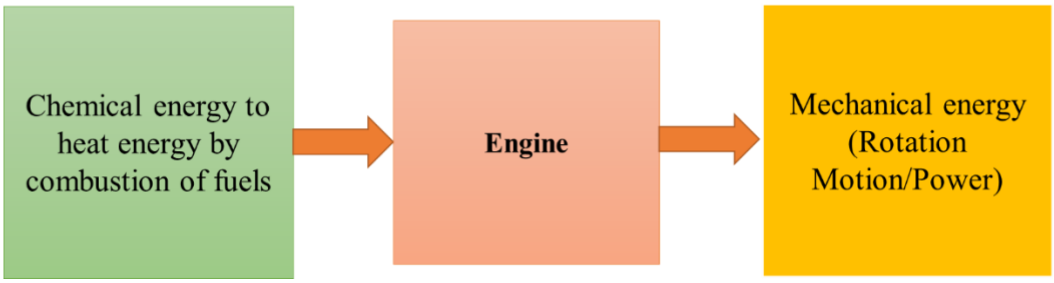
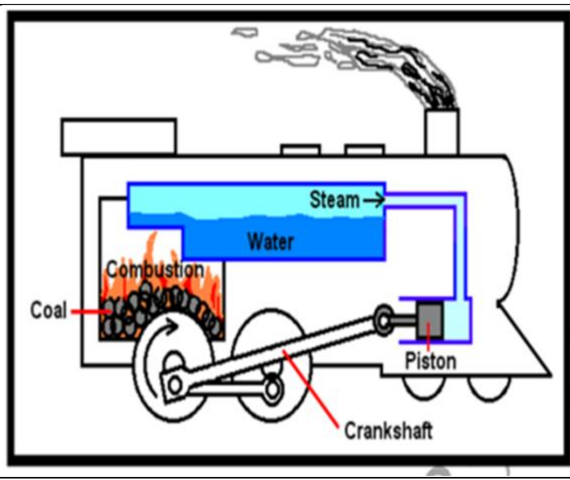
ENGINE:

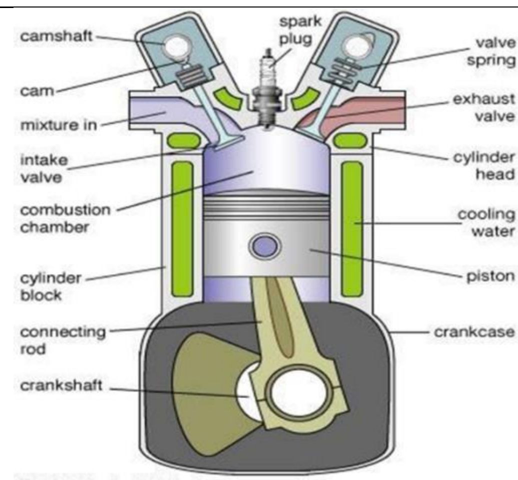
A heat engine is a machine, which converts heat energy into mechanical energy. The combustion of fuel such as coal, petrol, and diesel generates heat. This heat is supplied to a working substance at high temperature. By the expansion of this substance in suitable machines, heat energy is converted into useful work. Heat engines can be further divided into two types: (i)External combustion and (ii) internal combustion.



External combustion Engine: - In a steam engine the combustion of fuel takes place outside the engine and the steam thus formed is used to run the engine. Thus, it is known as external combustion engine.



External combustion Engine



Internal combustion Engine

Internal combustion Engine: - In the case of internal combustion engine, the combustion of fuel takes place inside the engine cylinder itself.

I C ENGINE: An internal combustion engine (I C Engine) is a heat engine, which converts the heat energy released by the combustion of the fuel taking place inside the engine cylinder into mechanical work. The advantages of I C Engines compared to External combustion Engines are high efficiency, light weight, compactness, easy starting, suitable for mobile applications and comparatively lower initial cost.

CLASSIFICATION OF I C ENGINES:

According to the type of fuel used: a) Petrol engine - If the fuel used is petrol, the engine is called as petrol engine. b) Diesel engine - If the fuel used is diesel, the engine is called as diesel engine. c) Gas engine - gaseous fuels like bio-gas, natural gas, or liquefied petroleum gas (LPG), etc., are used as fuels. d) Bi-fuel (Bio-fuel) engine - these engines use a mixture of more than one fuel. For example, mixture of diesel and natural gas, mixture of diesel and neem oil, etc.

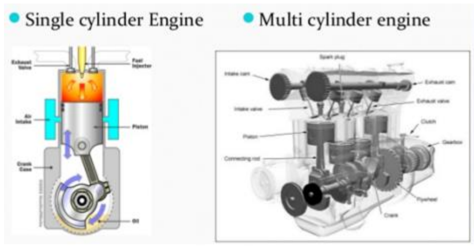
According to the number of strokes per cycle: a) 4-stroke engine - if the engine completes its working cycle in four different strokes of the piston, or two revolutions of the crankshaft, it is called as 4-stroke engine. b) 2-stroke engine - if the engine completes its working cycle in two different strokes of the piston, or one revolution of the crankshaft, it is called as 2-stroke engine.

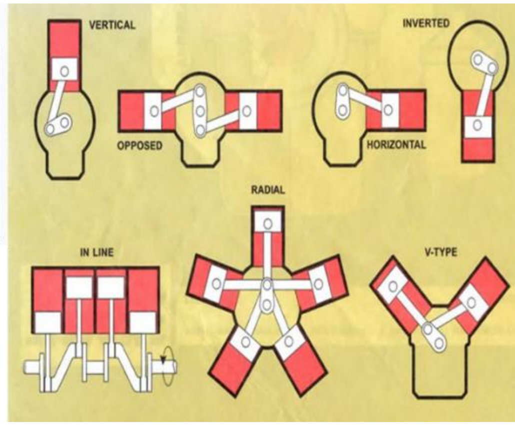
According to the method of ignition: a) Spark Ignition (SI) engine - If the fuel is ignited by an electric spark generated by a spark plug, the engine is called as spark ignition engine. b) Compression Ignition (CI) engine - In these engines, the fuel ignites when it comes in contact with the hot compressed air.

According to the cycle of combustion: a) Otto cycle engine - If the combustion of fuel takes place at constant volume, the engine is called Otto cycle engine. b) Diesel cycle engine - combustion of fuel takes place at constant pressure. c) Dual combustion cycle engine - combustion of fuel first takes place partially at constant volume, and then at constant pressure.

According to the number of cylinders used: a) Single cylinder engine - If the engine consists of only one cylinder, then it is called as single cylinder engine. b) Multi-cylinder engine - If the engine consists of more than one cylinder, then it is called as multi-cylinder engine.

According to the arrangement of cylinders: a) Vertical engine - If the cylinder is arranged in a vertical position, the engine is called vertical cylinder engine. b) Horizontal engine - cylinder is arranged in horizontal position. c) Inline engine - cylinders are arranged in a line. Most trucks are of inline configuration. d) Radial engine - cylinders are arranged along the circumference of a circle. e) V-engine - It is a combination of two inline engines equally set at an angle. Passenger vehicles have V-type configuration. f) Opposed type engine - cylinders are arranged opposite to each other.





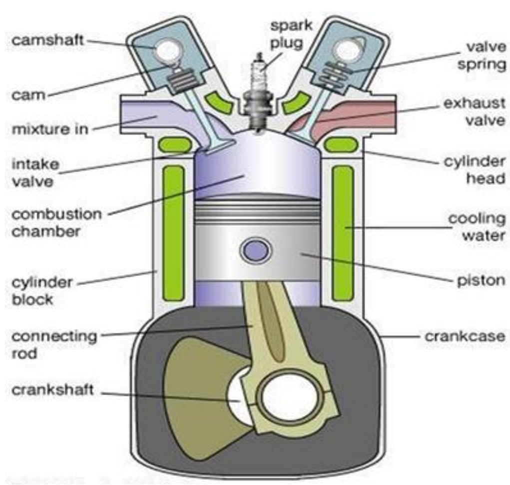
According to the method of cooling: a) Air cooled engine - If the heated cylinder walls (due to combustion of fuel) are cooled by circulating air, the engine is called air cooled engine.

b) Water cooled engine - water is circulated through the jacket surrounding the healed cylinder walls.

According to their uses: a) Stationary engine b) Automobile engine c) Marine engine d) Aircraft engine, etc.

PARTS OF AN IC ENGINE:

The following are the main parts of an internal combustion engine. 1) Cylinder 2) Piston 3) Piston rings 4) Connecting rod 5) Crank 6) Crankshaft 7) Crankcase 8) Fly wheel 9) Valves



Cylinder: It is the heart of an I C Engine, as the name indicates is a cylindrical shaped component in which combustion of fuel takes place. The cylinder is usually made from gray cast iron or steel alloys in order to withstand the high pressure and temperature generated inside the cylinder due to combustion of fuel.

Piston: The piston is a close fitting hollow cylindrical plunger moving to and fro in the cylinder. The power developed by the combustion of the fuel is transmitted by the piston to the crankshaft through the connecting rod.

Piston Rings: The piston rings are the metallic rings inserted into the circumferential grooves provided at the top end of the piston. These rings maintain a gas-tight joint between the piston and the cylinder while the piston is reciprocating in the cylinder. They also help in conducting the heat from the piston to the cylinder.

Connecting Rod: It is a link that connects the piston and the crankshaft by means of pin joints. It converts the rectilinear motion of the piston into rotary motion of the crankshaft.

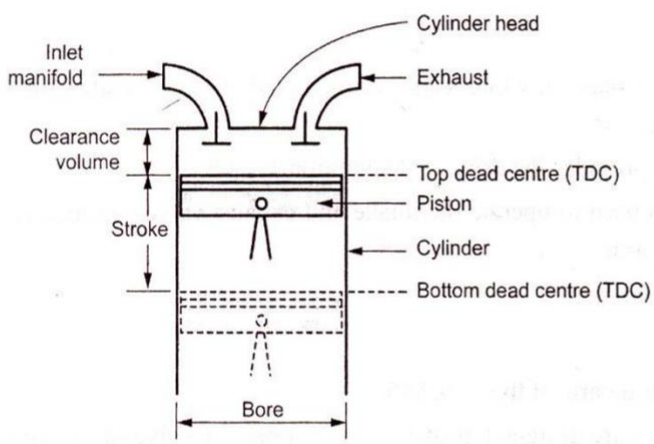
Crank: The crank is a lever, with one of its end connected to the lower end of the connecting rod, while the other end connected to the crankshaft. Crankshaft: The function of the crankshaft is to transform reciprocating motion into rotary motion. The crankshaft transmits the power developed by the engine through the flywheel, clutch, transmission and differential to drive (move) the vehicle. The crankshafts are made of carbon steel.

Crankcase: The crankcase is the lower part of the cylinder block that encloses the crankshaft and provides a reservoir for the lubricating oil.

Flywheel: It is a heavy wheel mounted on the crankshaft of the engine to maintain uniform rotation of the crankshaft.

Valves: The valves are the devices which controls the flow of the intake and the exhaust gases to and from the engine cylinder. They are also called poppet valves. These valves are operated by means of cams driven by the crankshaft through a timing gear or chain.

IC ENGINE TERMINOLOGY:



Top Dead Centre (TDC) or Cover end: The extreme position of the piston near to the cylinder head is called top dead centre. Briefly abbreviated as TDC. In horizontal engines, like the opposed type engine, the term top dead centre becomes irrelevant, and hence the term cover end is used in-place of top dead centre.

Bottom Dead Centre (BDC) or Crank end: The extreme position of the piston near to the crankshaft is called bottom dead centre. Briefly abbreviated as BDC. In horizontal engines, like the opposed type engine, the term bottom dead centre becomes irrelevant, and hence substituted by the term crank end.   Bore: The inner diameter of the cylinder is called bore. It is denoted by d.

Stroke or Stroke length: The linear distance travelled by the piston when it moves from top dead centre to bottom dead centre is called stroke or stroke length. It is denoted by L.

Stroke volume or Swept volume or Piston displacement: The volume swept by the piston when it moves from the top dead centre to bottom dead centre is called stroke volume or swept volume or piston displacement. It is denoted by Vs.

Swept volume= Vs = A * L = $(\pi/4)*D^2*L$

where

A = Cross sectional area of the piston in Sq.m,

L = Stroke in m, and

D = Cylinder bore i.e., inner diameter of the cylinder in m.

Clearance volume: The volume of the cylinder above the top of the piston when the piston is at the top dead centre is called clearance volume. It is denoted by Vc.

Compression Ratio (CR): Compression ratio is a ratio of the volume when the piston is at bottom dead centre to the volume when the piston is at top dead center.

Mathematically,

Compression ratio $= \frac{MaximumCylinderVolume}{MinimumCylinderVolume}$

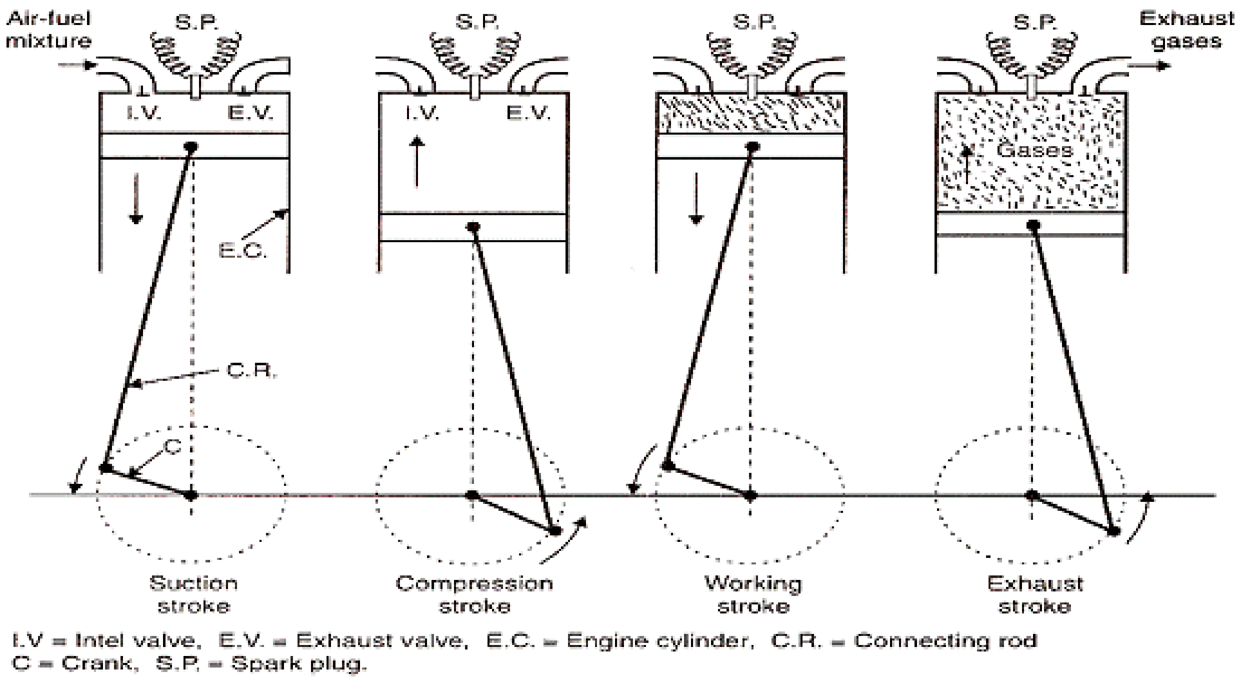
Compression ratio $= \frac{(Swept\ volume + Clearnce\ Voume)}{Clearnce\ Voume}$

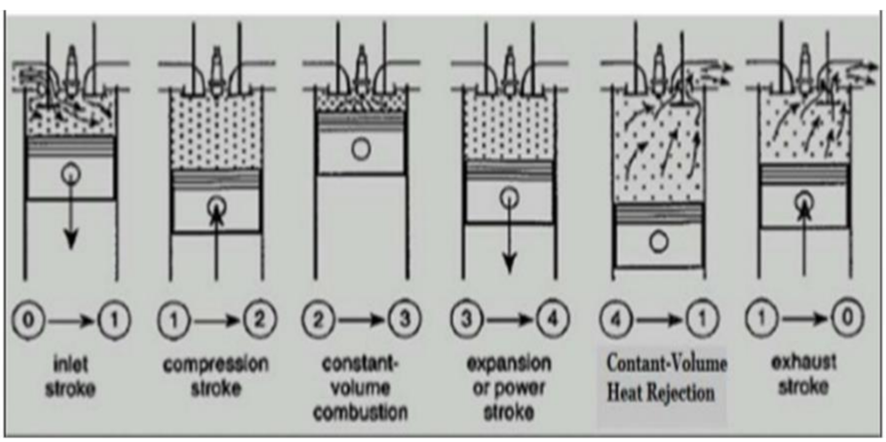
Compression ratio $= \frac{(Vs+Vc)}{Vc}$

FOUR-STROKE PETROL ENGINE (4-S-P-E):-

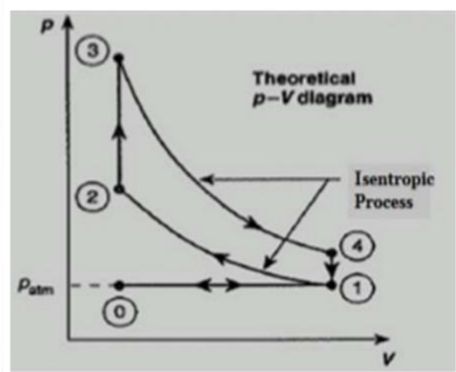
A four-stroke petrol engine works on Otto cycle. Hence it is also called Otto cycle engine.

The charge used in a 4-Stroke petrol engine is a mixture of air and petrol, and is supplied by the carburettor in suitable proportions. The charge is ignited by the spark generated by a spark plug, and for this reason, petrol engines are also called Spark Ignition (SI) engines.





P V diagram of otto cycle



Working: In a 4-Stroke petrol engine, the working cycle is completed in four different strokes of the piston.

1) Suction stroke: At the beginning of the suction stroke, the piston is at the top dead centre (TDC), and is about to move towards the bottom dead centre (BDC). At this instance, the inlet valve is opened and the exhaust valve is closed. The downward movement of the piston produces suction (partial vacuum) in the cylinder, due to which fresh charge of air and petrol mixture is drawn into the cylinder through the inlet valve. When the piston reaches the BDC, the suction stroke ends and the inlet valve is closed. With this stroke, the crankshaft rotates through 180° or half-revolution. The energy required for the piston movement is taken from a battery. The suction of air takes place at atmospheric pressure, and is represented by the line AB on p-v diagram.

2) Compression stroke: During the compression stroke, the piston moves from BDC to TDC. Both the inlet and exhaust valves remain closed. As the piston moves upwards, the air petrol mixture in the cylinder gets compressed (squeezed), due to which the pressure and temperature of the mixture increases. Compression ratio varies from 6:1 to 12:1. The compression process is adiabatic [Adiabatic - It is a process in which there is no heat transfer from the system to the surroundings or vice-versa.] in nature and is shown by the curve BC on p-v diagram. When the piston is about to reach the TDC, the spark plug initiates a spark that ignites the air-petrol mixture. Combustion of fuel takes place at constant volume as shown by the line CD on p-v diagram. Since combustion of fuel takes place at constant volume, 4-Stroke petrol engines are also called as constant volume cycle engines. With this stroke, the crankshaft rotates by another 180° or half revolution. The energy required for the piston movement is taken from a battery.

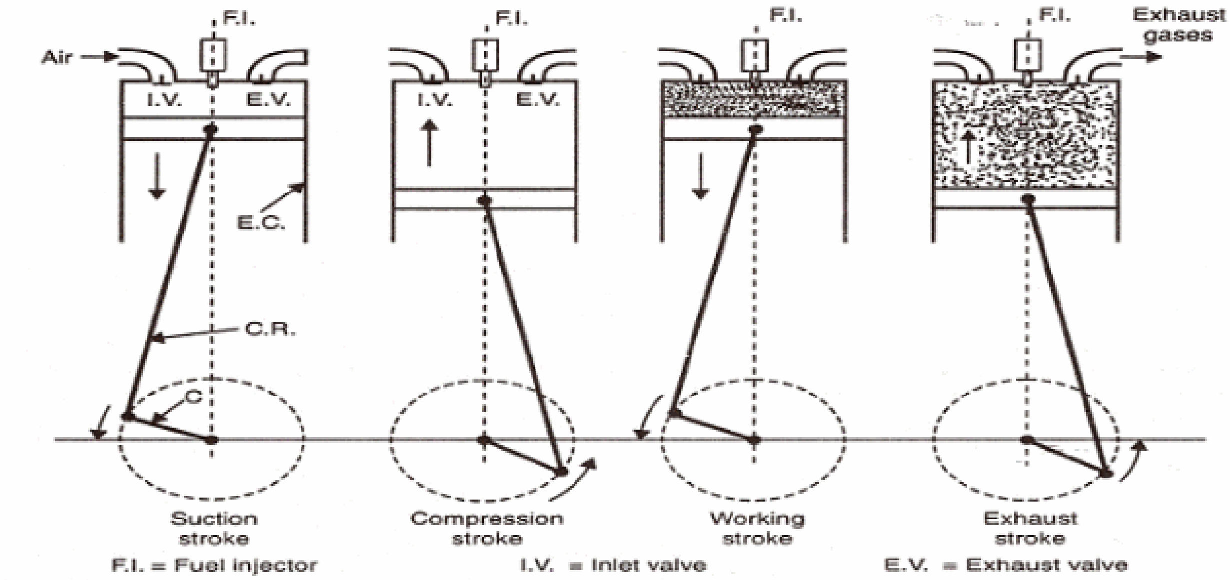
3) Power stroke (Expansion stroke or Working stroke): During this stroke, both the valves will remain closed. As the combustion of fuel takes place, the burnt gases expand and exert a large force on the piston causing it to move rapidly from the TDC to BDC. The force (or power) is transmitted to the crankshaft through the connecting rod. As a result, the crankshaft rotates at high speeds. The crankshaft then transmits the power through clutches, gears, chains, etc... To turn the wheels of the vehicle and cause it to move. The expansion of gases is adiabatic in nature and is shown by the curve DE on p-v diagram. Since the actual power or work is produced by the engine in this stroke, it is also called as power stroke or working stroke. Also, expansion of gases occurs during this stroke, and hence the name expansion stroke.

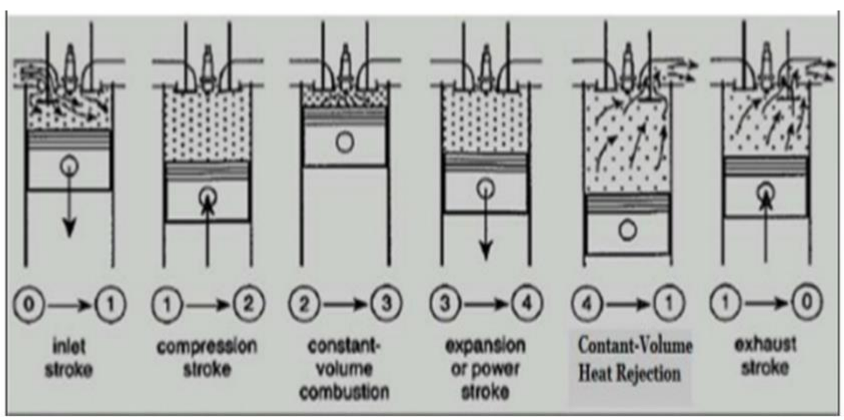
4) Exhaust stroke: Towards the end of the expansion stroke, the exhaust valve opens, while the inlet valve remains closed. A part of the burnt gases due to their own expansion escapes out of the cylinder through the exhaust valve.

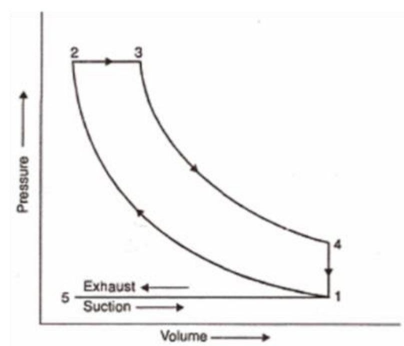
This drop in pressure at constant volume inside the cylinder is represented by the line EB on p-v diagram. The exhaust stroke begins when the piston starts moving from the BDC to TDC. The energy for this stroke is supplied by the flywheel, which it had absorbed in the previous stroke. As the piston moves upwards, it forces the remaining burnt gases to the atmosphere through the exhaust valve. The exhaust taking place at atmospheric pressure is shown by the line BA on p-v diagram. When the piston reaches the TDC, the exhaust valve closes and the working cycle is completed. In the next cycle, the piston starts moving from TDC to BDC, the inlet valve opens allowing fresh charge to enter into the cylinder, and the process continues. Thus it is clear that, the four different strokes or one working cycle is completed when the crankshaft rotates through 720° or two revolutions. Four-stroke petrol engines are commonly used in scooters, motor bikes, cars, large boats, etc.

FOUR STROKE DIESEL ENGINE (4-S-D-E):-

A 4-stroke diesel engine works on Diesel cycle. Hence it is also called Diesel cycle engine. The working principle is similar to that of 4-stroke petrol engine, except a fuel injector is used in place of spark plug, and only air enters the cylinder during the suction stroke and gets compressed in the compression stroke.







Working:

1) Suction stroke: At the beginning of the suction stroke, the piston is at the top dead centre (TDC), and is about to move towards the bottom dead centre (BDC). At this instance, the inlet valve is opened and the exhaust valve is closed. The downward movement of the piston produces suction (partial vacuum) in the cylinder, due to which air from the atmosphere is drawn into the cylinder through the inlet valve. When the piston reaches the BDC, the suction stroke ends and the inlet valve is closed. With this stroke, the crankshaft rotates through 180° or half-revolution. The energy required for the piston movement is taken from a battery. The suction of air takes place at atmospheric pressure, and is represented by the line AB on p-v diagram.

2) Compression stroke: During the compression stroke, the piston moves from BDC to TDC. Both the inlet and exhaust valves remain closed. As the piston moves upwards, the air in the cylinder gets compressed (the compression ratio varies from 12:1 to 22:1), due to which the pressure and temperature of the air increases. The compression process is adiabatic in nature and is shown by the curve BC on p-v diagram. When the piston is about to reach the TDC, a quantity of diesel is

injected in the form of fine sprays into the hot compressed air by a fuel injector. Combustion of fuel takes place at constant pressure as shown by the line CD on p-v diagram. Since combustion of fuel takes place at constant pressure, 4-Stroke diesel engines are also called as constant pressure cycle engines. With this stroke, the crankshaft rotates by another 180° or half revolution. The energy required for the piston movement is taken from a battery. Since the heat of compression ignites the diesel injected into the cylinder, diesel engines are also called as compression ignition engines.

3) Power stroke (Expansion stroke or Working stroke): During this stroke, both the valves will remain closed. As the combustion of fuel takes place, the burnt gases expand and exert a large force on the piston causing it to move rapidly from the TDC to BDC. The force (or power) is transmitted to the crankshaft through the connecting rod. As a result, the crankshaft rotates at high speeds. The crankshaft then transmits the power through clutches, gears, and other transmission elements to turn the wheels of the vehicle and cause it to move. The expansion of gases is adiabatic in nature and is shown by the curve DE on p-v diagram.

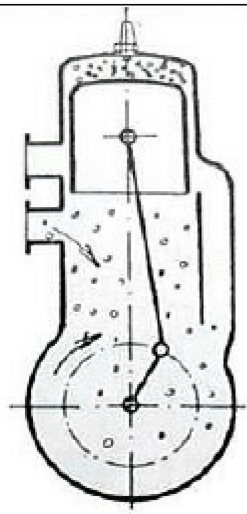
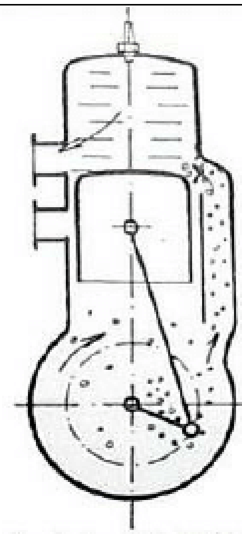
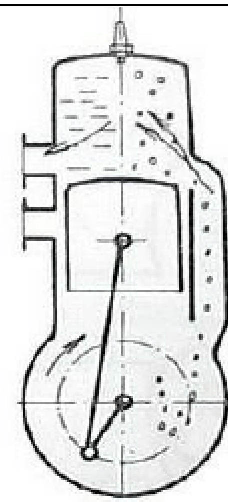
4) Exhaust stroke: During this stroke, the inlet valve remains closed and the exhaust valve opens. The greater part of the burnt gases escape because of their own expansion. The drop in pressure at constant volume is represented by the vertical line EB. The piston moves from bottom dead centre to top dead centre and pushes the remaining gases to the atmosphere. When the piston reaches the top dead centre the exhaust valve closes and the cycle is completed.

TWO- STROKE PETROL ENGINE (2-S-P-E):

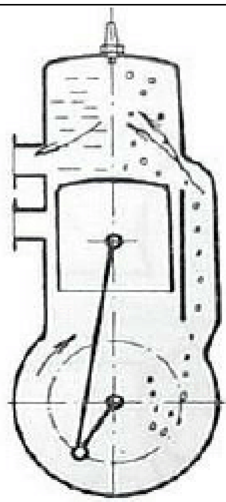
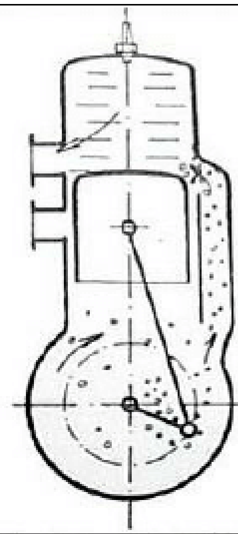
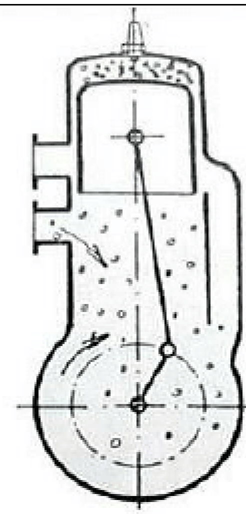
(dRAW ONLY 2 FIGURES. 1. WHEN THE PISTON AT tdc

In two stroke cycle engines, the suction and exhaust strokes are eliminated. There are only two remaining strokes i.e., the compression stroke and power stroke and these are usually called upward stroke and downward stroke. Also, instead of valves, there are inlet and exhaust ports in two stroke cycle engines. The burnt exhaust gases are forced out through the exhaust port by a fresh charge, which enters the cylinder nearly at the end of the working stroke through the inlet port. The process of removing burnt exhaust gases from the engine cylinder is known as scavenging.

First Stroke/Downward stroke: At the beginning of the first stroke the piston is at the cover end (TDC) .It moves from the cover end (TDC) to crank end (BDC). The spark plug ignites the compressed petrol-air mixture. The combustion of the petrol will release the hot gases which increases the pressure in the cylinder. The high pressure combustion gases force the piston downwards. The piston performs the power stroke till it uncovers the exhaust port. During the earlier part of this stroke which is performed by the pressure of the combustion gases exerted on it, the power is produced. The combustion gases which are still at a pressure slightly higher than the atmospheric pressure escape through the exhaust port. As soon as the top edge of the piston uncovers the transfer port, the fresh petrol-air mixture flows from the crankcase into the cylinder. The fresh petrol-air mixture which enters the cylinder drives out the burnt exhaust gases through the exhaust port .This driving out of exhaust gases by the incoming fresh charge is called scavenging. This will continue till the piston covers both the exhaust and transfer ports during the next ascending stroke. The crankshaft rotates by half rotation.

		
When the piston at -TDC	**When the piston moving from TDC to BDC**	**When the piston at -BDC**
Inlet port opened fully, exhaust port & transfer port completely closed 1. Combustion of previous cycle compressed air fuel mixture due to spark given by spark plug 2. Staring of power stroke 3. Inlet of fresh air fuel mixture to crank case	Inlet port gradually closed, exhaust port & transfer port gradually opened. 1. Power stroke 2. Initial compression of air fuel mixture in the crank case 3. Exhaust of expanded hot gases 4. Transfer of initially compressed air fuel mixture to cylinder through transfer port	Inlet port completely closed, exhaust port & transfer port opened fully. 1. Exhaust of expanded hot gases 2. Transfer of initially compressed air fuel mixture to cylinder through transfer port

Second Stroke/Upward stroke: In this stroke the piston moves from the crank end (BDC) to cover end (TDC). When it covers the transfer port, the supply of petrol-air mixture is cut off and then when it moves further up it covers the exhaust port completely stops the scavenging. Further ascend of the piston will compress the petrol-air mixture in the cylinder. The compression ratio ranges from 1:7 to 1:11. After the piston reaches the cover end the first stroke as explained earlier repeats again. The crankshaft rotates by half rotation. Since this engine requires only two strokes to complete one cycle, it is called a two stroke engine. The crankshaft makes only one revolution to complete the cycle. The power is developed in every revolution of the crankshaft.

		
When the piston at -BDC	**When the piston moving from TDC to BDC**	**When the piston at -TDC**
Inlet port completely closed, exhaust port & transfer port opened fully. 1. Exhaust of expanded hot gases 2. Transfer of initially compressed air fuel mixture to cylinder through transfer port	Inlet port gradually closed, exhaust port & transfer port gradually opened. 1. Power stroke 2. Initial compression of air fuel mixture in the crank case 3. Exhaust of expanded hot gases 4. Transfer of initially compressed air fuel mixture to cylinder through transfer port	Inlet port opened fully, exhaust port & transfer port completely closed 1. Combustion of previous cycle compressed air fuel mixture due to spark given by spark plug 2. Staring of power stroke 3. Inlet of fresh air fuel mixture to crank case

The two-stroke petrol engines are generally used in mopeds, scooters, motor-cycles because they run at high speeds with moderate power outputs.

Differences between Petrol and diesel engine (Differences between spark-ignition and Compression-ignition engine):

Sl No	Parameters	SI Engine (4 stroke petrol engine)	CI Engine (4 stroke Diesel engine)
1.	Cycle of operation	Otto cycle	Diesel cycle
2.	Presence of spark plug/Fuel injector	Spark Plug	Fuel injector
3.	Inlet of fresh charge to cylinder during suction stroke	Mixture of fuel & Fuel from carburetor	Only air through air filter
4.	Compression ration	1:6 to 1:12	1:12 to 1:22
5.	Ignition of fuel	By spark given by spark plug	High temperature compressed air ignites the fuel when it mixed with it
6.	Type of combustion	Constant volume combustion	Constant pressure combustion
7.	Starting of engine	Easy due to less compression ratio	Difficult due to High compression ratio
8.	Speed	Operates at High speed	Operates at Low speed
9.	Rate of combustion	Almost complete combustion (combustion of whole mass of fuel)	Full complete combustion (fuel injected in spray from, so each molecules of fuel combust completely)
10.	Fuel consumption	More	Less
11	Thermal efficiency	Less	More
12.	Size & Weight	Small & Less for unit kw power output	Big & More for unit kw power output
13.	Initial cost & Maintenance cost	Less	More

14.	Application	Used in Lighter vehicles	Used in Heavy vehicles

Differences between FOUR-Stroke and TWO-Stroke engine:

Sl no	Principle	Four-stroke engine	Two-stroke engine
1	Number of strokes per cycle	Four strokes per	cycle Two strokes per cycle
2	Number of cycles per min	Half of the speed of the engine n=N/2	Equal to the speed of the engine n=N
3	Power	Power is developed in every alternate revolution of the crankshaft	Power is developed in every revolution of the crankshaft
4	Flywheel	Heavy flywheel is required	Lighter flywheel is required
5	Admission of the charge	The charge is directly admitted into the engine cylinder during the suction stroke	The charge is first admitted into the crankcase and then transferred to the engine cylinder
6	Exhaust gases	The exhaust gases are driven out through the outlet by the piston during the exhaust stroke	The exhaust gases will be expelled out of the cylinder by scavenging operation by the incoming fresh charge
7	Valves/Ports	Inlet and the exhaust valves	inlet, transfer and the exhaust ports
8	Valves	The inlet and the exhaust are opened and closed by mechanical valves	The piston itself opens and closes the inlet, transfer and the exhaust ports
9	Engine cooling	The cooling can be made more effective since the combustion takes place in alternate revolution of the crankshaft	The rate of cooling must be very high since the combustion takes place in every revolution of the crankshaft

10	fuel consumption	Fuel consumption is Less	Fuel consumption is More (fresh fuel mixed with exhaust gas)
11	Mechanical efficiency	Less (due to 4 stroke, more movement of piston)	High (due to 2 stroke, less movement of piston)
12	Thermal efficiency	More (Due to less fuel consumption)	Less (Due to more fuel consumption)
13	Noise	Noise will be less	Noise will be More
14	Uses	Used in slow speed and High power applications like cars, trucks, tractors, jeeps, buses etc	Used in High speed and Low power applications like mopeds, scooters, motor cycles etc..

Performance of IC Engines (ENGINE CALCULATIONS)

1. Mean effective pressure (MEP): Pm- The mean effective is defined as mean or average pressure acting on a piston throughout the power stroke. It is also the average pressure developed inside the engine cylinder of an IC engine. It is expressed in Bar. (1 Bar = 105 N/m2)

The mean effective pressure of an engine is obtained diagram. The indicator diagram is the p –V diagram for one cycle at that load, drawn with the help of an indicator fitted on the engine.

The indicated mean effective pressure is then calculated using the equation:

$$\mathbf{P_m} = \frac{(Spring\ value\ or\ spring\ stiffness\ of\ the\ spring\ used\ in\ the\ indicator\ (S) in\ bar\ per\ mt) * Net\ are\ of\ the\ indicator\ digram\ (a)\ in\ m2}{(Length\ of\ the\ indicator\ diagram\ (l) in\ m}$$

$\mathbf{P_m} = \frac{S*a}{l}$ in bar

2. Indicated Power: Indicated power is defined as the total power developed inside the engine cylinder due to combustion of fuel. It denoted by IP and is expressed in kW.

When Pm is in N/m2, $\mathbf{IP} = \frac{\boldsymbol{nPmLANK}}{\mathbf{60}*1000}$ in Kw

When Pm is in bar $\mathbf{IP} = \frac{\mathbf{100} * \boldsymbol{nPmLANK}}{60}$ in Kw $= \mathbf{nPmLANK} * \frac{10}{6}$ in Kw

Where

n= number of cylinders

Pm = indicated mean effective pressure in bar

L = length of stroke in m

A = cross-sectional area of the cylinder in m^2 = A =$\frac{\pi}{4}d^2$ in m^2

where

d= diameter of cylinder or bore in m

N = engine speed in rpm

K = factor used for easy simplification

K = 1/2 for four stroke engine K = 1 for two stroke engine

3. Brake Power (BP): The net power available at the crank shaft of the engine for performing useful work is called brake power. It is denoted by BP and expressed in kW.

BP = $\frac{2\pi NT}{60 * 1000}$ in kW

Where

N = Speed of the engine in rpm

T = Torque is measured by using either belt or rope brake dynamometer.

T = Torque in N – m = W * R.

W = Net load acting on the brake drum in N

R = Radius of the brake drum in m

4. Friction power = Indicated power – Brake power. (FP=IP-BP)KW

5. Mechanical Efficiency (η_{mech}): It is the efficiency of the moving parts of mechanism transmitting the indicated power to the crankshaft. Therefore it is defined as the ratio of the brake power and the indicated power. It is expressed in percentage.

$$(\eta_{mech}): \frac{\textbf{Brake power }(BP)}{\textbf{Indicated power }(IP)} * 100 \text{ in } \%$$

6. Thermal Efficiency ($\eta_{Thermal}$): it is the efficiency of the conversion of the heat energy produced by the actual combustion of the fuel into the power output of the engine. Therefore it is defined as the ratio of power developed by the engine by the fuel in the same interval of time. It is expressed in percentage.

$$\eta_{Thermal}: \frac{Mechanical\ Output}{Heat\ Supplied} * 100 \text{ in } \%$$

$$\eta_{Thermal}: \frac{Mechanical\ Output}{Heat\ supplied} * 100 \text{ in } \%$$

Where

Heat Supplied = $M_f * C_V$

M_f = Mass of the fuel in kg/sec

C_V = Calorific value of the fuel in KJ/Kg

7. Indicated Thermal Efficiency ($\eta i_{Thermal}$): Indicated thermal efficiency can be defined as the ratio of indicated power to the heat supplied by the burning fuel.

(η_{ITH}): $\frac{Indicated\ power\ (IP)}{Heat\ Supplied} * 100$ in %

8. Brake Thermal Efficiency ($\eta b_{Thermal}$): Brake thermal efficiency is defined as the ratio of brake power to the heat supplied by the burning fuel.

(η_{BTH}): $\frac{Brake\ power\ (BP)}{Heat\ Supplied} * 100$ in %

9. Specific fuel consumption: SFC is defined as the amount of fuel consumed by an engine for one unit of energy that is produced. SFC is used to express the fuel efficiency of an IC engine .it measures the amount of fuel required to provide a given power for a given period. It is expressed in kg/kW - hr. Specific fuel consumption is expressed as the mass of fuel consumed per kW of power developed per hour.

Indicated specific fuel consumption is given by

(ISFC) : $\frac{Mass\ of\ the\ fuel\ consumed\ in\ kg/Hour}{Indicated\ power\ (IP)}$ in $\frac{kg}{kw-hr}$

Brake specific fuel consumption is given by

(**ISFC**): $\frac{Mass\ of\ the\ fuel\ consumed\ in\ kg/Hour}{Brake\ power\ (BP)}$ in $\frac{kg}{kw-hr}$