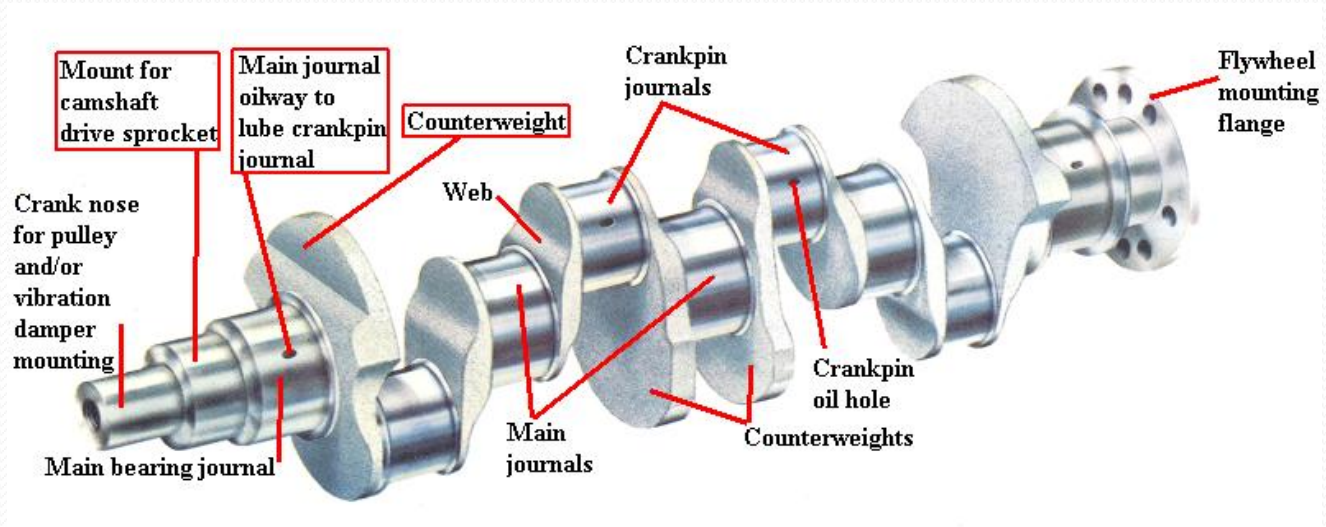


# Engine Parameters

## Gudgeon Pin (*wrist pin or piston pin*):



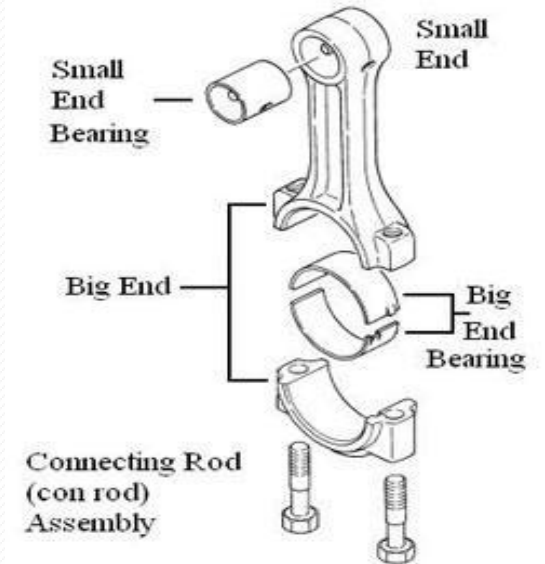
## Crankshaft:



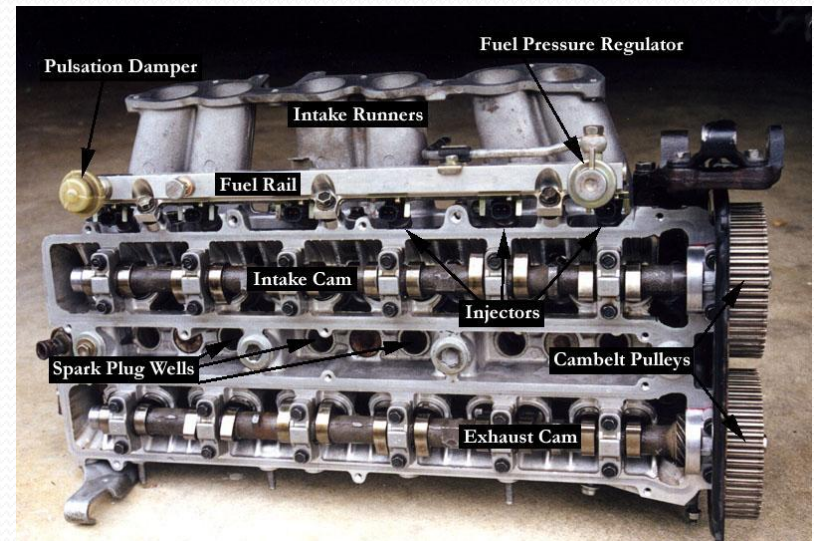
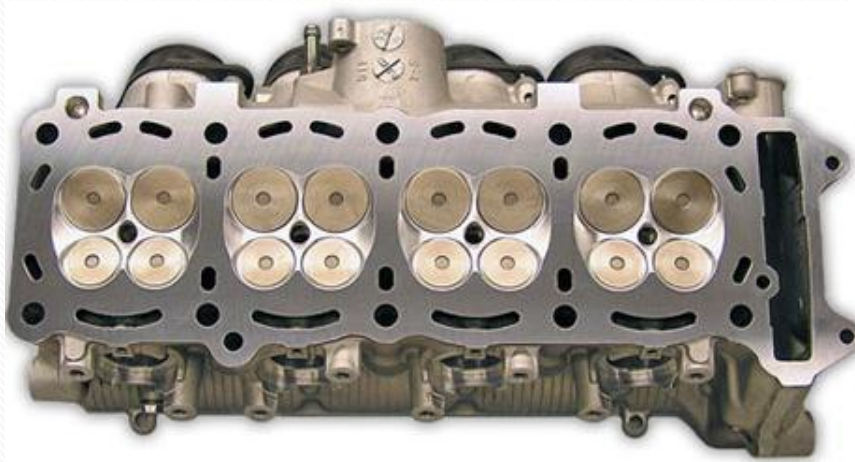


# Engine Parameters

## Connecting Rod:



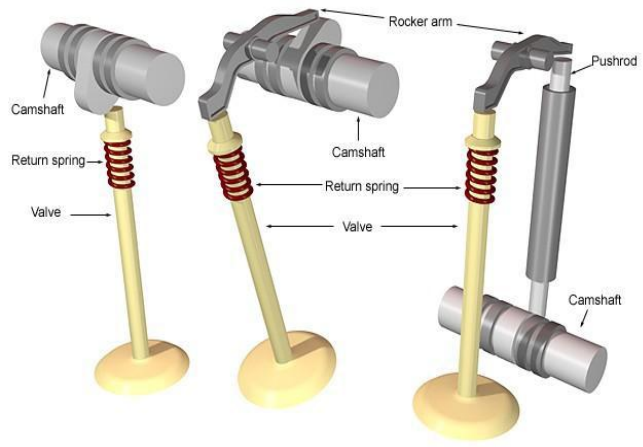
## Cylinder Head:



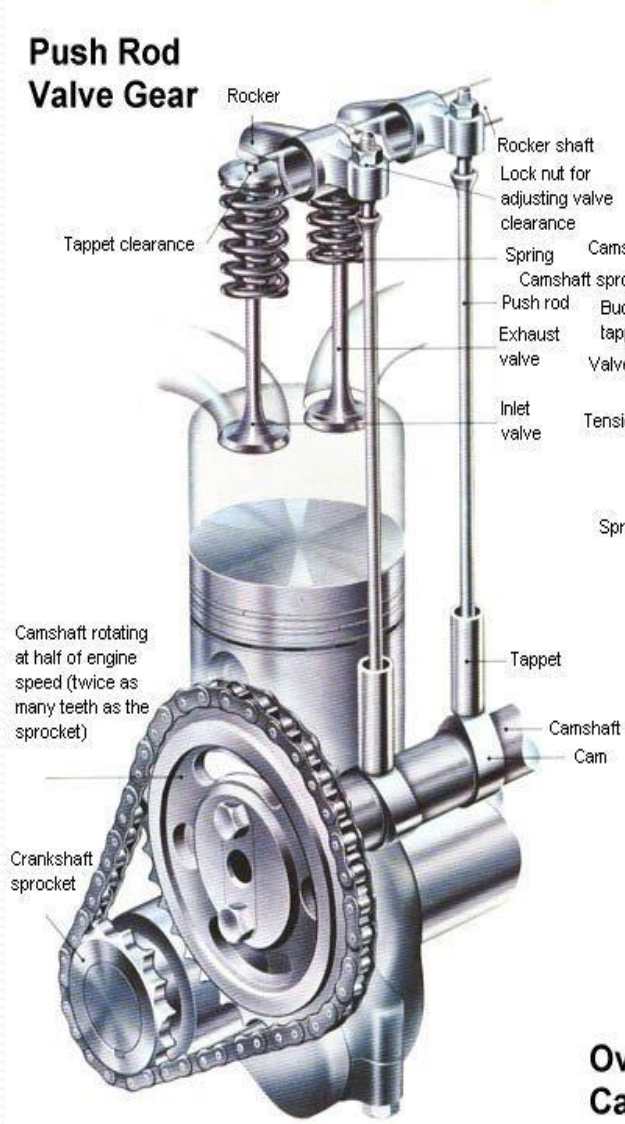


# Engine Parameters

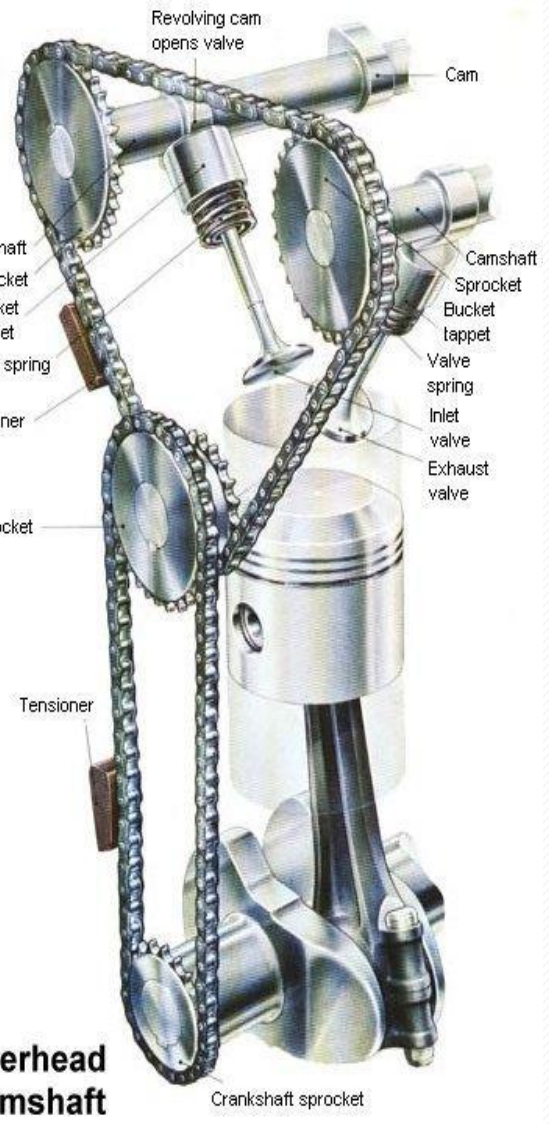
## Camshaft:



## Push Rod Valve Gear

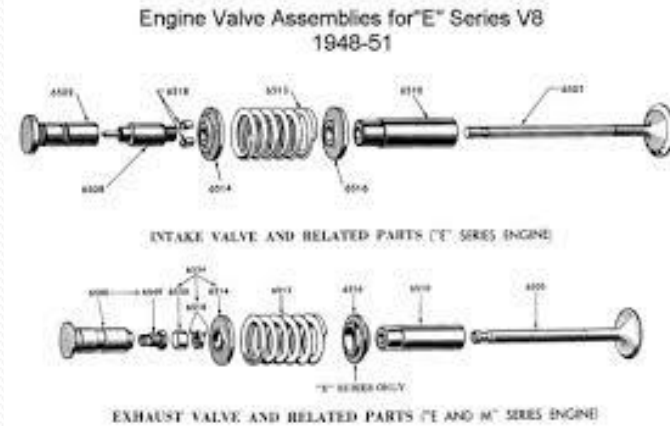


## Overhead Camshaft



# Engine Parameters

## Engine Valves:

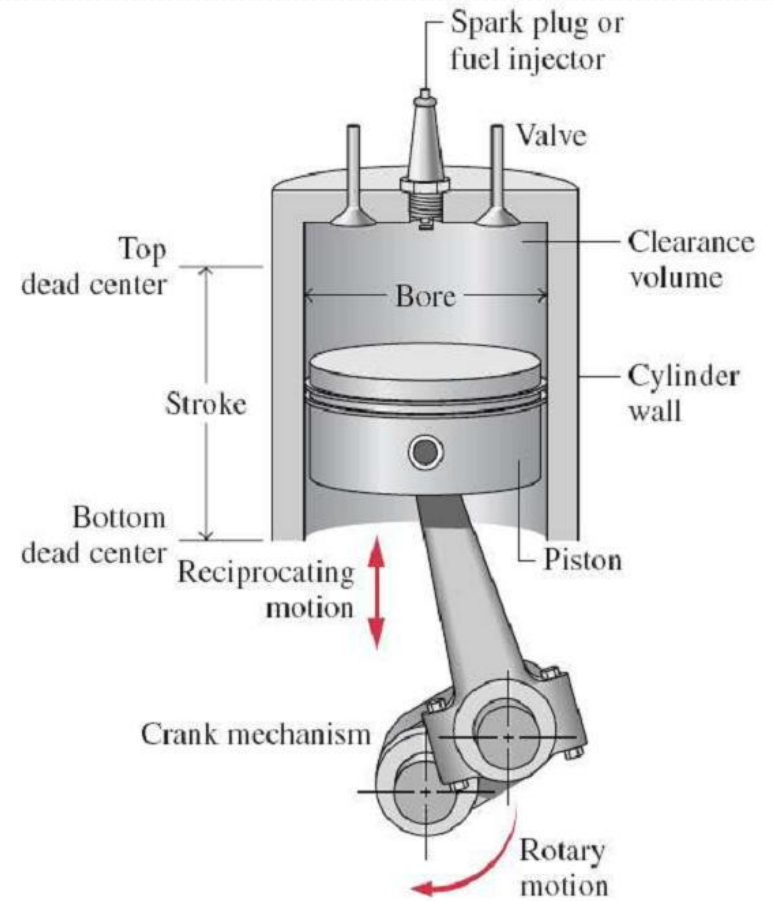
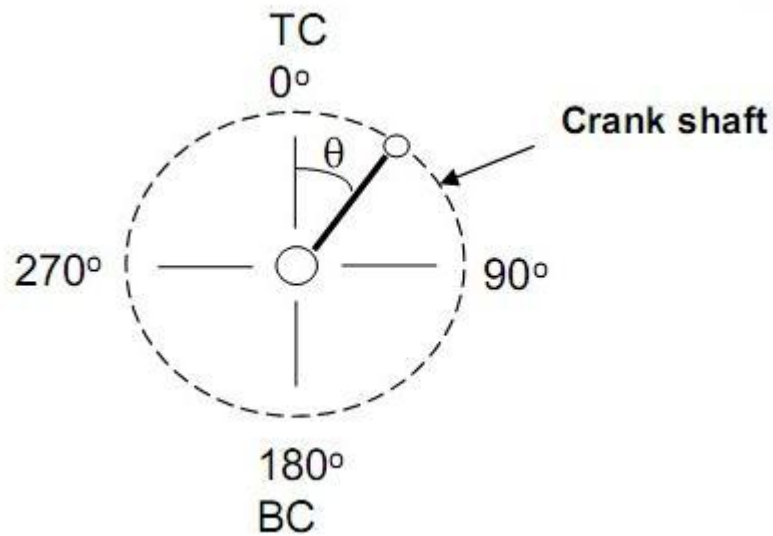






# Engine Terminology

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# Engine Terminology

**Bore (d)**: the inside diameter of the cylinder.

**Stroke Volume**: the displacement volume swept by the piston in one stroke and is equal to the product of the inner cross-sectional area of the cylinder and the stroke length of the piston.

$$V_d = V_{BDC} - V_{TDC} = \left(\frac{\pi}{4}\right)D^2 L$$

**Clearance Volume**: the volume of the compressed charge which is also the volume contained in the cylinder above the top or crown of the piston when the piston is at TDC.

**Compression Ratio**: the ratio between the total volume to the clearance volume.

**The mean effective pressure: (mep)**

The mean effective pressure is the average pressure on the piston during the working stroke and is obtained by dividing the work per cycle by the cylinder volume displaced per cycle.

$$mep = \frac{W}{V_d}$$



## Firing order:

- The firing order is the sequence of power delivery of each cylinder in a multi-cylinder reciprocating engine.
- This is achieved by sparking of the **spark plugs** in a gasoline engine in the correct order. Or by the sequence **of fuel injection** in a diesel engine.
- When designing an engine, choosing an appropriate firing order is critical to minimizing vibration and achieving smooth running, for long engine fatigue life and user comfort, and heavily influences crankshaft design.

**ملاحظة:** عند ترتيب الاسطوانات للاحتراق يجب عدم جعل ترتيب الحريق بالتتابع لترتيب الاسطوانات فى المحرك و ذلك:  
• ليتم توزيع الحرارة على اجزاء المحرك كلها ولا تتداد فى جزء عن الاخر.  
• ليتم توزيع الضغط فى المحرك على عمود المرفق فلا يودى الى احداث اهتزاز كبير فى المحرك.

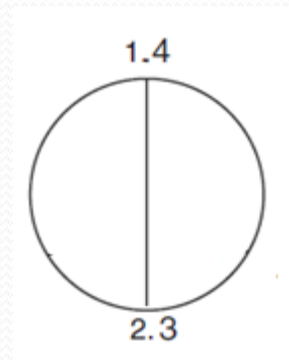
# Engine Terminology

## In case of 4 cylinder engine:

the four crankpins are in one plane, 180° opposed. Since two pistons each are at the extreme position, the inline design permits following firing orders: 1-3-2-4 or 1-3-4-2

firing order				
1. cylinder	work	exhaust	intake	compression
2. cylinder	intake	compression	work	exhaust
3. cylinder	compression	work	exhaust	intake
4. cylinder	exhaust	intake	compression	work
half a revolution of crank-shaft				

firing order				
1. cylinder	work	exhaust	intake	compression
2. cylinder	intake	compression	work	exhaust
3. cylinder	exhaust	intake	compression	work
4. cylinder	compression	work	exhaust	intake
half a revolution of crank-shaft				

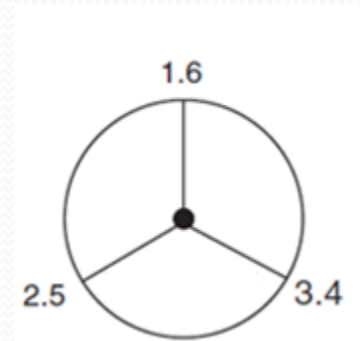


# Engine Terminology

**In case of 6 cylinder engine:**

the crankpins are in one plane, 120° apart. The inline design permits following firing orders: 1-5-3-6-2-4 or 1-4-2-6-3-5

Firing order													
1. cylinder	work		exhaust			intake			compression				
2. cylinder	exhaust		intake			compression			work		exh		
3. cylinder	int.	compression			work			exhaust		intake			
4. cylinder	work		exhaust			intake			compression		work		
5. cylinder	compression		work			exhaust			intake		com.		
6. cylinder	intake			compression			work			exhaust			
Crank shaft	0	60	120	180	240	300	360	420	480	540	600	660	720



# Comparison of SI and CI Engines:

NO	Description	SI Engine	CI Engine
1	Basic cycle	Operated on Otto cycle.	Operated on Diesel cycle
2	Fuel Used	Gasoline fuel, highly volatile fuel and self ignition temperature	Diesel, on- volatile, lower self ignition temp.
3	Induction of fuel	A gaseous mixture of fuel and air is introduced during suction stroke. Carburetor or injector are necessary	Fuel is injected inside the cylinder at high pressure near the end of compression stroke by fuel pump and injector
4	Load control	Quantity control by throttle	Quality control
5	Ignition	Requires an ignition system with spark plug in the combustion chamber.	The injected fuel ignited due to the high pressure and temp. of air at the end of compression stroke.
6	Compression ratio	Operating at range of 6-11. Upper is limited by detonation	Operating at range of 12-24. Upper limit is limited by weight increase of the engine
7	Thermal efficiency	Lower due to the lower comp. ratio	Higher due to the comp. ratio
8	Weight	Lighter than Diesel. Due to lower comp. ratio and lower max press., the cylinder dimension and weight be small.	Heavier than Petrol. Because it has high comp. ratio and higher max pressure so that the cylinder thickness be high and heavier for the same power.
9	Air/Fuel ratio	10:1 to 20:1	18:1 to 100:1 or more according to the load on the engine
10	Operating speed	Up to 6000 r.p.m or more	Low speed 400 r.p.m, medium 400-1200 r.p.m, high speed 1200 to 3500 r.p.m or more
11	Weight per unit power	Low (0.5 to 4.5 kg/kW).	High (3.3 to 13.5 kg/kW).
12	Exhaust gas temperature.	High due to the lower thermal effic.	High due to high thermal effic.
13	Uses	Small passenger cars, scooters, motor cycles, small aircrafts, motor boats	Railway locomotive, heavy commercial road vehicles, ships motor boats, power generation.



# Comparison Four Stroke and Two Stroke Cycle Engines:

No	Criteria of comparison	2- stroke engine	4- stroke engine
1	Power Stroke	One working stroke in each cylinder per revolution of the crankshaft	One working stroke in each cylinder per two revolution of the crankshaft
2	Thermal efficiency	Thermal efficiency lower, part load efficiency lesser than four stroke cycle engine. In two stroke engines some fuel is exhausted during scavenging	Thermal efficiency higher, part load efficiency better than two stroke cycle engine
3	Weight and size	Lighter and compact for the same power	Heaver and larger
4	Volumetric efficiency	Volumetric efficiency less due to lesser time of induction	Volumetric efficiency more due to greater time of induction
5	Flywheel size	Smaller	Larger
6	Turning moment	More uniform turning moment and hence lighter flywheel is needed	Turning moment is not uniform and hence heavier flywheel is needed
7	Mechanical efficiency	More due to lesser moving parts	Lesser
8	Construction	Simpler and easy to manufacture	More complicated due to valves and valves mechanism
9	Scavenging	Required and done by fresh charge	More efficient
10	Fuel consumption	More fuel consumption for the same power	Less for the same power
11	Cooling and lubrication	Greater cooling and lubrication .Great rate of wear and tear	Lesser cooling and lubrication. Lesser rate of wear and tear
12	Applications	Used where cost and weight low. Scooters motors cycles lawn movers. Large sizes diesel engine	Cars, buses, trucks, tractors, industrial engines, aero plane, power generation