Introduction

Heat Engine:

- Heat Engine is a machine which converts heat energy supplied to it into mechanical work.
- Heat energy is supplied to the engine by burning the fuel.

Classification of Heat Engines

- **Internal Combustion Engines (IC Engines)**

In IC engines, combustion of fuel takes place inside the engine cylinder.

Examples: Diesel Engines, Petrol Engines, Gas engines.

- **External Combustion Engines (EC Engines)**

In EC engines, combustion of fuel takes place outside the working cylinder.

Examples: Steam Engines and Steam turbines

The Internal Combustion Engine

Classification of IC Engines

IC Engines are classified into,

(1) Cycle of operation (No of Strokes per cycle)

- Two Stroke cycle Engines
- Four Stroke Cycle Engines

(2) Thermodynamic Cycle or Method of Heat addition:

- Otto Cycle Engines (Combustion at constant volume)
- Diesel Cycle Engines (Combustion at constant Pressure)
- Semi Diesel Engines (Dual Combustion Engines)

Classification of IC Engines

(3) Types of Fuel Used :

- **Petrol Engines**
- **Diesel Engines**
- **Gas Engines**

(4) Ignition Method :

- **Spark Ignition (SI)**
- **Compression Ignition (CI)**

Classification of IC Engines

(5) Cooling System:

- Air cooled Engines
- Water Cooled Engines

(6) Valves Location :

- L head (Side valve) engine
- T Head (Side valve) engine
- I head (over head valve) engine
- F head (over head inlet and side exhaust) engine

I.C ENGINE TERMINOLGOGY

The standard terms used in I.C Engines are

1. **Bore:** Inside diameter of the cylinder is termed as Bore.
2. **Top Dead Center (TDC):** The extreme position reached by the piston at the top of the cylinder in the vertical engine is called Top Dead center.
3. **Bottom Dead Center (BDC):** The extreme position reached by the piston at the Bottom of the cylinder in the vertical engine is called Bottom Dead center.

I.C ENGINE TERMINOLGOGY

4. Stroke: The nominal distance travelled by the piston in the cylinder between the extreme upper and lower positions of the piston (TDC &BDC) is termed as stroke.

5. Compression ratio (r): It is the ratio of Maximum cylinder volume to the Clearance volume.

6. Cylinder volume (v): It is the sum of swept volume and the Clearance volume.

$$V = Vs + Vc$$

I.C ENGINE TERMINOLGOGY

7. Swept volume (Vs): It is the volume of space generated by the movement of piston from one dead center to another dead center.

8. Clearance Volume(Vc): It is the space in the cylinder, when the piston is at Top Dead Center

Main Components of IC Engine

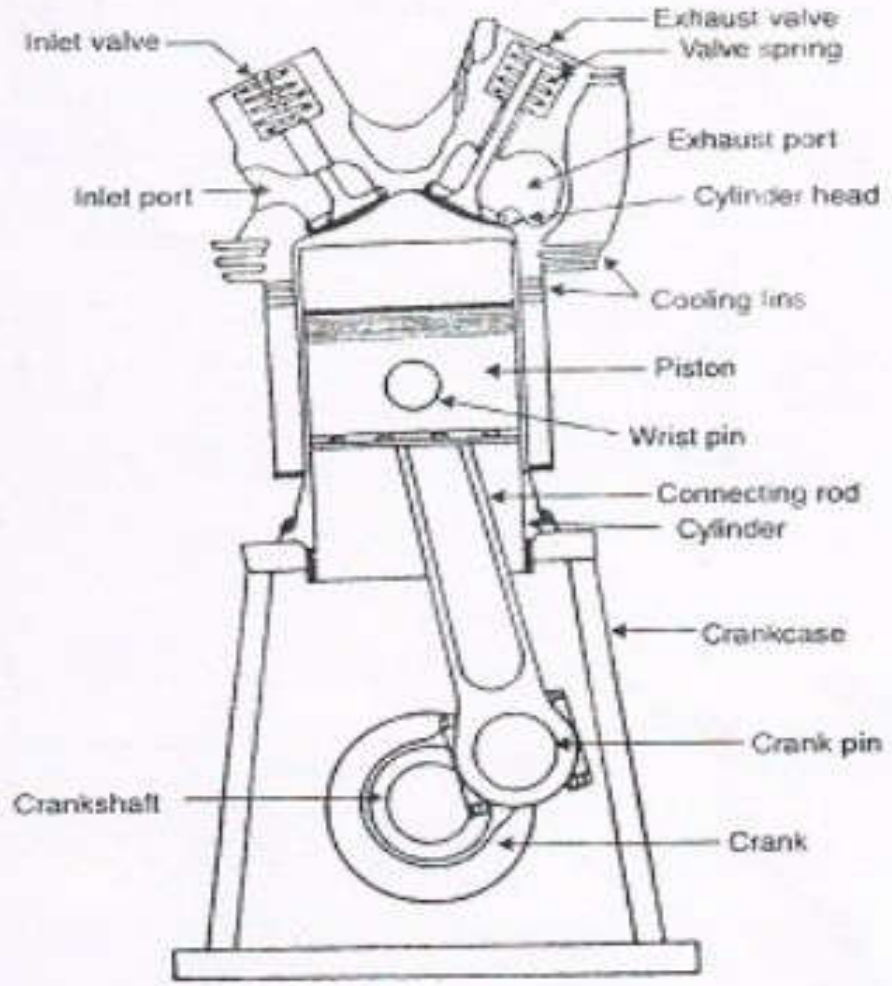


Fig. Air-cooled I.C. engine

Main Components of IC Engines

Cylinder Block:

- It is the main block of the engine.
- It contains cylinders accurately finished to accommodate pistons
- The cylinder block houses crank, camshaft, piston and other engine parts.
- In water cooled engines, the cylinder block is provided with water jackets for the circulating cooling water.
- The materials used for cylinder are grey cast iron, aluminium alloys etc.,
- It is usually made of a single casting

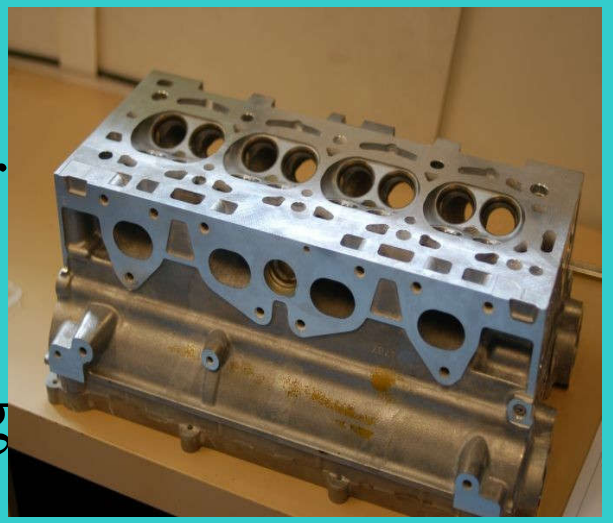
Main Components of IC Engines

Cylinder block of motor cycle

Cylinder block of Car

Main Components of IC Engines

Cylinder Head:



- The cylinder head is bolted to the cylinder Block by means of studs.
- The water jackets are provided for cooling water circulation.
- The materials used for cylinder head are cast iron, aluminium alloy etc.,
- This is also generally made of single cast iron.

Main Components of IC Engines

Cylinder Liners:

The liner is a sleeve which is fitted into the cylinder bore.

It provides wear resisting surface for the cylinder bores.

Liners are classified into

(a) Wet liner (b) Dry liner

Main Components of IC Engines

Cylinder Liners

Wet Liner : These liners are surrounded or wetted by cooling water.

It provides wear resisting

surface for the piston to reciprocate.

Also it acts as a seal for the water jacket.

Main Components of IC Engines

Dry Liner : Dry liners have metal to metal contact with the cylinder block. They are not directly in touch with the cooling water.

Liner Materials:

- Liner material should withstand abrasive wear and corrosive.
- Chromium plated mild steel tubes are used as liners.

Main Components of IC Engines

Crankcase :

It may be cast integral with the cylinder block.

Some times, it is cast separately and then attached to the block.

These materials are used for crank case are cast iron, aluminium alloys or alloy steels.

Main Components of IC Engines

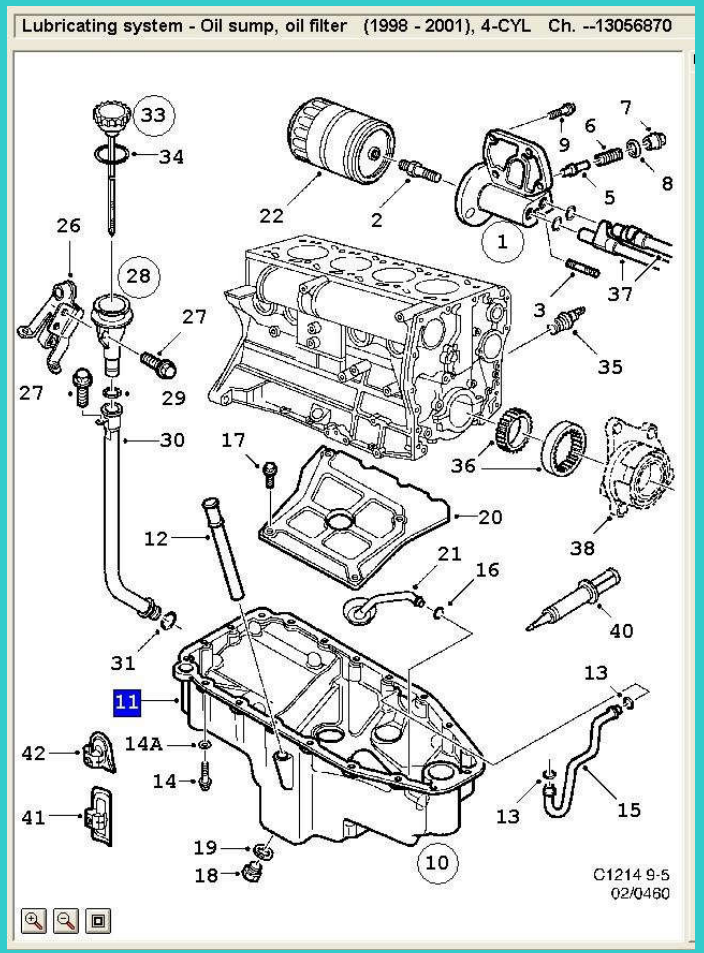
Oil pan or oil sump:

Oil sump is the bottom part of the engine.

It contains lubricating oil.

A drain plug is provided the oil sump to drain out the oil.

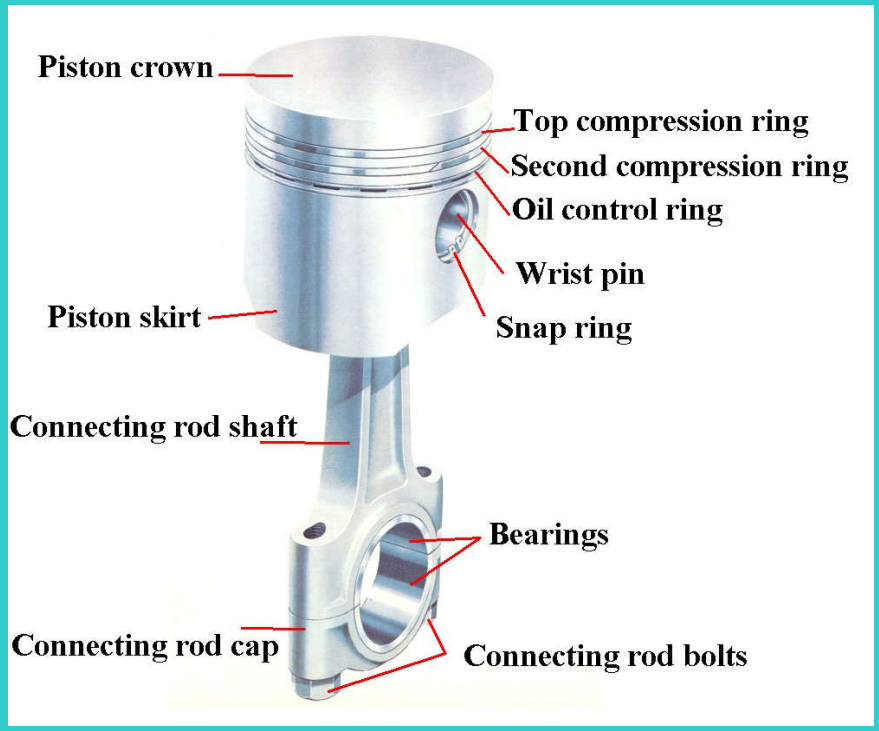
It is made of the pressed sheet.



Main Components of IC Engines

Piston :

The piston serves the following purposes



- It acts as a movable gas tight seal to keep the gases inside the cylinder
- It transmits the force of explosion in the cylinder to the crankshaft through the connecting rod.
- Some of the materials used for piston are cast iron, aluminium alloy, chrome nickel alloy, nickel iron alloy and cast steel.

Main Components of IC Engines

Piston rings :

Piston rings are inserted in the grooves provided in the piston. Two types of piston rings are used in the piston.

1. Compression rings
2. Oil rings or oil control rings

Main Components of IC Engines

Compression rings :

- Compression rings provide an effective seal for the high pressure gases inside the cylinder.
- They prevent the leakage of high pressure gases from the combustion chamber into the crank case.
- Each piston is provided with atleast
- two compression rings.

Main Components of IC Engines

Oil rings :

- Oil rings wipe off the excess oil from the cylinder walls.
- It also returns excess oil to the oil sump, through the slots provided in the rings.

The materials used for piston rings should be wear resistant.

Normally piston rings are made of alloy steel iron containing silicon, manganese alloy steels etc.,

Main Components of IC Engines

Connecting Rod:

- It connects the piston and crank shaft.
- It transmits the force of explosion during power stroke to the crankshaft.
- The connecting rod has bearings at both ends.
- The small end of the connecting has a solid or split eye and contains a bush.
- This end is connected to the piston by means of a gudgeon pin.
- The other end is called as big end of the connecting rod.
- The connecting rods must withstand heavy thrusts.
- Hence it must have strength and rigidity.
- They are usually drop forged I sections.
- The materials used are plain carbon steel, aluminium alloys, nickel alloy steels etc,

Main Components of IC Engines

Crank Shaft :

- It is the main rotating shaft of the engine.
- Power is obtained from the crank shaft.
- **The crank shaft is combination with connecting rod converts reciprocating motion of the piston into rotary motion.**
- The crank shaft is held in position by the main bearings.
- There are two main bearings to support the crank shaft.
- The materials used for crank shaft are billet steel, carbon steel, nickel chrome and other heat treated alloy steels.

Main Components of IC Engines

Camshaft:

- Camshaft contains number of cams.
- It is used to convert rotary motion into linear or straight line motion.
- It has so many cams as the number of valves in an engine.
- An additional cam is also provided to drive the fuel pump.
- A gear is provided in the cam shaft to drive the distributor or oil pump.
- The opening and closing of the engine valves are controlled by the cams provided on the cam shaft.

Petrol Engines

Classification of Petrol Engines

- Two Stroke cycle Petrol Engines
- Four Stroke cycle petrol Engines

Four stroke cycle Petrol Engines

Construction :

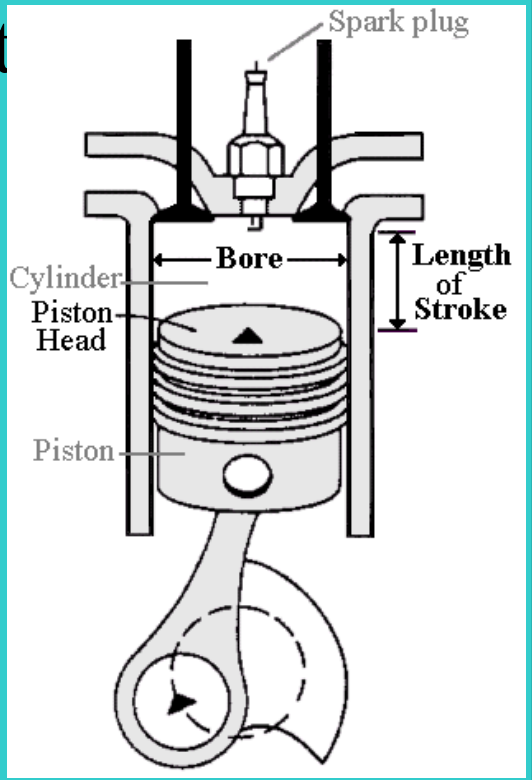
•A piston reciprocates inside the cylinder

•The piston is connected to the crank shaft by means of a connecting rod and crank.

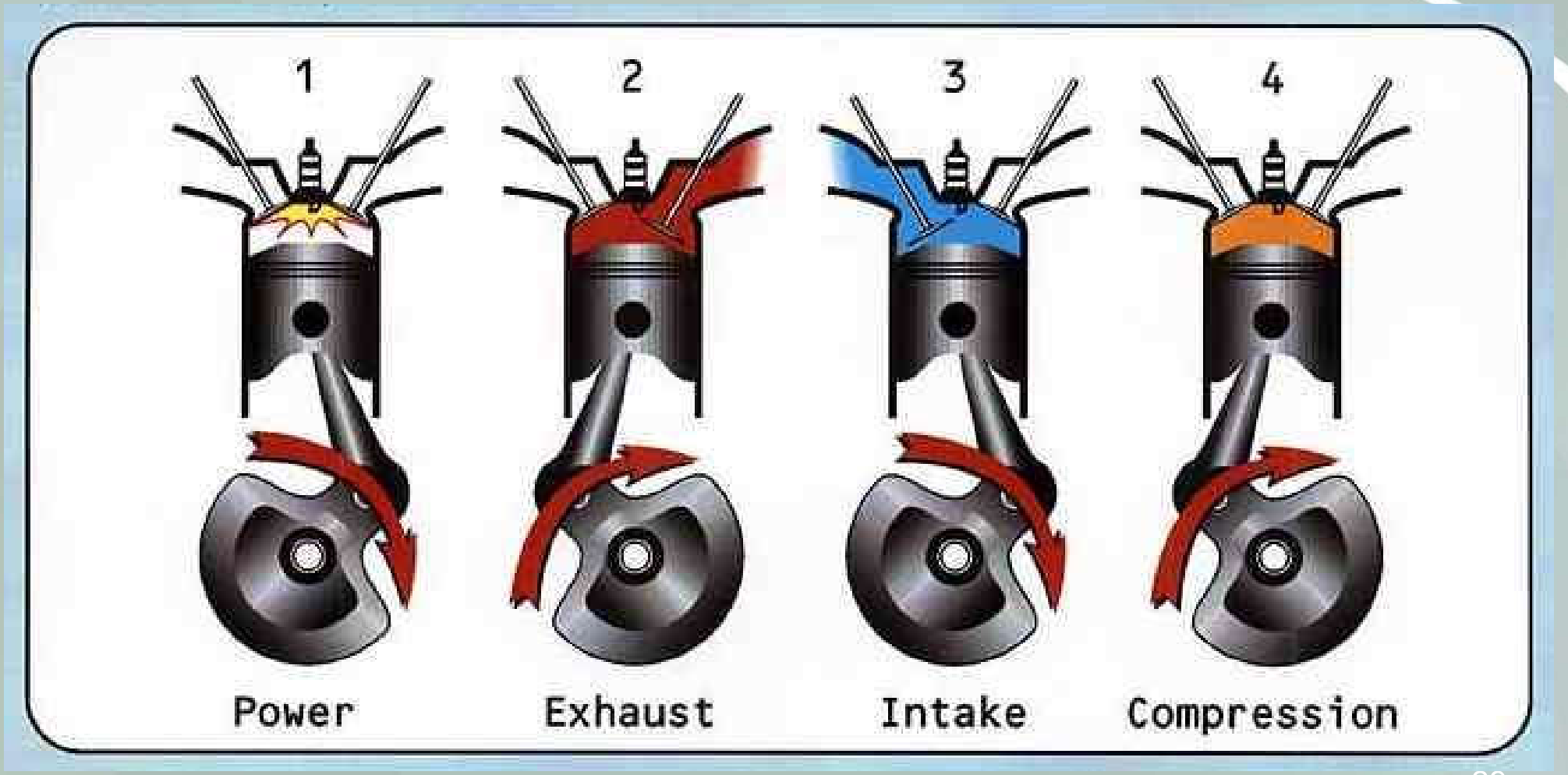
• The inlet and exhaust valves are Mounted on the cylinder head.

•A spark is provided on the cylinder Head.

• The fuel used is petrol



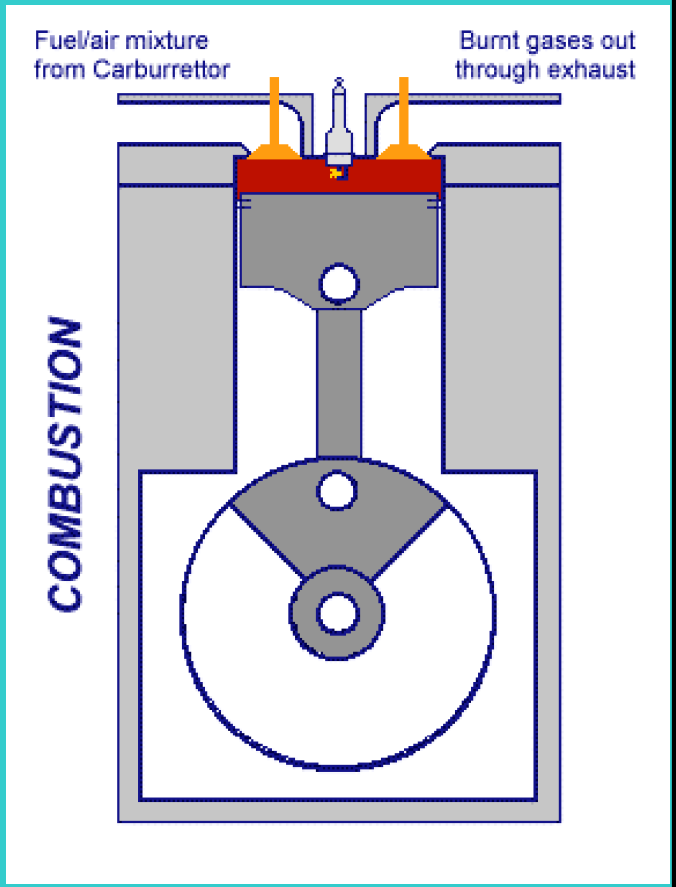
Four Stroke Petrol Engine- Working



Four Stroke Petrol Engine - Working

(a) Suction Stroke (First Stroke of the Engine)

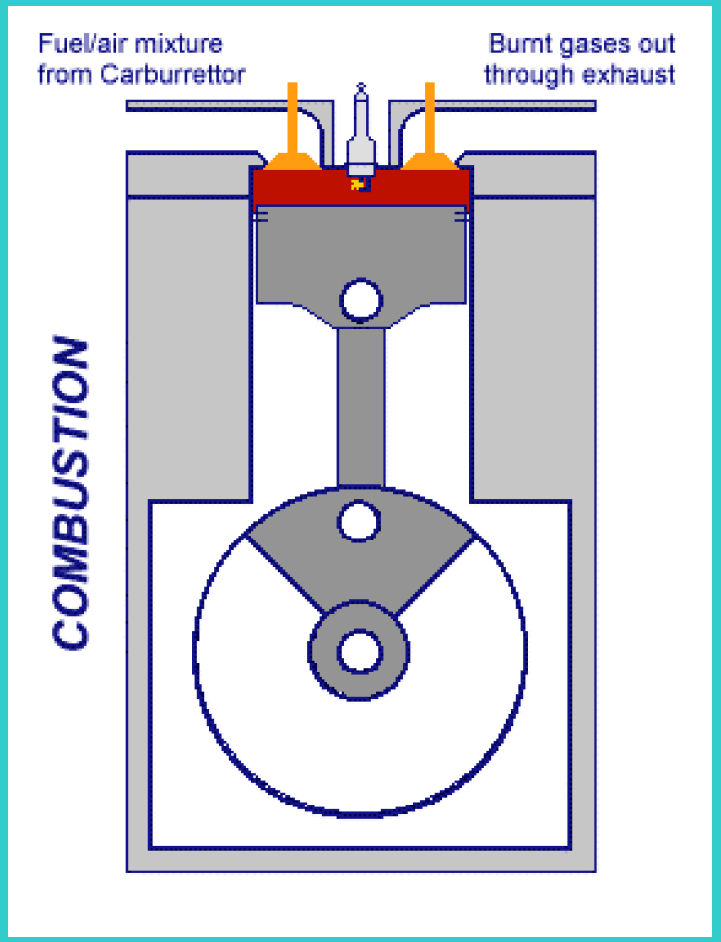
- Piston moves down from TDC to BDC
- Inlet valve is opened and the exhaust valve is closed.
- Pressure inside the cylinder is reduced below the atmospheric pressure.
- The mixture of air fuel is sucked into the cylinder through the inlet valve



Four Stroke Petrol Engine - Working

(b) Compression Stroke : (Second Stroke of the piston)

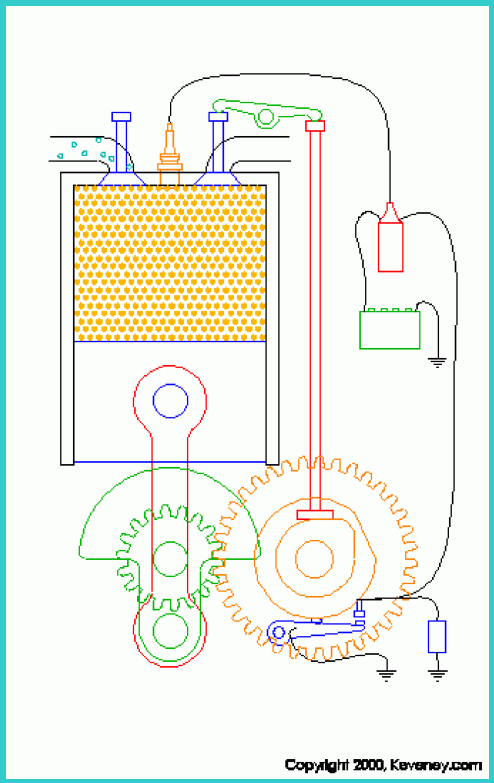
- Piston moves up from BDC to TDC
- Both inlet and exhaust valves are closed.
- The air fuel mixture in the cylinder is compressed.



Four Stroke Petrol Engine - Working

(c) Working or Power or Expansion Stroke: (Third Stroke of the Engine)

- The burning gases expand rapidly. They exert an impulse (thrust or force) on the piston. The piston is pushed from TDC to BDC
- This movement of the piston is converted into rotary motion of the crankshaft through connecting rod.
- Both inlet and exhaust valves are closed.

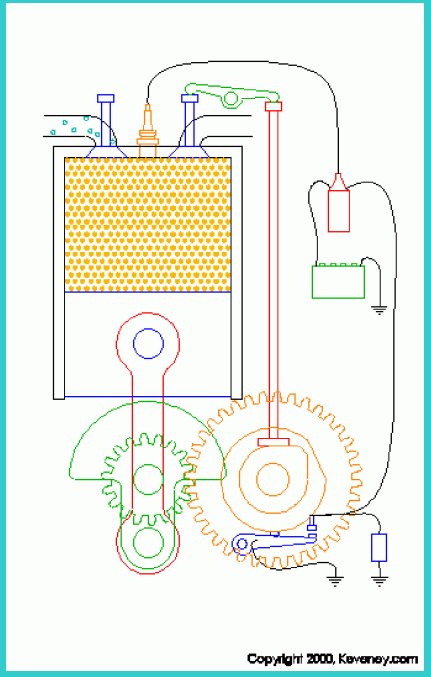


Four Stroke Petrol Engine - Working

(d) Exhaust Stroke (Fourth stroke of the piston)

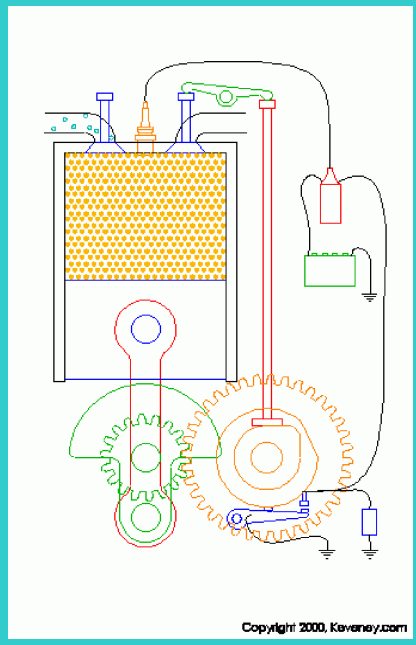
- Piston moves upward from BDC
- Exhaust valve is opened and the inlet valve is closed.
- The burnt gases are forced out to the atmosphere through the exhaust valve (Some of the burnt gases stay in the clearance volume of the cylinder)
- The exhaust valve closes shortly after TDC
- The inlet valve opens slightly before TDC

and the cylinder is ready to receive fresh charge to start a new cycle.

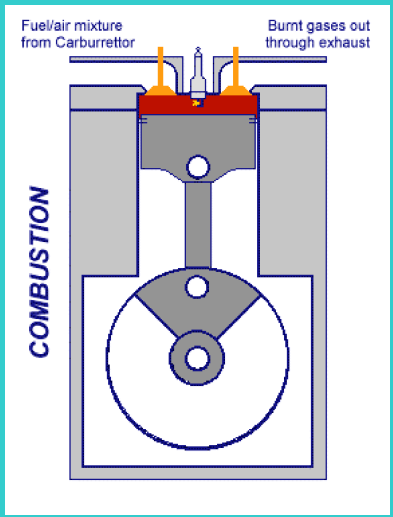


Four Stroke Petrol Engine - Working

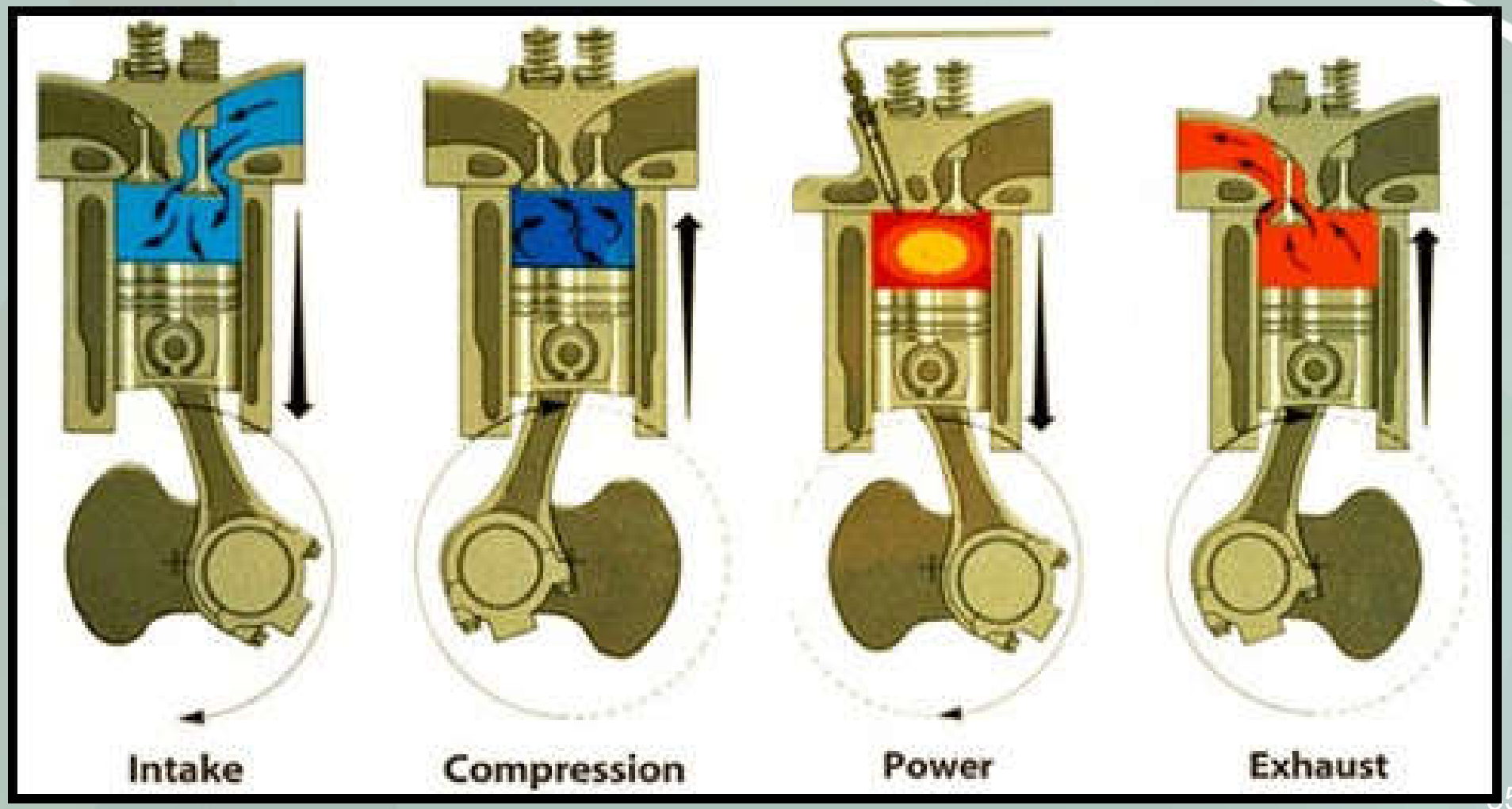
Summary :



- Compression ratio varies from 5 to 8
- The pressure at the end of compression is about 6 to 12 bar.
- The temperature at the end of the compression reaches 250^{o} C to 350^{o} C



Four Stroke Diesel Engine



Four Stroke Diesel Engine

Construction:

- A piston reciprocates inside the cylinder
- The piston is connected to the crankshaft by means of a connecting rod and crank.
- The inlet and exhaust valves are mounted on the cylinder head.
- A fuel injector is provided on the cylinder head
- The fuel used is diesel.

Four Stroke Diesel Engine - Working

(a) Suction Stroke (First Stroke of the piston)

- Piston moves from TDC to BDC
- Inlet valve is opened and the exhaust valve is closed.
- The pressure inside the cylinder is reduced below the atmospheric pressure.
- Fresh air from the atmosphere is sucked into the engine cylinder through air cleaner and inlet valve.

Four Stroke Diesel Engine - Working

(b) Compression stroke (Second stroke of the piston)

- Piston moves from BDC to TDC
- Both inlet and exhaust valves are closed.
- The air is drawn during suction stroke is compressed to a high pressure and temperature

Four Stroke Diesel Engine - Working

(c) Working or power or expansion stroke (Third stroke of the piston)

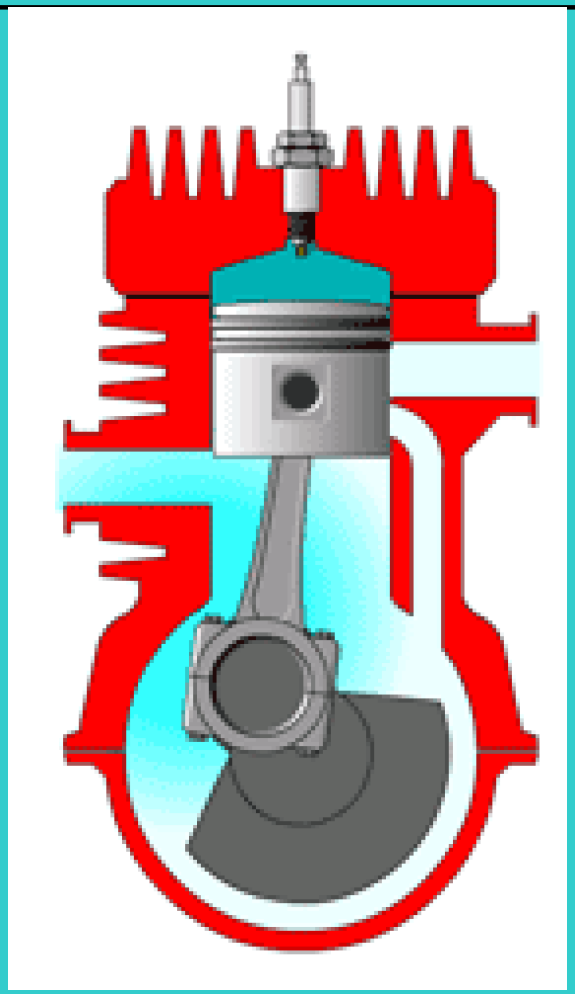
- The burning gases (products of combustion) expand rapidly.
- The burning gases push the piston move downward from TDC to BDC
- This movement of piston is converted into rotary motion of the crank shaft through connecting rod.
- Both inlet and exhaust valves are closed.

Four Stroke Diesel Engine - Working

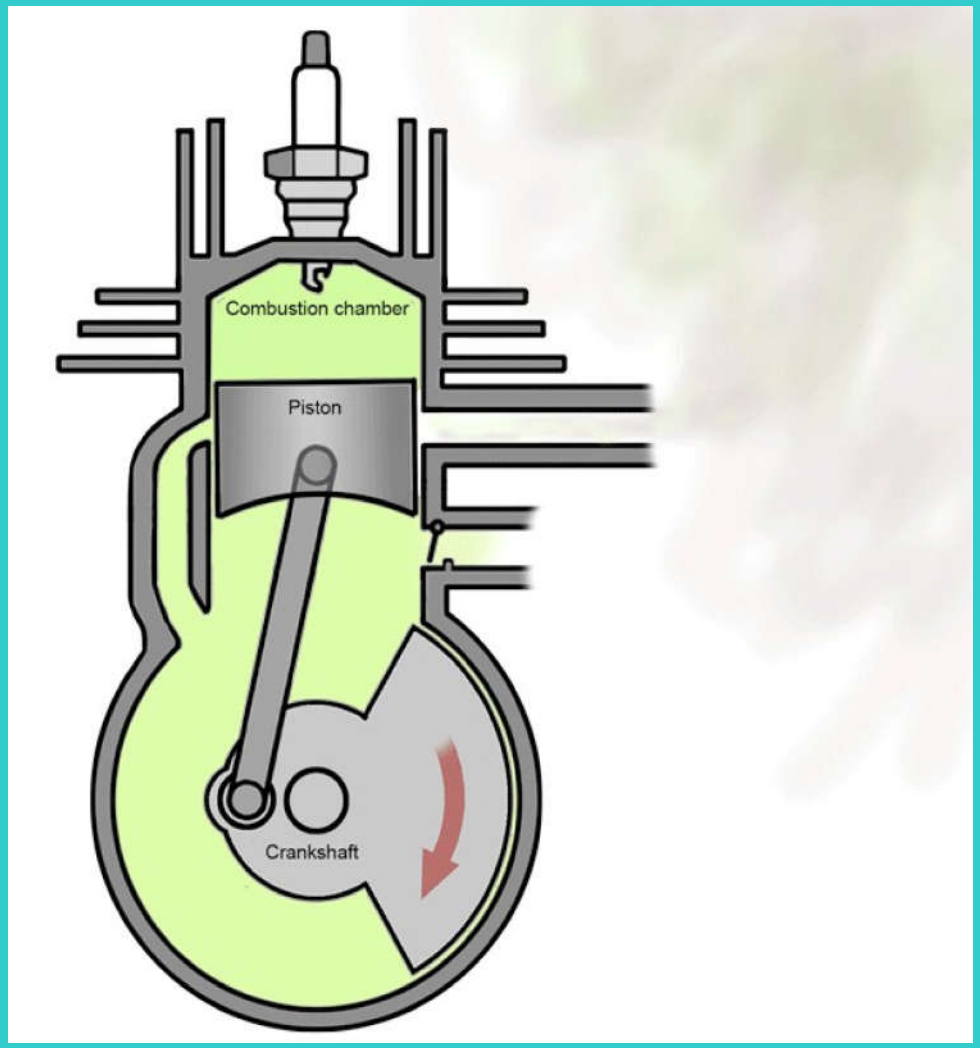
(d) Exhaust Stroke (Fourth stroke of the piston)

- Piston moves from BDC to TDC
- Exhaust valve is opened the inlet valve is closed.
- The burnt gases are forced out to the atmosphere through the exhaust valve. (some of the burnt gases stay in the clearance volume of the cylinder)
- The exhaust valve closes shortly after TDC
- The inlet valve opens slightly before TDC and the cylinder is ready to receive fresh air to start a new cycle.

Two Stroke cycle Petrol Engines



Two Stroke cycle Petrol Engines working



Two Stroke Cycle Petrol Engine - Construction

Construction :

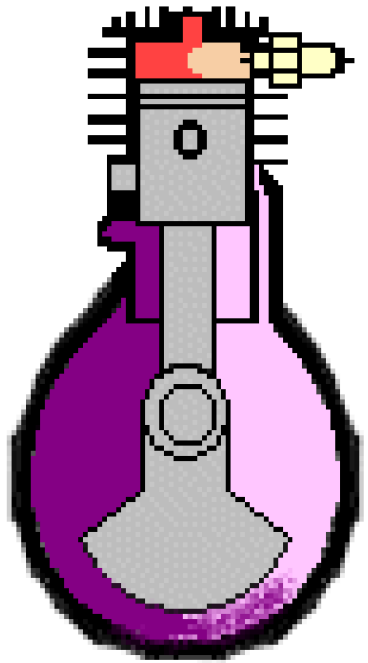
- A piston reciprocates inside the cylinder
- It is connected to the crankshaft by means of connecting rod and crank
- **There are no valves in two stroke engines, instead of valves ports are cut on the cylinder walls.**
- There are three ports, namely **inlet, exhaust** and **transfer** ports.
- The closing and opening of the ports are obtained by the movement of piston. The crown of piston is made in to a shape to perform this.
- A spark plug is also provided.

Two stroke cycle Petrol Engines - Working

First Stroke : (Compression, ignition and inductance) (Upward stroke of piston)

(a) compression:

- The piston moves up from Bottom Dead Centre (BDC) to Top Dead Centre (TDC)
- Both transfer and exhaust ports are covered by the piston.
- Air fuel mixture which is transferred already into the engine cylinder is compressed by moving piston.
- The pressure and temperature increases
- at the end of compression.

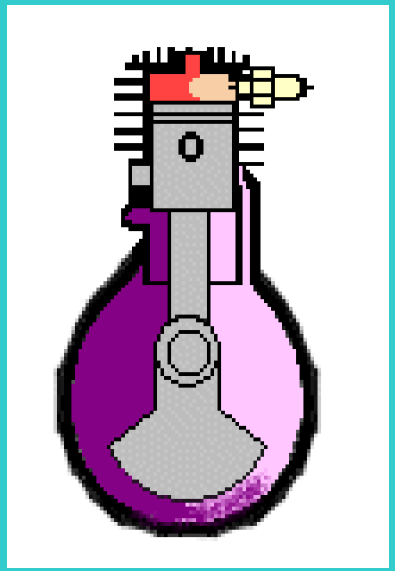


Two stroke cycle Petrol Engines - Working

First Stroke : (Compression, ignition and inductance) (Upward stroke of piston)

(b) Ignition and Inductance:

- Piston almost reaches the top dead centre
- The air fuel mixture inside the cylinder is ignited by means of an electric spark produced by a spark plug
- At the same time, the inlet port is uncovered by the plane.
- Fresh air fuel mixture enters the crankcase through the inlet port.

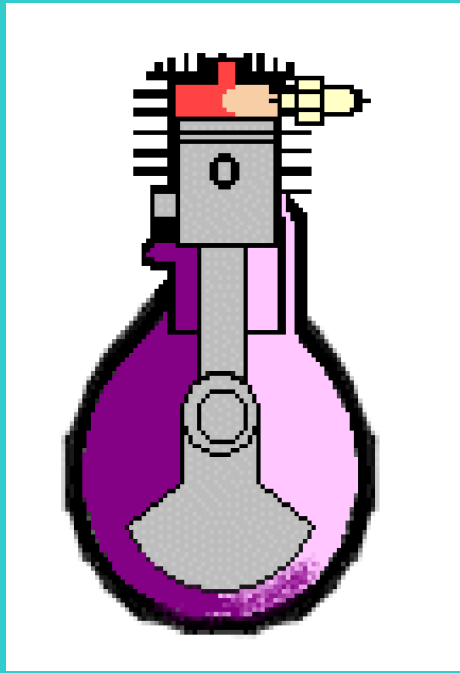


Two stroke cycle Petrol Engines - Working

Second Stroke: (Downward Stroke of the engine) :

(c)Expansion and Crankcase compression

- The burning gases expand in the cylinder
- The burning gases force the piston to move down. Thus useful work is obtained.
- When the piston moves down, the air fuel mixture in the crankcase is partially compressed. This compression is known as ***Crank case compression.***

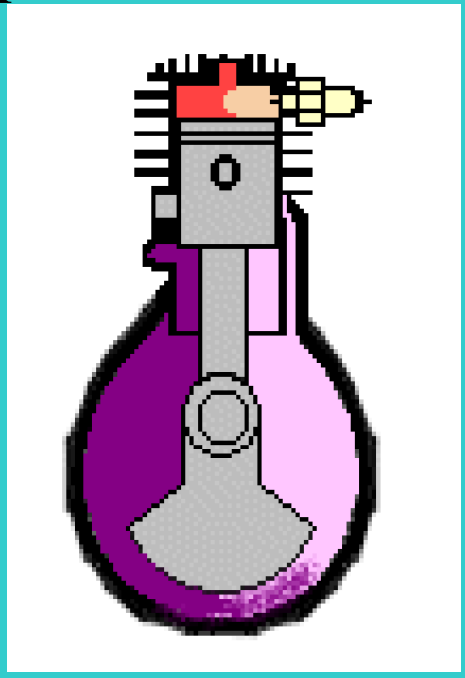


Two stroke cycle Petrol Engines - Working

Second Stroke: (Downward Stroke of the engine) :

(d) Exhaust and transfer:

- At the end of expansion, exhaust port is uncovered.
- Burnt gases escape to the atmosphere.
- Transfer port is also opened. The partially compressed air fuel mixture enters the cylinder through the transfer port.
- The crown of the piston is made of a deflected shape. So the fresh charge entering the cylinder is deflected upwards in the cylinder.
- Thus the escape of fresh charge along with the exhaust gases is reduced.



Two stroke cycle Diesel Engines- Construction

Construction :

- Two stroke cycle diesel engines require air supply
- This air is used to blow out the exhaust gases and to fill the cylinder with clean air
- This air is supplied by a blower or air compressor which is driven by engine itself.
- These engines may be valve or port type.
- A plate is provided in the crank case to admit air into the crank case.
- Transfer and exhaust ports are provided in the cylinder.
- These ports are covered and uncovered by the moving piston.

Two stroke cycle Diesel Engines-Working

First Stroke (Upward Stroke of the piston)

(a) Compression and inductance:

- The piston moves upwards from Bottom Dead Centre (BDC) to Top Dead Centre (TDC).
- Both transfer and exhaust ports are covered.
- Air which is transferred already into the engine cylinder is compressed by moving piston.
- The pressure and temperature of the air increases.
- At the same time, fresh air is admitted into the crankcase through the plate valve (reed valve)

Two stroke cycle Diesel Engines- Working

First Stroke (Upward Stroke of the piston)

(b) Ignition and inductance.

- Piston almost reaches the top dead centre.
- The fuel is injected into the hot compressed air inside the cylinder. The fuel mixed with hot air and burns.
- The admission of fresh air into the crankcase continues till the piston reaches the top centre.

Two stroke cycle Diesel Engines-Working

Second Stroke (Downward Stroke of the piston)

(c) Expansion and crank case compression:

- The burning gases expand in the cylinder.
- Burning gases force the piston to move down. Thus useful work is obtained.
- At the same time, the air in the crank case is compressed by the movement of the piston.
- All the ports and the plate valve are in closed position

Two stroke cycle Diesel Engines- Working

Second Stroke (Downward Stroke of the piston)

(d) Exhaust and Transfer:

- At the end of expansion, the exhaust port is uncovered.
- The burnt escape to the atmosphere through the exhaust port.
- Transfer port is also uncovered shortly after the exhaust port is opened.
- The partially compressed air from crank case enters the cylinder the transfer port.
- This air is deflected upwards by the deflected shape of the piston.
- Thus the entering air helps in forcing out the combustion products from the cylinder
- The plate valve remains during this period.

Scavenging

Scavenging :

- It is the process of forcing out the burnt exhaust gases from the cylinder for admitting the fresh charge into the cylinder.
- This action takes place in the two stroke cylinder.

Scavenging Process

- The charge (air fuel mixture or air) enters the engine cylinder from the crank case at a pressure higher than the exhaust gases.
- This fresh charge forces the exhaust gases to the atmosphere through the exhaust port.
- During the period both the transfer and exhaust ports are kept open for a short period.
- Hence there is a possibility of the fresh charge escaping out with the burnt gases.
- This is over come by designing the piston to have a deflected shape.
- This shape of piston deflects the fresh charge upward in the engine cylinder.
- It also helps out in forcing out the exhaust gases to atmosphere.
- This process is known as **Scavenging.**

Comparison between SI and CI Engines (General Comparison)

S.No.	Spark Ignition Engines (SI)	Compression Ignition Engines (CI)
1	It draws air fuel mixture into the cylinder during suction stroke	It draws only air into the cylinder during suction stroke.
2	Petrol engines operate with low pressure and temperature	Diesel engines operate with high pressure and temperature
3.	Pressure ranges from 6 to 12 bar Temperature ranges from 250^{o} to 300^{o} C	Pressure ranges from 35 to 40 bar Temperature ranges from 600^{o} to 700^{o} C

Comparison between SI and CI Engines (General Comparison)

S.No.	Spark Ignition Engines (SI)	Compression Ignition Engines (CI)
4	It is fitted with carburettor and spark plugs	It is fitted with fuel injection pump and injectors
5	The burning of fuel takes place at constant volume	The burning of fuel takes place at constant pressure
6.	Ignition of air fuel mixture takes place by an electric spark produced by spark plug	Ignition of air fuel takes placed by a injection of fuel into the hot compressed air.

Comparison between SI and CI Engines (General Comparison)

S.No.	Spark Ignition Engines (SI)	Compression Ignition Engines (CI)
7	Petrol engines are quality governed engines. The speed of petrol engines are controlled by varying the quantity of air fuel mixture.	Diesel engines are quantity governed engines. The speed of diesel engines are controlled by varying quality of air fuel mixture. (rich or weak mixture)
8	Petrol engines are widely used in automobiles and aeroplanes etc.,	Diesel engines are widely used in heavy vehicles, such as buses, lorries, trucks etc.,

Comparison between SI and CI Engines (Merits and Demerits)

S.No.	Spark Ignition Engines (SI)	Compression Ignition Engines (CI)
1	**Merits:** Otto cycle is employed in petrol engine. Otto cycle is more efficient for a given compression ratio.	**Demerits:** Diesel engines works on diesel cycle. Diesel cycle is less efficient than Otto cycle for a given compression ratio.
2	Operating speed is more. Speed range is 3000 to 6000 rpm	Operating speed is less. Speed range is 400 to 3500 rpm.
3.	Starting is easy, since cranking effort required is less	Starting is difficult since more cranking effort is required.

Comparison between SI and CI Engines (Merits and Demerits)

S.No.	Spark Ignition Engines (SI)	Compression Ignition Engines (CI)
4	**Merits:** Initial cost and maintenance cost are less	**Demerits:** More initial and maintenance costs since the construction is heavy and sturdy.
5	Produces less noise.	Produces more noise.
6	Weight per unit power is less	Weight per unit power is more.

Comparison between SI and CI Engines (Merits and Demerits)

S.No.	Spark Ignition Engines (SI)	Compression Ignition Engines (CI)
4	**Demerits:** Thermal efficiency is less, since compression ratio is limited. 5 – 8	**Merits:** Thermal efficiency is high since compression ratio is high. 12 to 18.
5	Specific fuel consumption is more.	Specific fuel consumption is less
6	The fuel used is petrol. It is costlier than diesel. It is volatile and fire hazard is more	The fuel used is diesel. It is cheaper than petrol. It is less volatile and fire hazard is less.

Comparison between Four stroke cycle and two stroke cycle engine (Merits and Demerits)

S.No.	Two Stroke Cycle Engine	Four Stroke Cycle Engine
1	**Merits:** One power stroke in one revolution of the crankshaft	**Demerits:** One power stroke in two revolutions of the crank shaft
2	Power developed for the same engine speed theoretically twice that of a four stroke engine	Power developed for the same engine speed is theoretically half that of two stroke engine.
3	Simple design and lighter in construction for the same power	For the same power complicated design and heavier in construction

Comparison between Four stroke cycle and two stroke cycle engine (Merits and Demerits)

S.No.	Two Stroke Cycle Engine	Four Stroke Cycle Engine
4	**Merits:** Uniform torque is obtained. Hence a lighter fly wheel can be used	**Demerits:** Non uniform torque on the crankshaft. Hence a heavier flywheel is required for balancing.
5	Design of ports is simpler. Hence initial cost is less	Design valve mechanism is difficult. Hence initial cost is more.
6	Mechanical efficiency is high. No moving parts like cam, follower, rocker	Mechanical efficiency is less. Power is lost due to friction caused by valve mechanism

Comparison between Four stroke cycle and two stroke cycle engine (Merits and Demerits)

S.No.	Two Stroke Cycle Engine	Four Stroke Cycle Engine
7	**Merits:** Starting is easy	**Demerits:** Starting is not so easy
8	These engines are generally air cooled	These engines are generally water cooled.

Comparison between Four stroke cycle and two stroke cycle engine (Merits and Demerits)

S.No.	Two Stroke Cycle Engine	Four Stroke Cycle Engine
1	**DeMerits:** Consumption of lubricating oil is more, because less time is available to remove the heat	**Merits:** Consumption of lubricating oil is less, because more time is allowed for removing heat from the cylinder.
2	More wear and tear of moving parts.	Less wear and tear of parts is less
3	Some of the fresh air fuel mixture may escape with exhaust gases. Hence fuel consumption is more	Fuel cannot escape with exhaust gases. Hence fuel consumption is less.

Comparison between Four stroke cycle and two stroke cycle engine (Merits and Demerits)

S.No.	Two Stroke Cycle Engine	Four Stroke Cycle Engine
4	**DeMerits:** Thermal efficiency is less.	**Merits:** Thermal efficiency is more.
5	It produces more noise due to sudden release of exhaust gases	Noise is less is less. Exhaust gases are released in separate stroke.
6	Scavenging is poor, since exhaust port is open only for a short time	Scavenging is better, since there is a separate exhaust stroke for the removal of exhaust gases

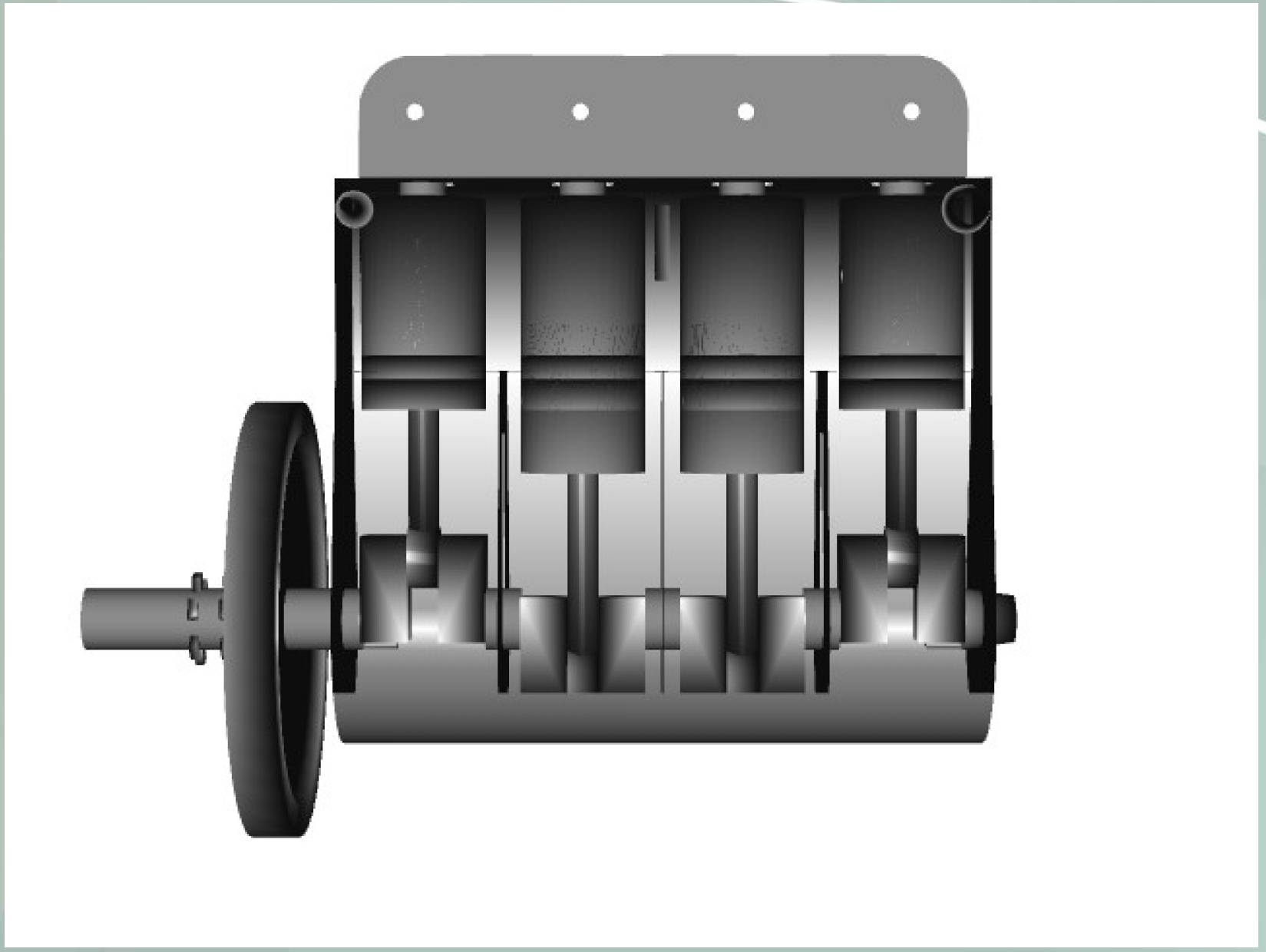
Comparison between Four stroke cycle and two stroke cycle engine (Merits and Demerits)

S.No.	Two Stroke Cycle Engine	Four Stroke Cycle Engine
7	**Merits:** Poor scavenging leads to mixing of fresh charge with exhaust gases. This results in poor performance, slow running	**Demerits:** Better performance and efficiency is more
8	Used in light vehicles, like bikes, scooters, mopeds, etc.,	Used in heavy vehicles, like buses, lorries, trucks etc.,

Characteristics of Four Stroke Compression Ignition & Spark Ignition Engines

Characteristics	Compression-Ignition Engine	Spark- Ignition Engine
Compression Ratio	14-22 : 1	5-8 : 1
Ignition	Compression	Electric Spark
Thermal Efficiency	30-60%	25-30%
Fuel induction	Injector	Carburettor (Fuel Injection)
Fuel System	Fuel Oil / Diesel	Gasoline (LP gas)
Fire Hazard	Less	Greater
Power Variation	Increase in Fuel	Increase in Air/Fuel Mixture
Air Induction	Constant	Variable
Air-Fuel Ratio	15-100 : 1	10-20 : 1
Relative Fuel Consumption	Lower	Higher
Energy per litre of fuel	Higher	Lower
Manifold Throttle	Absent	Present
Exhaust Gas Temperature	482° C / 900 F	704° C / 1300 F
Starting	Harder	Easier
Lubricants	Heavy duty oils	Regular and Premium Oils
Speed Range	Limited (600-3200 rpm)	Wide range (400-6000 rpm)
Engine Mass per Horsepower	8 kg (17.5 lb)	Average 4 kg (9 lb)
Initial Cost	High	Much Lower
Lugging ability (Torque)	Excellent	Less
Time Before Maintenance	Good	Fair
Continuous Duty	Good	Fair

Animation of Crank shaft , connecting rod and piston



Disassembly of IC Engine

Engine removal

- Disconnect battery cables
- Remove the hood
- Remove air cleaner
- Label all wires and vacuum lines
- Drain coolant and oil
- Remove the radiator
- Remove the distributor and spark plug wiring

Figure 50.1 Remove the air cleaner and hose. Be careful not to crack the hose.

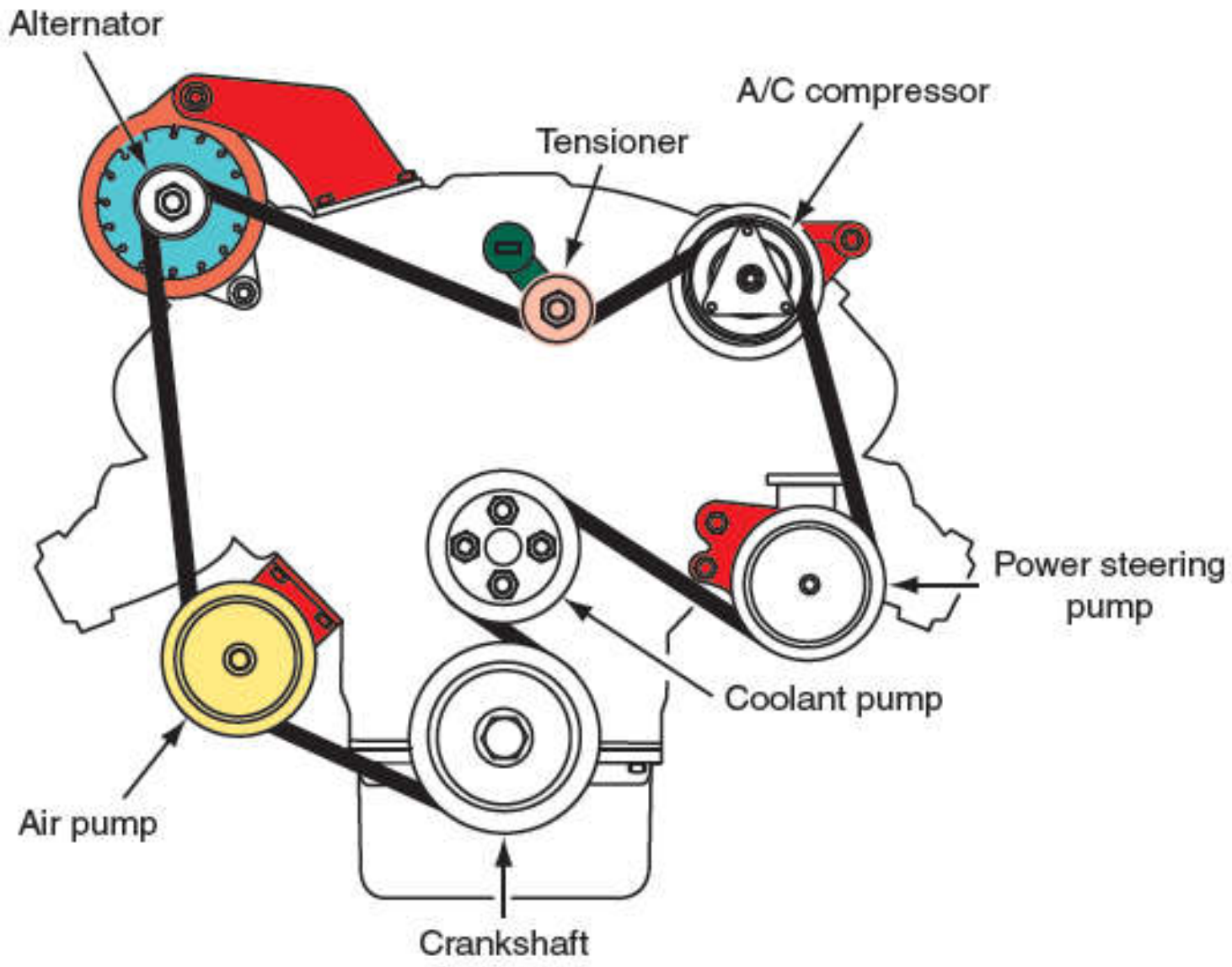


Figure 50.5 Remove the alternator and air pump.

Engine Disassembly

- Important steps
  - Remove clutch parts
  - Remove hybrid armature (puller required)
  - Mount engine to a stand
  - Remove coolant pump
  - Remove oil pan
  - Remove valve covers

Thank you