ELEMENTS OF MECHANICAL ENGINEERING

PART – A

Unit - III

UNIT – III

Internal Combustion Engines (I.C. Engines)

Thermodynamics and Mechanism

Unit - III

Objectives:

1.1 To understand the fundamentals & operation Mechanism of – I C Engines

1.2 Classification/ Kinds

1.3 I C Engines Parts & Their Functions

1.4 I C Engine Terminology

1.5 Thermodynamics relations

1.0 Introduction

The **internal combustion engine** is a type of heat engine in which the combustion of fuel and an oxidizer (typically air) occurs in a confined space called a combustion chamber. This exothermic reaction creates gases at high temperature and pressure, which are permitted to expand and converts chemical energy into mechanical energy. Internal combustion engines are defined by the useful work that is performed by the expanding hot gases acting directly to cause the movement of piston down the cylinder on the power stroke.

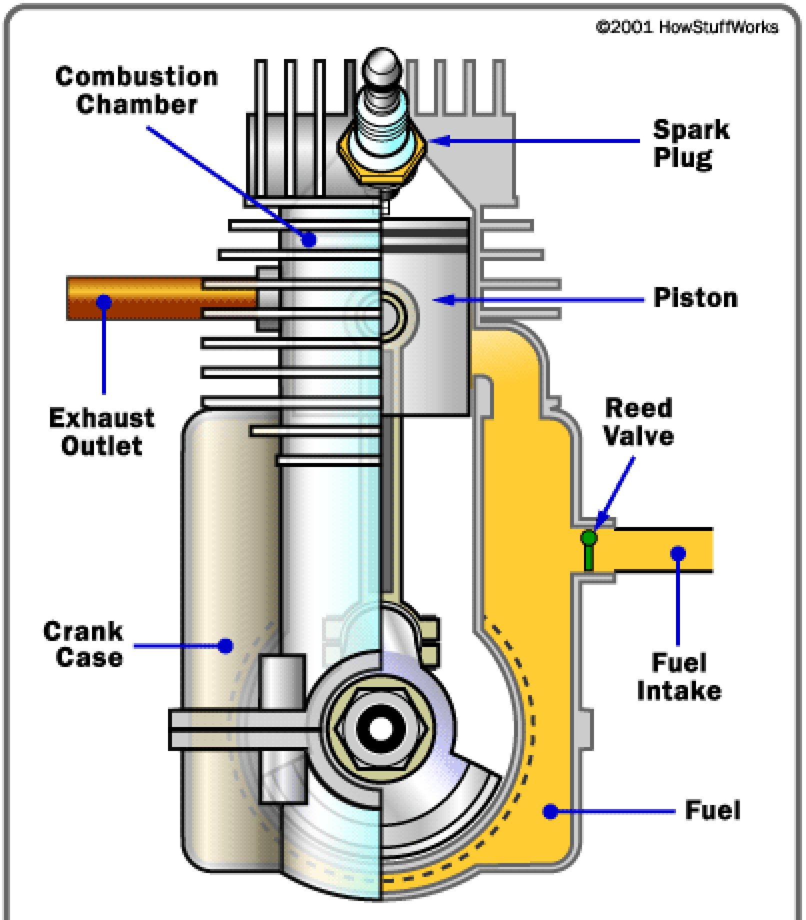
Ex: Petrol & Diesel Engines.

I C Engine

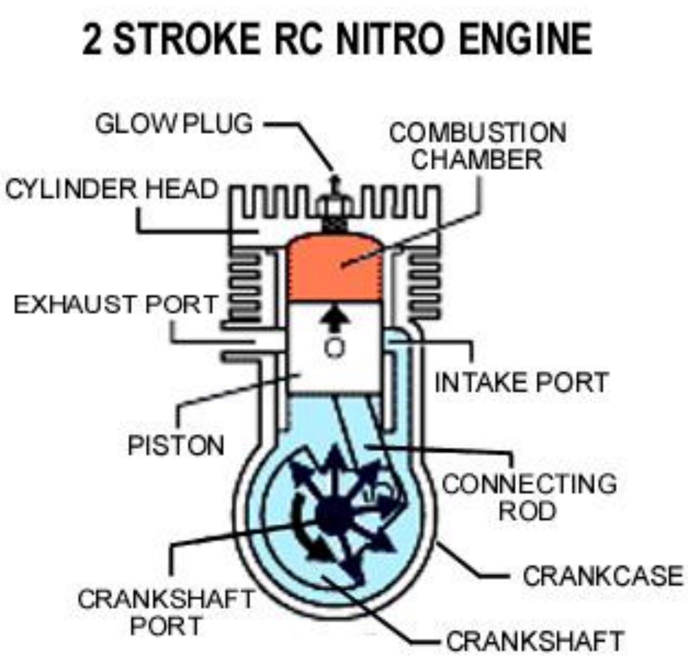
Classification

BASIS	TYPES
Operating Cycle or Thermodynamic cycle or Combustion	Otto Cycle Engine, Diesel Cycle, Dual Combustion Cycle engines
No of Strokes	Two Stroke, Four stroke Engines
Method of Ignition	Spark Ignition (S.I) & Compression Ignition (C.I) Engine
No of Cylinders	Single & Multi cylinder
Arrangement/ position of Cylinder	Vertical, Horizontal, In-Line, Vee-engines, Radial engines, opposed cylinder, Bi-Fuel etc.
Design of Engine	Reciprocating. Rotary
Fuel Used	Petrol & Diesel, Single Fuel, Dual fuel, Multi fuel, Gasoline – CNG/LPG
Speed	Low, Medium, High Speed
Cooling System	Water cooled, Air coled.

Engine Parts



The basic components of a two-stroke engine



Cylinder: It is a cylindrical container, fitted with liners and piston, in which the fuel is burnt and the power is developed. As a result the piston executes reciprocating motion. It is made of grey cast iron. The top of the cylinder is covered by a cylinder head.

Cylinder Head: It is a cylindrical cover for the top of the cylinder having provision for inlet and out let valves. It is made of cast iron or alloy cast iron containing nickel, chromium & molybdenum.

Piston: It is a close fitting hollow cylindrical plunger, which reciprocate inside the cylinder due to expansion of gases. It transmits the energy to the crankshaft through the connecting rod. The space formed between the cylinder head and top of the piston during the process of combustion is known as combustion chamber. The piston transfers a large amount of heat from the combustion chamber to the cylinder walls. Pistons are made of cast iron or aluminum alloys for lightness.

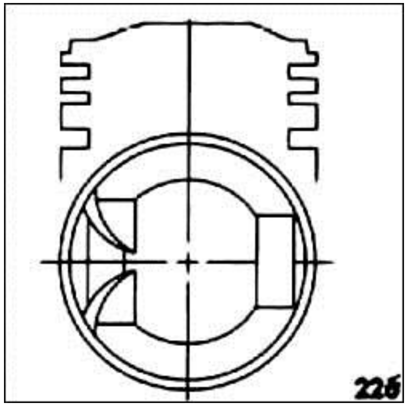
Piston rings: these are the split cast iron rings made to fit in the grooves of the piston to maintain a pressure tight seal between the piston and cylinder walls. They conduct heat away from the piston head and prevent oil from entering the combustion chamber.

Unit - III

Cylinder

Cylinder Head

Piston and piston rings



Connecting Rod: it is a tapered link that connects the piston and the crank, using pins. It converts the reciprocating motion of the piston into rotary motion of the crank. As a result it oscillates between piston & crank. The small end (eye) of the rod is connected to piston using a piston pin, which is also called wrist pin or gudgeon pin. The other big end (split) is connected to the crank using a crank pin. Both ends contain a journal bearing. It is made of carbon steel or aluminium alloys for lightness.

Crank: it is a lever connected between the connecting rod and the crank shaft. As the piston reciprocates, it rotates about the axis of the crank shaft and causes the connecting rod to oscillate.

Crank shaft: It is a shaft partly enclosed in the crank case. It revolves in the main bearing. It supports the crank and the flywheel. It also drives the output camshaft.

Crank case: it supports and covers the cylinder and the crank shaft. Its base is closed to store the lubricating oil.

Cylinder liners

Connecting Rod

Crank shaft

Inlet manifold: it is a passage in a 4-stroke engine through which the charge enters into the cylinder. It may be provided either on the cylinder or on the side of the cylinder.

Outlet (Exhaust) manifold: it is a passage in 4-stroke engine through which the products of combustion escape into the atmosphere. It may be provided either on the cylinder head or on the side of the cylinder.

Inlet & outlet valves (Poppet valves): it is a device used in engines fitted in the manifolds for the purpose of charging the cylinder and for discharging the products of combustion from the cylinder after thrusting the piston respectively.

Ports (Inlet, Outlet & Transfer ports): these are the passages cut circumferentially in a 2-stroke engine cylinder walls. These ports are covered and un covered during the piston movement.

Cam: It is a machine element designed to control the movement of the valves.

Camshaft: It is the output shaft which supports the cam. It is driven through gear or chain drive.

Bed plate: It is the lower portion of the crankcase. It is fitted by means of bolt.

Governor: It is a control device used to maintain the engine speed constant by regulating charge when the load changes.

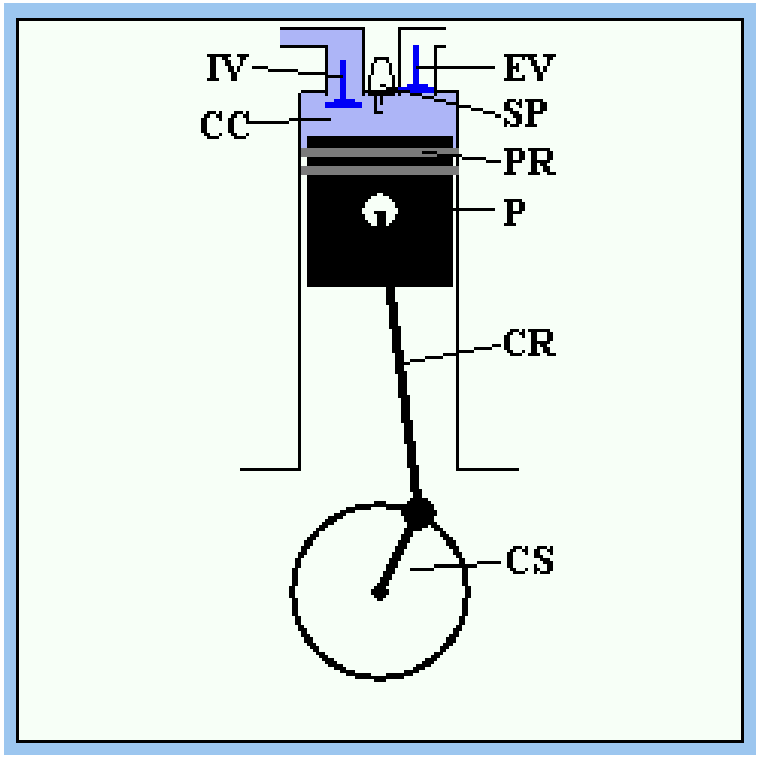
Valve springs: These are the springs fitted inside the valves.

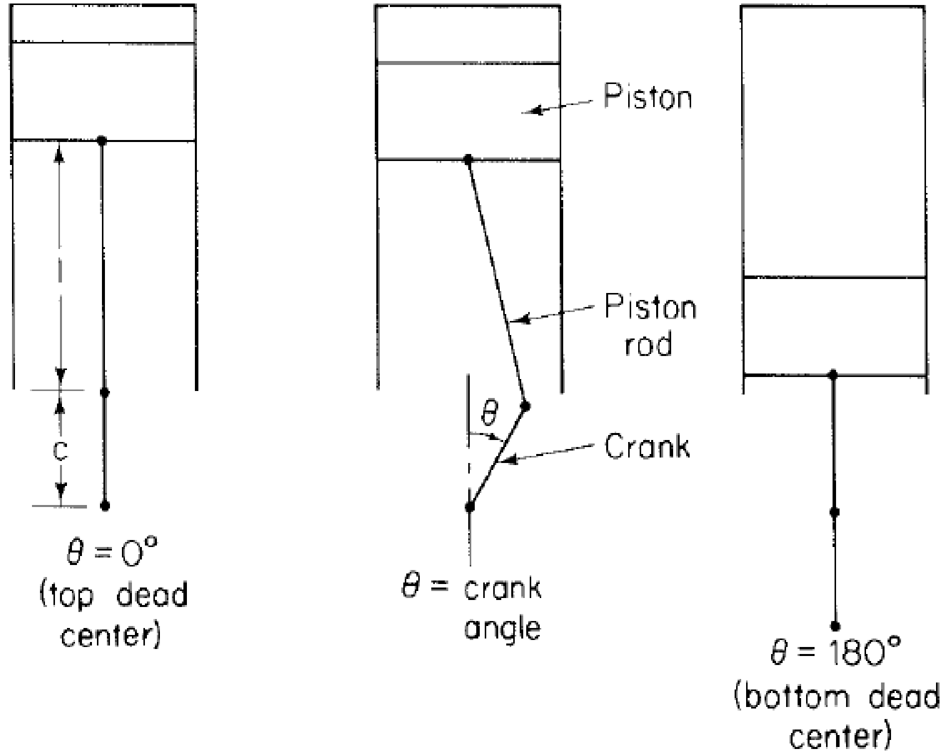
Flywheel: It is a heavy disc mounted on the crankshaft. It is used as an energy reservoir. It stores the excess energy delivered by the engine during power stroke and supplies the energy needed during other strokes. Hence it keeps the fluctuations in the crankshaft speed within desired limits.

Spark Plug: It is component fitted on the cylinder head of petrol (S.I) engines to initiate the spark for igniting the charge.

Injector: It is component fitted on the cylinder head of diesel (C.I) engines to spray a metered quantity of diesel oil which gets ignited by the high temperature air.

ENGINE TERMINOLOGY





I.C. Engine Terminology:

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

2) **Crank radius (r_c):** It is the linear distance between the shaft centre and crank pin centre. It is equal to half of the stroke length.

3) **Dead Centres:** These are the two positions of the crankshaft where the crank and connecting rod are in a line. As a result the piston is pushed to the extreme positions, once near to the cover and next near to the crank. These are named as Top dead Centre (TDC) and Bottom Dead Centre (BDC) in vertical engines. In case of horizontal engines these are called as Inner Dead Centre (IDC) and Outer Dead Centre (ODC) respectively.

Top dead centre/ inner dead centre: It is the extreme position of the piston towards cover end side of the cylinder. The crank pin comes between the piston and the crankshaft.

Bottom dead centre / outer dead centre: it is the extreme position of the piston towards the crank end side of the cylinder. The crank pin moves to the farthest distance from the cylinder.

4) Stroke (L = 2 rc): i*t s the linear distance* travelled by the piston from one dead centre position to the another dead centre position. It is equal to twice the crank radius.

5) Swept volume (Piston Displacement) Vs = (π d² /4) L: t is the volume through which the piston sweeps during a stroke. It is equal to the product of surface area of the piston and its stroke length.

6) Clearance Volume V_c : It is the volume included between the top of the piston and the cylinder head, when the piston is at the TDC or IDC. Generally it is expressed as a %age of the swept volume, since practically the piston never touches the cylinder head.

7) Compression ratio (C.R) : It is the ratio of the total cylinder volume to the clearance volume.

$$C.R = Vc + Vs / Vc > 1$$

For petrol engines CR varies from 4:1 to 10:1 and for diesel engines 12:1 to 22:1.

8) Piston Speed / velocity of piston V_p= 2Ln' m/s: it is the distance travelled by the piston per unit time.

9) Cycle of operation: It is the complete series of events, in which suction/ induction, compression of charge, burning of fuel & expansion and expulsion/exhaust of the working medium are accomplished before repetition occurs.

In two stroke engine, a cycle of operation completes in every one revolution of the crankshaft. In a four stroke engine a cycle of operation completes in every two revolution of the crank shaft.

Adiabatic

—A process during which no heat is transferred between the system and surroundings is described as "adiabatic."

Heat engine

—A device converts heat to mechanical work in a periodic process.

Reversible

—A process occurs in such a way that both the system and its surroundings can be returned to their initial states.

Supercharging

—Methods to increase the inlet manifold air pressure above ambient pressure so that power output in engines is increased.

Thermal efficiency

—The ratio of net work to thermal energy input.

Turbo charging

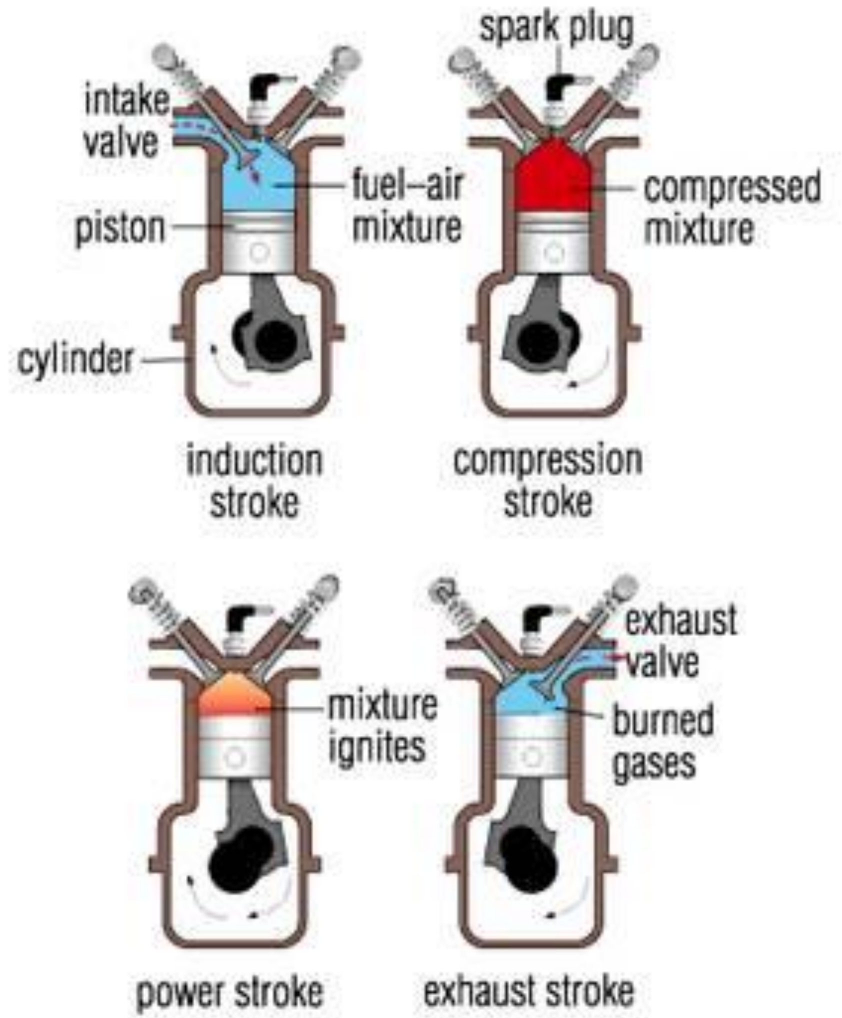
—An approach to utilizing high-temperature exhaust gas by expanding it through a turbine for driving the supercharging compressor.

Mr. Nicolaus August Otto is the inventor of the four-stroke cycle - GERMAN Scientist

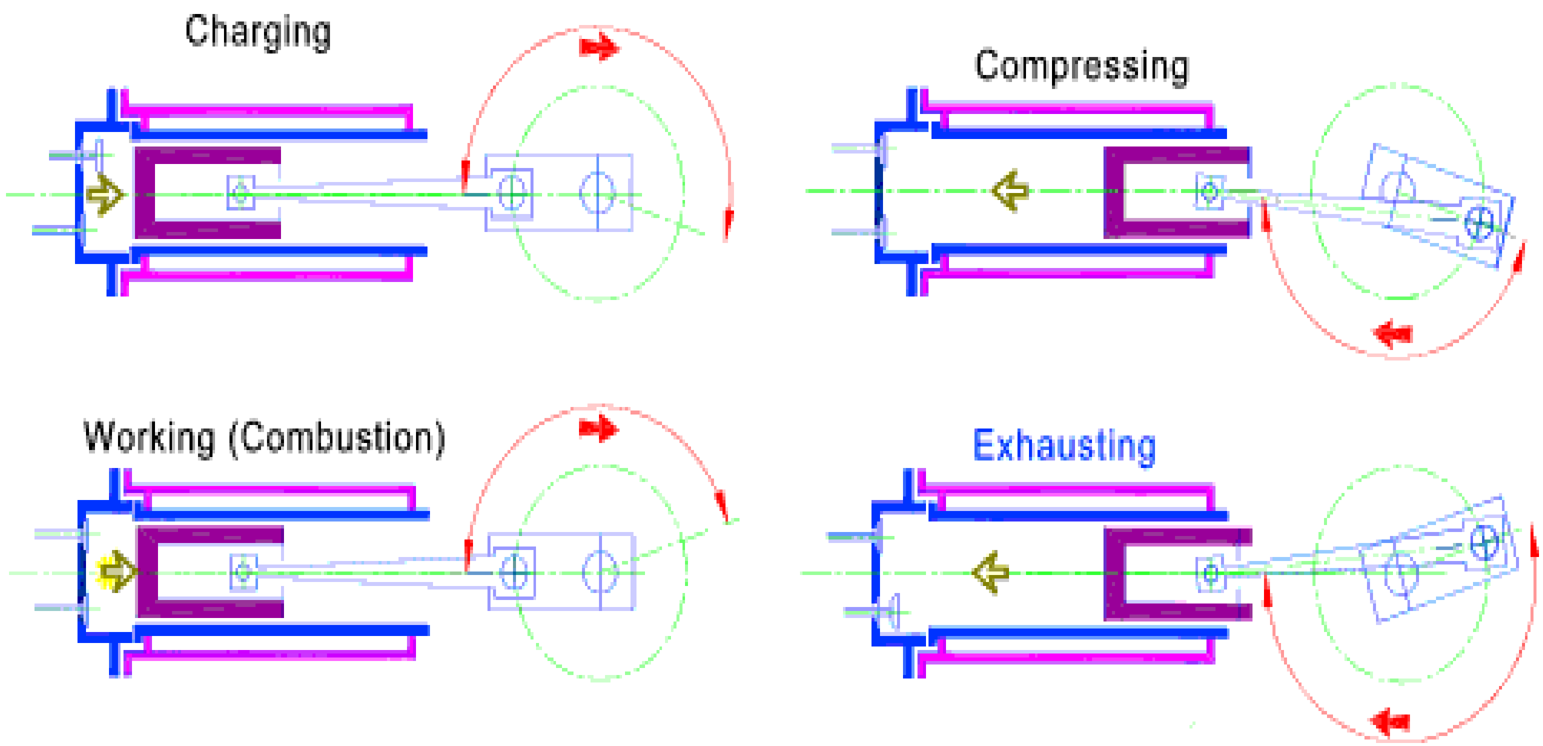
FOUR STROKE PETROL ENGINE

It operates on theoretical Otto Cycle. It is also called as constant volume combustion cycle, as the combustion/ heat addition takes place at constant volume with increase in pressure. It works on reciprocating piston principle wherein a piston slides back & forth in a cylinder and transmits power through connecting rod and crank mechanism to the crank shaft. Inlet & exhaust valves regulate the flow of air-fuel mixture and exhaust gases respectively. Combustion is ignited by spark plug, hence the engines are known as spark ignition engines or SI engines. here the cycle is completed in two revolutions of the crankshaft with four strokes of the piston, namely i) Suction Stroke ii) Compression stroke iii) Working/ Power stroke iv) Exhaust stroke.

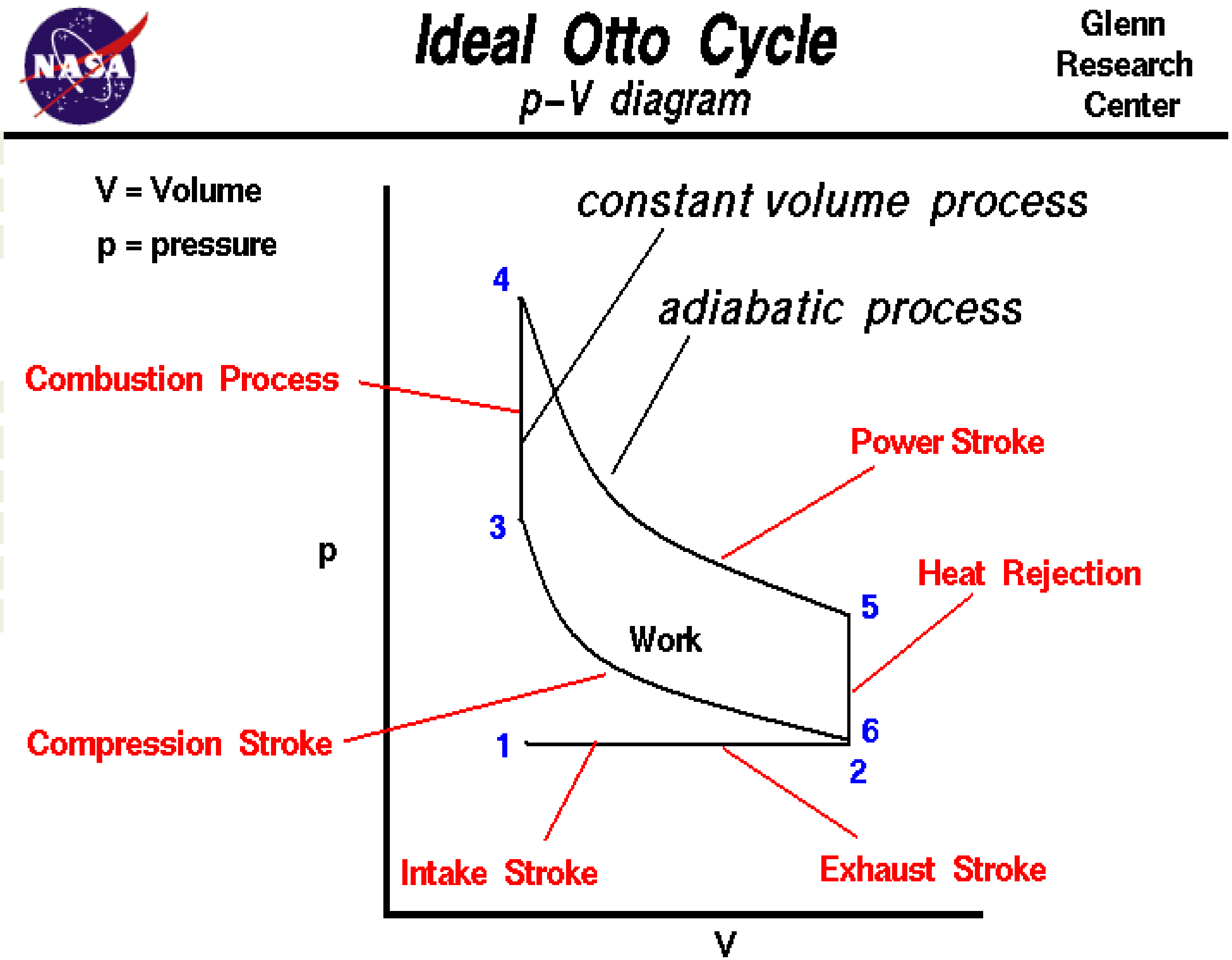
Unit – III, I C Engines

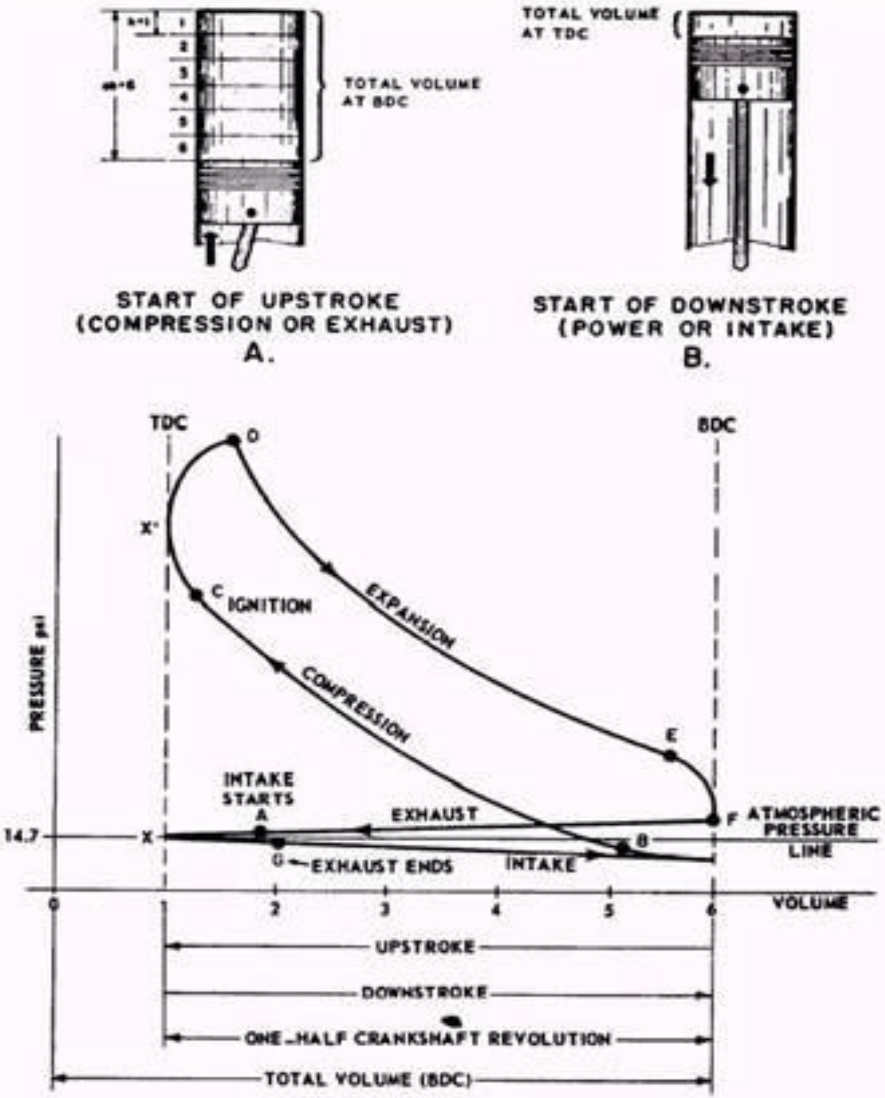


four stroke internal-combustion engine an explosive mixture is drawn into the cylinder on the first stroke, it is compressed and ignited on the second stroke; work is done on the third stroke and the products of combustion are exhausted on the fourth stroke.



OTTO CYCLE


Ideal Otto Cycle
p-V diagram
Glenn
Research
Center
V = Volume
p = pressure
constant volume process
adiabatic process
4
Combustion Process
Power Stroke
3
p
Heat Rejection
5
Work
Compression Stroke
1
6
2
Intake Stroke
Exhaust Stroke
V



C-CYCLE DIAGRAM
C.

P-V DIAGRAM

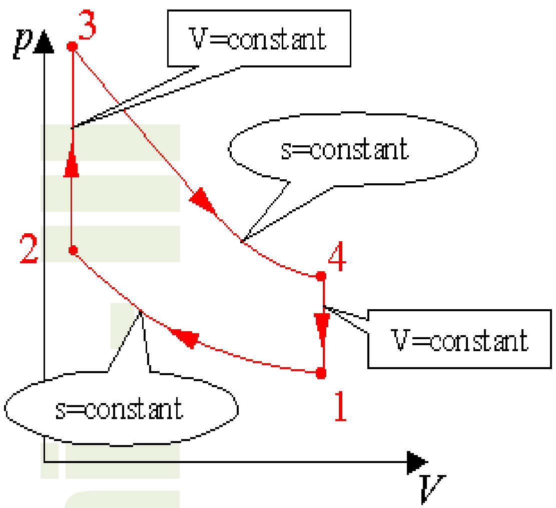
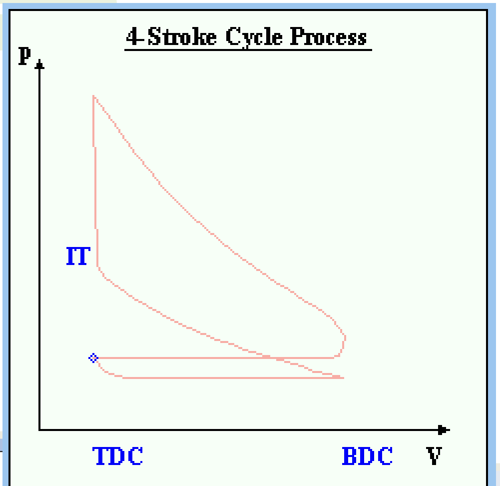
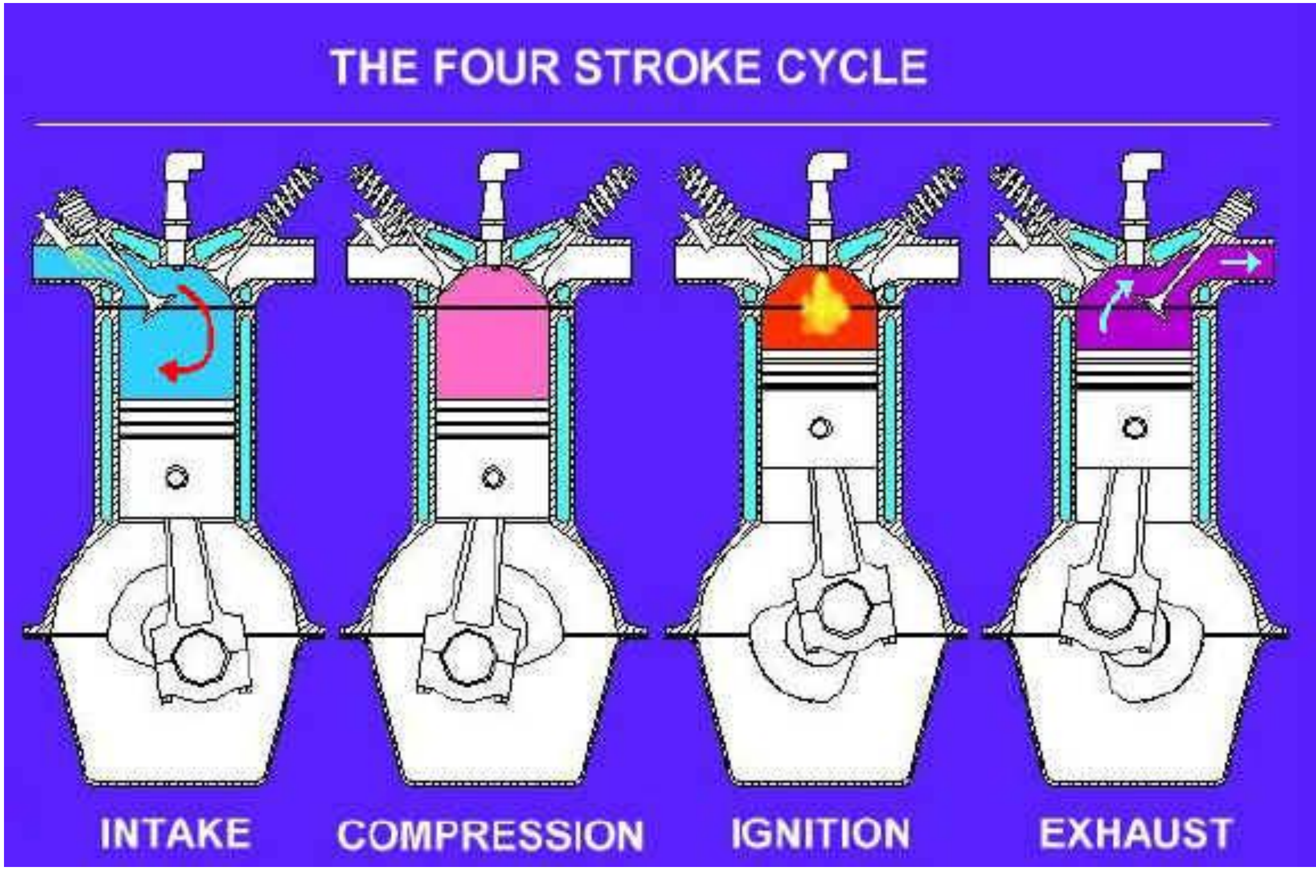


Fig. 1. The Otto cycle on a p-v diagram.





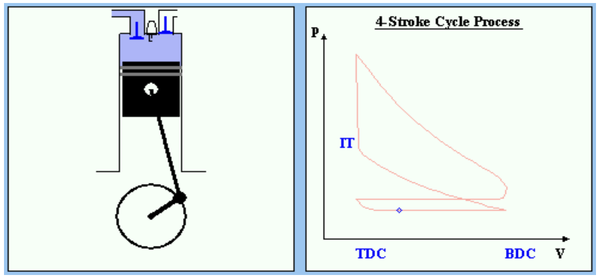
FOUR STROKE PETROL ENGINE

In petrol engine the petrol is vaporized by means of a device called carburetor.

Suction Stroke:

a)Suction stroke starts when piston starts moving from TDC to BDC, since the crankshaft is revolved by the momentum of flywheel/by electric motor/ by cranking.

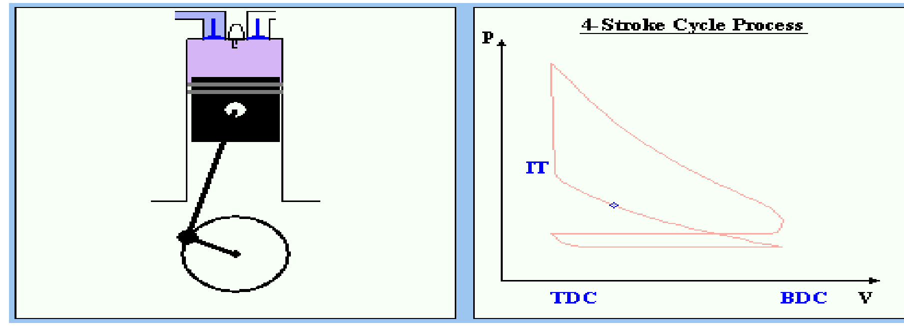
b)Inlet valve is open & exhaust is closed



c)At beginning the pressure in the cylinder will be atmospheric, as piston moves the volume in the cylinder increases and pressure decreases. Due this pressure differential the suction created and fresh charge consisting of petro & air mixture enters the cylinder through the carburetor.

d)It is represented by S-1 on the P-V Diagrams.

e) When the crank completes half revolution, the piston reaches BDC – the suction stroke ends by filling the cylinder with petrol & air mixture and inlet is closed by inlet valve.



Compression Stroke

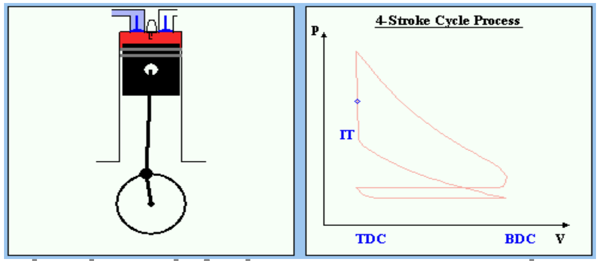
a) Both Inlet & Exhaust are closed

b) Piston starts moving from BDC to TDC by compressing the charge and crankshaft revolves by half rotation. So the gradual increase in pressure & temperature of fuel- air mixture by decrease in volume. Hence the process of compression is reversible adiabatic or isentropic, represented by 1-2 on the P-V diagram.

c) The ratio of compression in petrol engine ranges from 1:7 to 1:11. The temperature rise may be about 1500 to 2000^{0}C.

d) Near the end of this stroke the charge is ignited by the electric spark given out by spark plug. The combustion of petrol releases the hot gases which will increases the pressure at constant volume as shown by 2-3 vertical line on the P-V diagram.

e) The crank completes one revolution.



Working or power stroke

a) Both inlet and exhaust valves are closed and the high pressure burnt gases push the piston from TDC to BDC. Hence the power is derived/ energy is liberated and crankshaft revolves by half rotation.

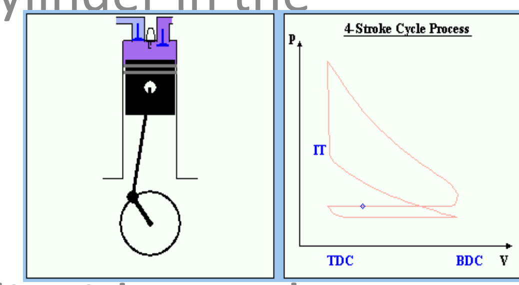
b) As result of burning of gases expand adiabatically with increase in volume and decrease in pressure and temperature inside the cylinder is shown by the curve 3-4.

c) At the end of the stroke, the exhaust valve opens by releasing the burnt gases to atmosphere by drop in pressure at constant volume as shown by 4-1 on P-V diagram. The crank completes one and half revolutions.

Exhaust stroke

a) The inlet valve is closed and exhaust is open and the piston moves from BDC to TDC by pushing the remaining burnt gases to the atmosphere at constant pressure with decrease in volume as shown by S-1 on P-V diagram.

b) At the end of stroke the exhaust valve closes and some quantity of gases gets trapped in the clearance volume, which mixes with fresh charge entering the cylinder in the succeeding cycle.



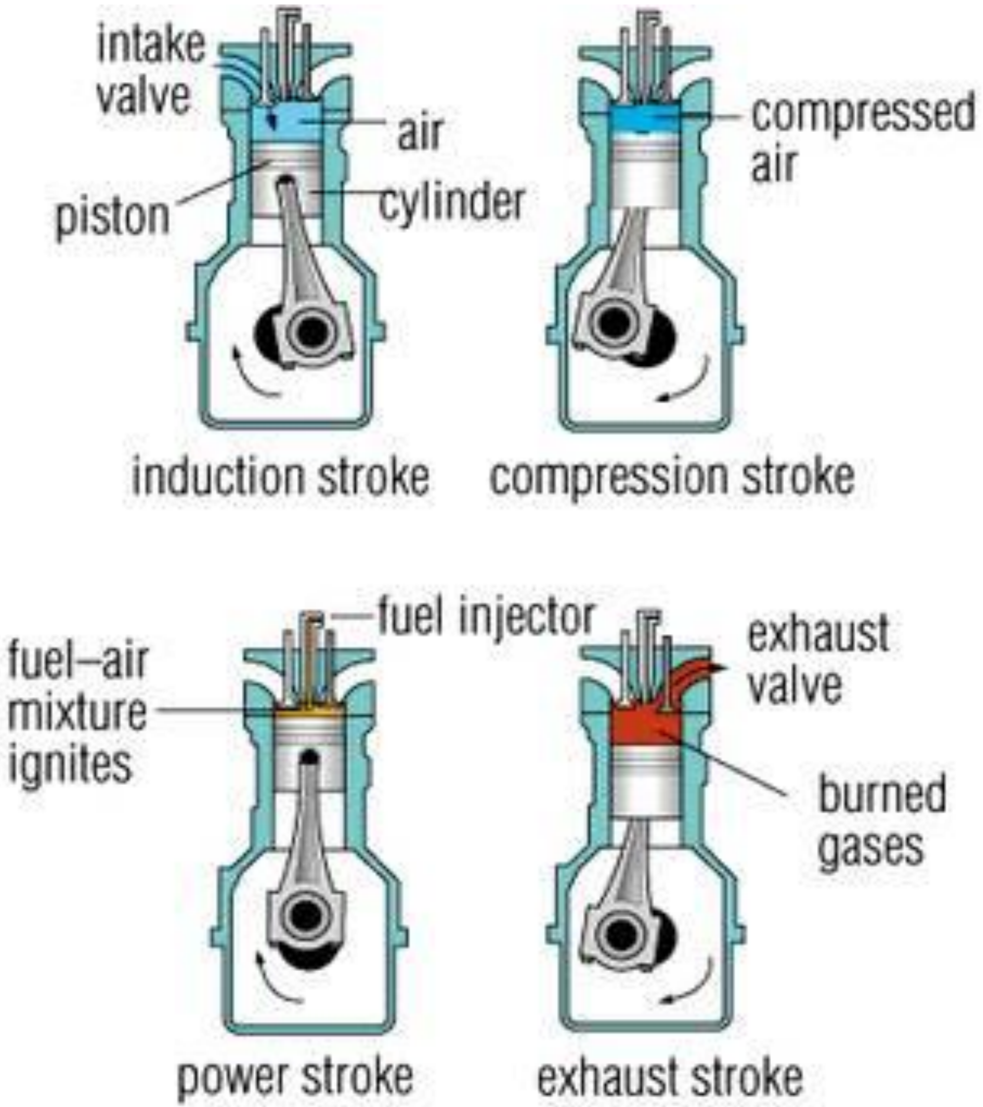
c) The crank completes two revolutions.

combustion products—mainly carbon dioxide, carbon monoxide, nitrogen oxides, and unburned hydrocarbons—out of the cylinder during the upward exhaust stroke.

FOUR STROKE DIESEL ENGINE

It operates on theoretical Diesel Cycle. It is also called as constant Pressure combustion cycle, as the combustion/ heat addition takes place at constant pressure with increase of temperature. It works on reciprocating piston principle wherein a piston slides back & forth in a cylinder and transmits power through connecting rod and crank mechanism to the crank shaft. Inlet & exhaust valves regulate the flow of air-fuel mixture and exhaust gases respectively. Combustion is ignited due to high temperature of compressed air; these are called (C.I) compression Ignition engines. Here the cycle is completed in two revolutions of the crankshaft with four strokes of the piston, namely i) Suction Stroke ii) Compression stroke iii) Working/ Power stroke iv) Exhaust stroke.

In diesel engine the diesel is injected by means of a device called fuel injector.

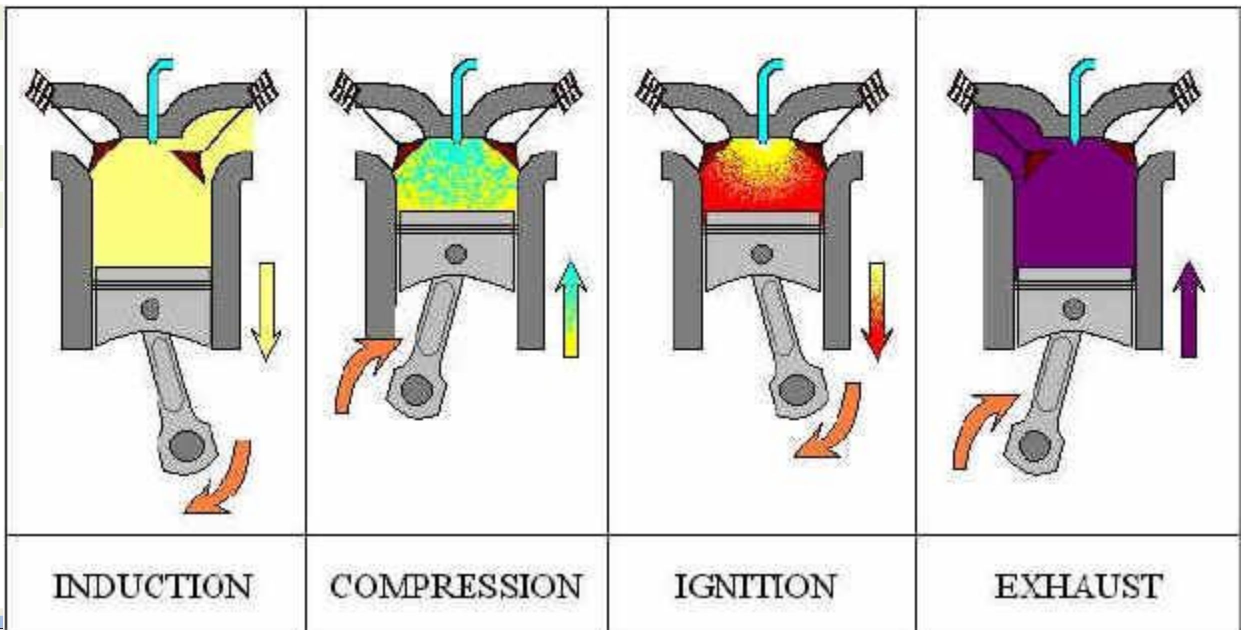

intake valve
air
piston
cylinder
compressed air
induction stroke
compression stroke
fuel injector
fuel–air mixture ignites
exhaust valve
burned gases
power stroke
exhaust stroke

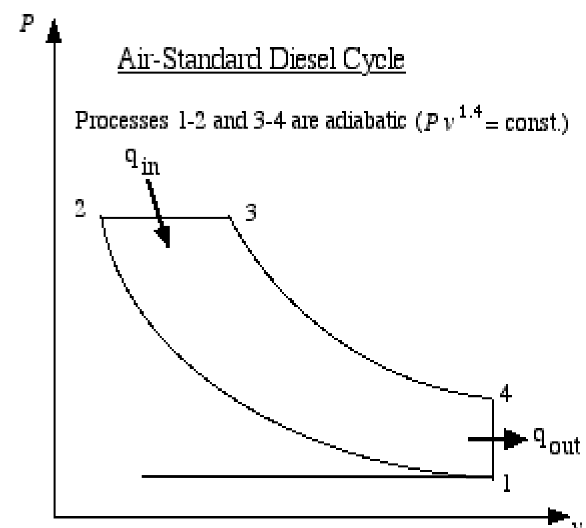
Process 1-2 is the adiabatic compression process. Work is done on the system.

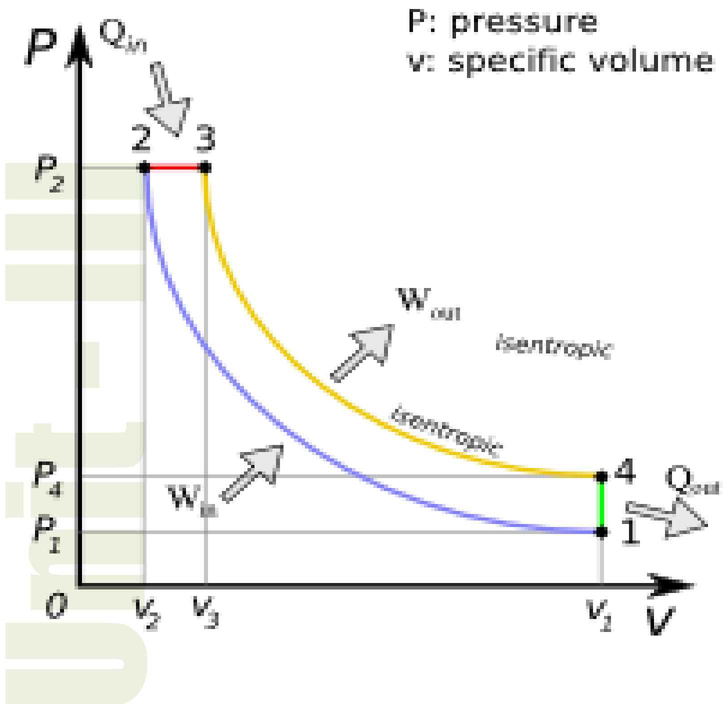
Process 2-3 is the constant pressure heat addition process.

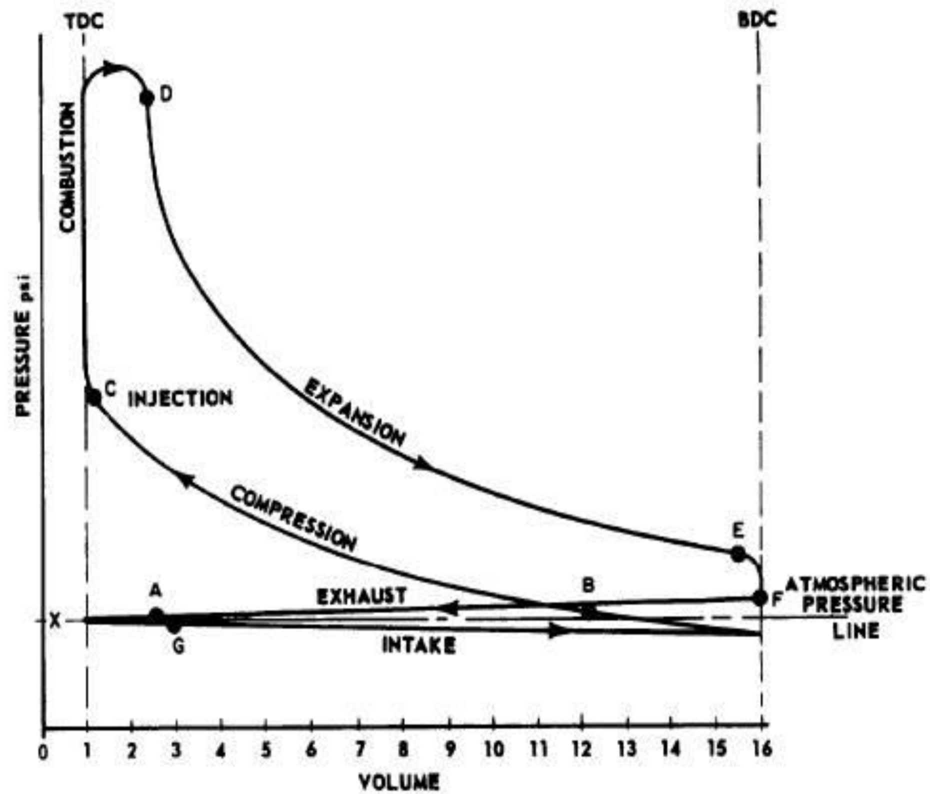
Process 3-4 is the adiabatic expansion process. Note that work we is done by the system during both processes 2-3 and 3-4.

Process 4-1 is the constant volume heat rejection process.






P
Qin
P: pressure
v: specific volume
2
3
P2
Wout
isentropic
isentropic
P4
4
Qout
Win
P1
1
0
V2
V3
V1
V


TDC
BDC
D
COMBUSTION
PRESSURE psi
C
INJECTION
EXPANSION
COMPRESSION
E
A
B
EXHAUST
F
ATMOSPHERIC PRESSURE LINE
X
G
INTAKE
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
VOLUME

Suspicion Stroke:

a) Suction stroke starts when piston starts moving from TDC to BDC, since the crank shaft is revolved by the momentum of flywheel/by electric motor/ by cranking

b) Inlet valve is open & exhaust is closed

c) Due to suction created by the downward motion of piston, only air from the atmosphere is drawn into the cylinder. It is represented by S-1 on the P-V Diagrams.

d) When the crank completes half revolution, the piston reaches BDC – the suction stroke ends by filling the air and inlet is closed by inlet valve.

ii) Compression Stroke

a) Both Inlet & Exhaust are closed

b) Piston starts moving from BDC to TDC by compressing the air adiabatically (isentropic) with decrease in volume and increase in pressure as high as 4 MPa and temperature as 1000^0C and is represented by 1-2 on the P-V diagram.

c) Near the end of this stroke the fuel injector opens & a fine spray of fuel is injected into the hot compressed air, where it starts burning with constant pressure as shown by 2-3 horizontal line on the P-V diagram. At point 3, the fuel supply is cut off.

d) The crank completes one revolution.

iii) Working or power stroke

a) Both inlet and exhaust valves are closed and the hot gases & air exert pressure on the piston and pushes from TDC to BDC. Hence the power is derived/ energy is liberated and crankshaft revolves by half rotation.

b) As result of burning of gases and air expand adiabatically with increase in volume and decrease in pressure inside the cylinder is shown by the curve 3-4 on the P-V Diagram.

c) At the end of the stroke, the exhaust valve opens by releasing the hot gases to atmosphere at constant volume as shown by 4-1 on P- V diagram. The crank completes one and half revolutions.

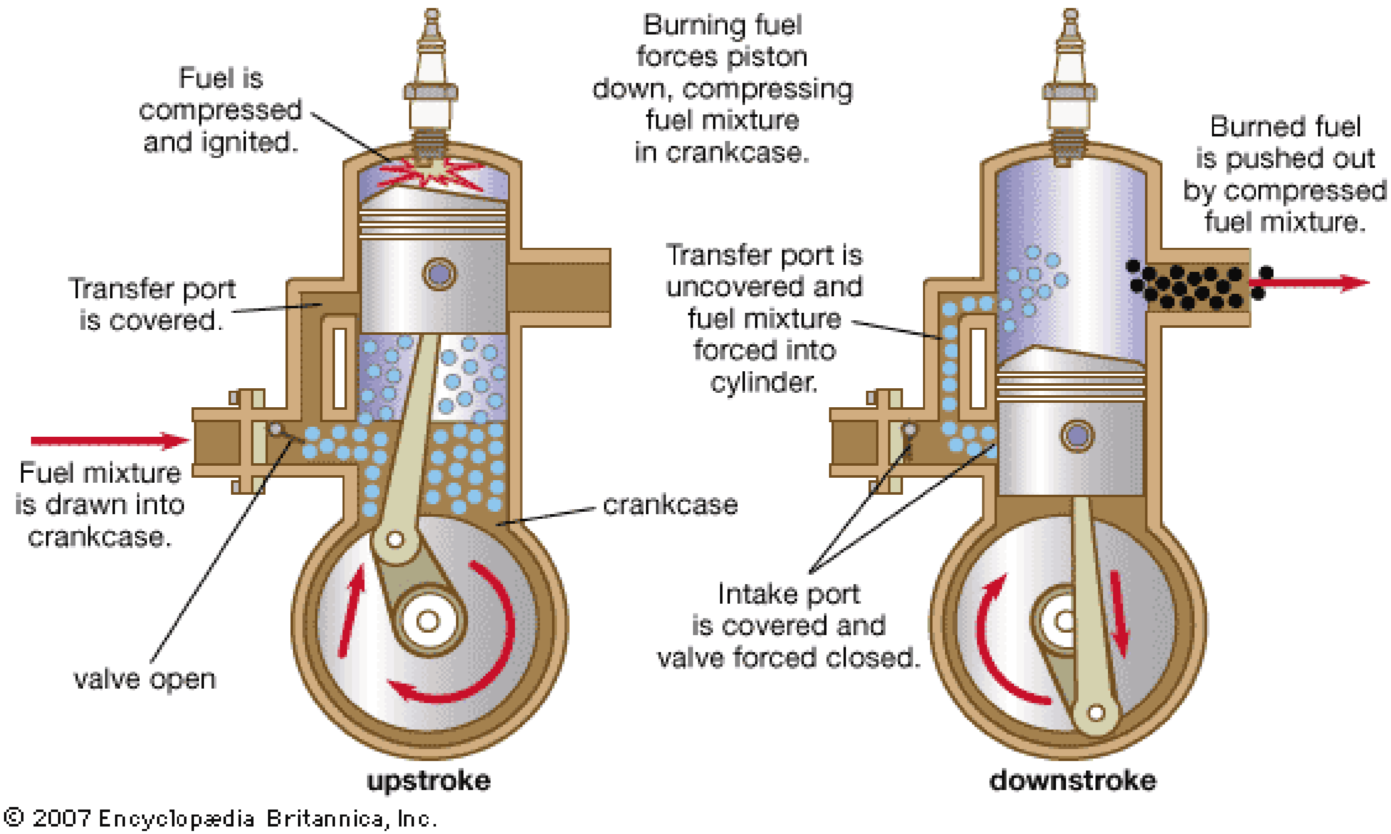
iv) Exhaust stroke

a) The inlet valve is closed and exhaust is open and the piston moves from BDC to TDC by pushing the remaining burnt gases to the atmosphere at constant pressure with decrease in volume as shown by 1-S on P-V diagram.

b) At the end of stroke the exhaust valve closes and some quantity of gases gets trapped in the clearance volume, which mixes with fresh air entering the cylinder in the succeeding cycle.

c) The crank completes two revolutions.

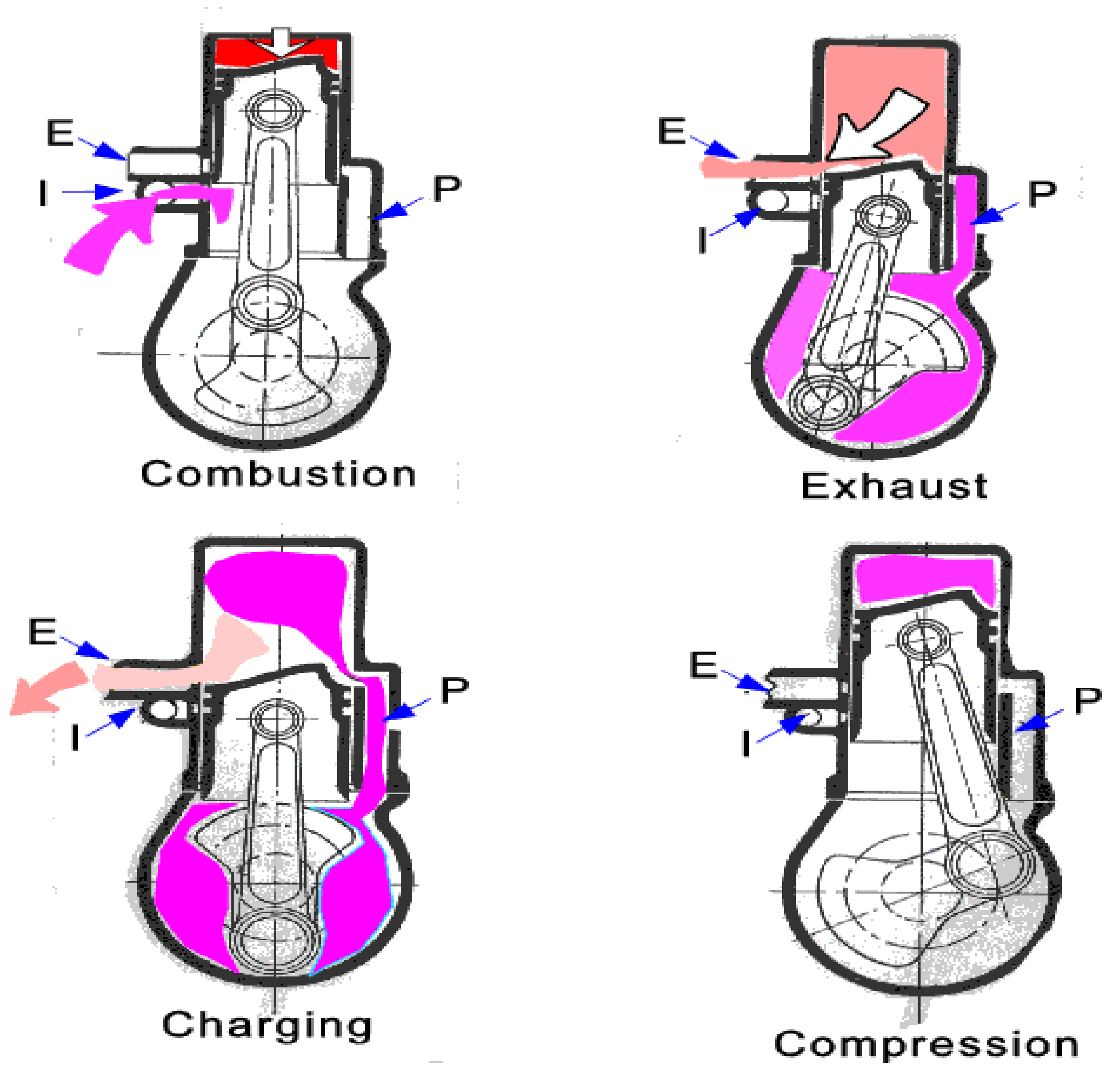
TWO STROKE PETROL ENGINE



Two –Stroke Petrol Engine

Works on

Theoretical Otto Cycle.



These are designed to drive the power stroke during every revolution of the crankshaft. Hence suction & exhaust stroke are eliminated. Valves are replaced by the ports and the burnt exhaust gases are forced out either by Scavenging pump system or closed crank case system. A specific shape is given to piston which helps to prevent the loss of incoming charge and helps to exhaust the hot gases effectively.

Applications Ex: Mopeds, Scooters, Motor Cycles.

Single cylinder – 3 Ports – Inlet, transfer & Exhaust

Power developed – 1.7 to 1.8 times of 4 stroke engine.

First Stroke:

a) Piston is at the end of compression.

b) Spark ignited by sparkplug as the piston reaches the TDC, is represented by point 1 in P-V diagram.

c) Combustion occurs at constant volume with increase in pressure & temperature as shown by line 1-2 on P-V diagram.

d) Hot gases expand adiabatically from 2-3 by exerting pressure on the piston and piston moves downward by producing the power stroke.

e) While moving down the piston uncovers the exhaust port, then the burnt gases rush out from the cylinder through exhaust port as shown by 3-4, hence the pressure drops. Later the top side of piston uncovers the transfer port as shown by point 5 and the charge in the crankcase is compressed by the underside of the piston, so the charge moves through transfer port to upper part of cylinder and pushes the exhaust gases out through exhaust port till piston reaches BDC. It is represented by 5-6 on p-v diagram.

Second Stroke:

a) Piston starts moving upward.

b) Exhaust gases are partially pushed through exhaust port as shown by line 6-5. further ahead of piston covers the transfer port at point 5 and stops the flow of fresh charge into the cylinder.

c) Later piston covers exhaust port & uncovers the inlet port, so the fresh charge is drawn into the cylinder, as represented by line 5-4.

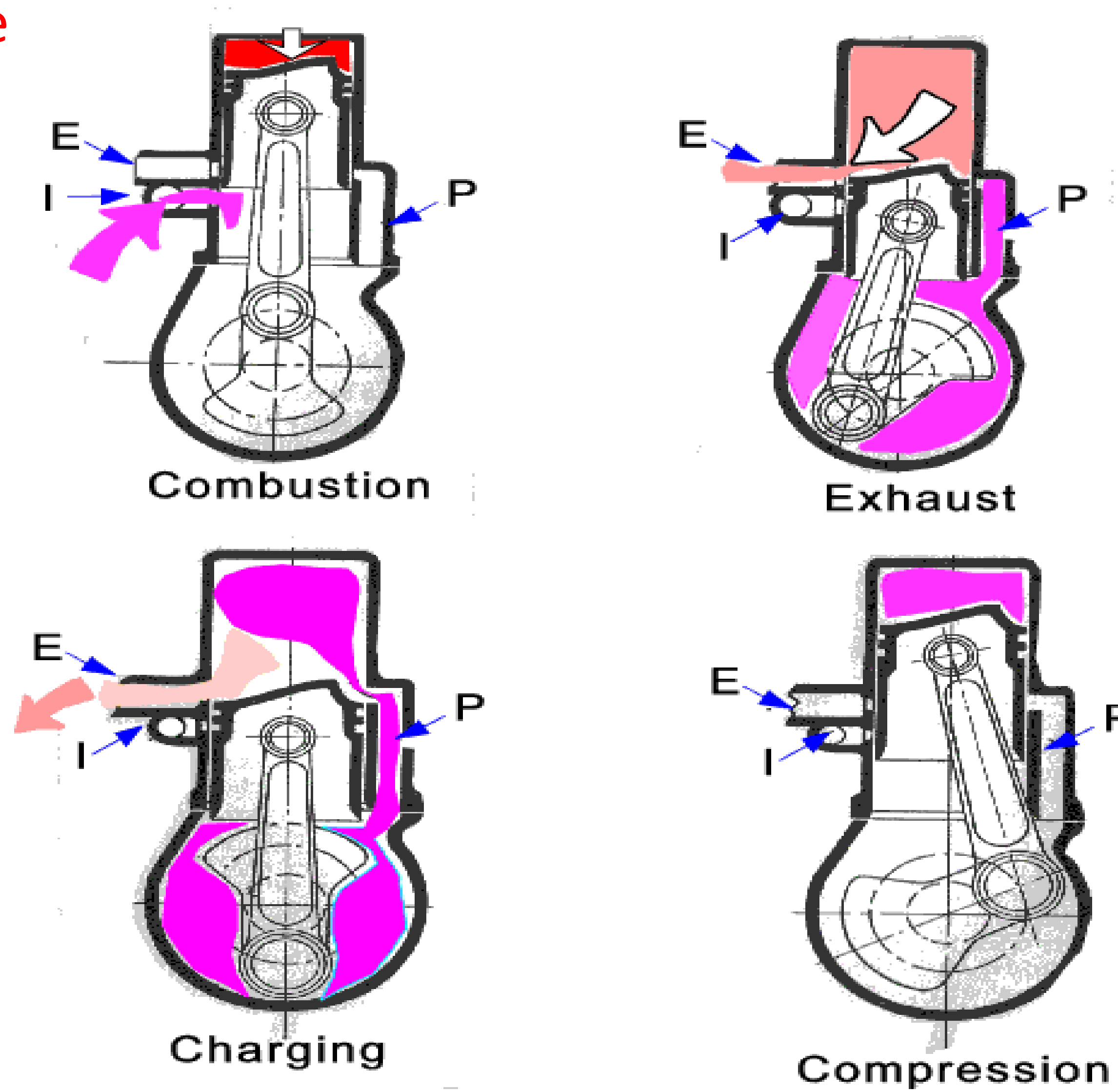
d) The actual compression of charge (air+fuel mixture) starts and follows the adiabatic compression shown by 4-1 on p-v diagram till piston reaches TDC.

e) Crank completes one complete revolution and finishes one complete cycle.

Two –Stroke Diesel Engine

Works on

Theoretical Diesel Cycle.



First Stroke:

a) Piston is at the end of compression.

b) The diesel fuel is injected by fuel injector before completing the compression and it starts burning at the end of compression and is represented by point 1 in P-V diagram. The pressure & temperature is sufficient inside the cylinder to burn the fuel.

c) The high pressure gases try to push the piston downwards at a constant pressure as shown by line 1-2. at point 2 the fuel supply is cut off.

d) Hot gases exert pressure and the gases are burnt and expand adiabatically by exerting pressure on the piston and piston moves downward by producing the power stroke. As a result there is a increase in volume & decrease in pressure as shown by line 2-3.

e) While moving down the piston uncovers the exhaust port, then the burnt gases rush out from the cylinder through exhaust port as shown by 3-4, hence the pressure drops. Later the top side of piston uncovers the transfer port as shown by point 5 and the air in the crankcase is compressed by the underside of the piston, so the air moves through transfer port to upper part of cylinder and pushes the exhaust gases out through exhaust port till piston reaches BDC. It is represented by 5-6 on p-v diagram. The crank completes half revolution.

Second Stroke:

a) Piston starts moving upward.

b) Exhaust gases are partially pushed through exhaust port as shown by line 6-5. further ahead of piston covers the transfer port at point 5 and stops the flow of air into the cylinder.

c) Later piston covers exhaust port & uncovers the inlet port, so the air is drawn into the cylinder, as represented by line 5-4.

d) The actual compression of air starts and follows the adiabatic compression shown by 4-1 on p-v diagram till piston reaches TDC.

e) Crank completes one complete revolution and finishes one complete cycle.

COMPARISION BETWEEN PETROL & DIESEL ENGINE

Sl. No	Principle	Petrol Engine (S. I Engine)	Diesel Engine (C.I Engine)
1	Theoretical Cycle of operation	It works on Otto Cycle which is also called as constant volume cycle.	It works on Diesel Cycle which is also called as constant pressure cycle.
2.	Fuel used	Petrol	Diesel
3.	Admission of the Fuel	During the suction stroke itself the petrol is first admitted in to the carburetor, which it gets mixed with the air and then mixture enters the cylinder.	The diesel oil is pressurized by the fuel pump and then injected into the engine cylinder by the fuel injector at the end of compression stroke.
4.	Charge drawn during the Suction Stroke	Air and petrol mixture is drawn during the suction stroke.	Only air is drawn during the suction stroke.
5.	Compression Ratio	Low compression ratio ranging from 7 : 1 to 12 : 1	High compression ratio ranging from 16 : 1 to 20 : 1

6.	**Ignition of the Fuel**	**The compressed air and petrol is ignited by the spark plug. This type of ignition is called spark ignition**	**The ignition of the diesel is accomplished by the compressed air which will have been heated due to high compression, to the temperatures higher than the ignition temperature of the diesel. This type of ignition is called compression ignition or auto ignition.**
7.	Governing	The quantitative method of governing is employed in petrol engines.	The qualitative method of governing is employed in diesel engines.
8.	Engine Speed	High engine speeds of about 3000 rpm.	Low engine speeds ranging from 500 to 1500 rpm.
9.	Power output Capacity	Because of the low compression ratio the power developed will be less.	Due to high compression ratio the power developed will be more.

10.	**Thermal Efficiency**	**The thermal efficiency of petrol engines is lower due to lower compression ratio.**	**The thermal efficiency of diesel engines is higher due to high compression ratio.**
11.	Noise and Vibration	Because of operating pressure is less the noise and vibrations are almost nil.	Because of higher operating pressures the noise and vibration are high.
12.	Weight of the Engine	Due to low compression ratio, temperature of firing is less therefore the engine need not be of robust construction, hence the weight of the engine is less.	Due to higher compression ratio, and higher maximum pressure and temperature, the engine will have to be strong and sturdy hence the weight of the engine is more.
13.	Initial Cost	For the same power output the initial cost of the engine is less because it is lighter in construction.	The initial cost of diesel engines is more due to costlier fuel injection systems and robust design.
14.	Operating Fuel Cost	The running or operating cost is high because the petrol is costlier	The running and operating cost is less because the diesel is cheaper.

15.	Maintenance Cost	Less	Slightly higher
16.	Starting of the Engine	The petrol engines can easily be started even in cold weather.	The diesel engines are difficult to start in cold weather.
17.	Exhaust Gas Pollution	The exhaust pollution is more in petrol engines, because the unburnt hydrocarbon and carbon monoxide are significant in the exhaust gases due to the constant air – fuel ratio and quantitative governing employed.	The exhaust gas pollution is less because there will be a larger amount of excess air which results in a wide range of air fuel ratios ranging from very lea mixture to very rich mixture. A well maintained diesel engine has very little carbon monoxide and hence less amount of smoke.
18.	Uses	Used in Scooter, Motor Cycle, Cars, etc.	Used in as Trucks, Tractors, Buses, Bulldozers.

Comparison between Two stroke and Four Stroke I.C Engines

Sl. No	Principle	Four – Stroke Engine	Two – Stroke Engine
1.	Number of stokers per Cycle	Requires four separate strokes of the piston to complete one cycle one cycle of operation.	Requires only two strokes of the piston to complete one cycle of operation.
2.	Number of Cycles per min	The number of cycles per min is equal to half the speed of the engine. Number of cycles / min	The number of cycles per minute will be equal to the speed of the engine. Number of cycles / min 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	The torque will not be uniform because the power is produced in every alternate revelation, hence heavy flywheel is required.	The torque will be more uniform because the power is produced in every revolution of the crankshaft hence a lighter flywheel is required.

Comparison between Two stroke and Four Stroke I.C Engines

5.	**Admission of Charge**	**The charge is directly admitted into the engine cylinder during the suction stroke.**	**The charges 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	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.
8.	Crankcase	Although the crankcase of a four stroke engine is closed, it will not be hermetically sealed.	Since the charge is admitted into the crankcase it is hermetically.
9.	Engine Cooling	The cooling can be made mote 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.

Comparison between Two stroke and Four Stroke I.C Engines

10.	**Direction of Rotation of CS**	**The crankshaft rotates only in one direction.**	**The crankshaft can rotate in either directions.**
11.	Lubricating Oil Consumption	Less	More.
12.	Fuel Consumption	Since there is no mixing of fresh charge with the exhaust gases, the fuel consumption is less.	There will be mixing of the fresh charge with the exhaust gases, hence there is a loss of fresh charge, hence the fuel consumption is more.
13	Mechanical Efficiency	The mechanical efficiency is low because of the increased number of strokes and more number of mechanical parts.	The mechanical efficiency is high because there are only two strokes per cycle and absence of the mechanical parts such as cams, camshafts, valves, valve gears, etc.
14.	Noise	Since the exhaust takes place gradually during the exhaust strokes, the noise will be less.	The opening of the exhaust port releases the exhaust gases suddenly, and hence noise will be more.
15.	Uses	Four stroke engines are used in slow speed high power applications like, cars, trucks, tractor, jeeps, buses, etc.	Two stroke engines are used for high speed and low power applications such as mopeds, scooters, motor cycles etc.

In the combustion phase an ignited charge exerts pressure on the piston crown whilst a fresh charge is drawn through the carburettor into the crankcase via inlet port I.

During the exhausting phase the piston moving down partly uncovers the exhaust port E allow the combustion gases to start to discharge. The downward movement of the piston also compresses the fuel air mixture in the crankcase.

At the end of the first stroke the exhaust port are fully open and the fuel inlet port P is now open allow the compressed fuel mixture to enter the cylinder above the piston. The piston crown is so shaped that the mixture is deflected upwards above the residue of the escaping exhaust gases. The fuel mixture helps to sweep out the exhaust gases.

During the upward compressing stroke, the piston covers the transfer ports , compresses the charge and creates a small vacuum in the crankcase. At the end of the upward stroke (inner dead centre) ignition occurs resulting in the ignited charge expanding and exerting pressure on the piston.

The two-stroke engine is simple in construction, but complex dynamics are employed in its operation. There are several features unique to a two-stroke engine. First, there is a reed valve between the air-fuel intake and the crankcase. Air-fuel mixture enters the crankcase and is trapped there by the one-way reed valve. Next, the cylinder has no valves as in a conventional four stroke engine. Intake and exhaust are accomplished by means of ports - special holes cut into the cylinder wall which allow fuel-air mixture to enter from the crankcase, and exhaust to exit the engine. These ports are uncovered when the piston is in the down position.

Air-fuel mixture is drawn into the crankcase from the carburetor or fuel injection system through the reed valve. When the piston is forced down, the exhaust port is uncovered first, and hot exhaust gases begin to leave the cylinder. As the piston is now in the down position, the crankcase becomes pressurized, and when the intake port into the cylinder is uncovered, pressurized air-fuel mixture enters the chamber. Both the intake and exhaust ports are open at the same time, which means the timing and air flow dynamics are critical to proper operation. As the piston begins to move up, the ports are closed off, and the air-fuel mixture compresses and is ignited; the hot gases increase in pressure, pushing the piston down with great force and creating work for the engine.

The major components of two-stroke engines are tuned so that optimum airflow results. Intake and exhaust tubes are tuned so that resonances in airflow give better flow than a straight tube. The cylinder ports and piston top are shaped so that the intake and exhaust flows do not mix.

Basic Performance Parameters

Mean Effective Pressure: **is the hypothetical pressure acting on the piston throughout the power stroke & is denoted by p_m.**

In indicator diagram the positive area refers to work out put where as negative area refers to work input, which is very small & is neglected.

Mean effective pressure p_m = Net Area of Indicator diagram a in m^2 x Spring Constant K bar per meter / base width of the indicator diagram b in meters

$$p_m = Ka/b \text{ -- in bar}$$

Indicated horsepower (IHP)

It is the power developed on the piston of the engine.

Indicated horsepower is the theoretical power of a reciprocating engine if it is completely efficient in converting the energy contained in the expanding gases in the cylinders. It is calculated from the pressures developed in the cylinders, measured by a device called an *engine indicator.*

Work developed by the cylinder in one cycle (Stroke) = Mean force on the piston X piston stroke length

= Mean effective pressure X area of the cylinder X piston stroke length

= Pm x A x L

Work developed by cylinder in one minute = W = work developed by cylinder in one stroke X engine speed / n- no of strokes

= Pm LAN/n

Work developed by one cylinder in one second = (Pm LA(N/60)) / n

i= No of cylinders

Work developed by I cylinders in one second = Pm L A N i / 60 x n J/s or watts or Nm/s

IHP = Pm LANi/1000 x 60 x n kW

Pm in bar then

IHP = 100 Pm LAN/60 (i/n)

Pm = Ka/b Bar, L= 2 rc Stroke length in meter, A= area of cylinder = $\pi d^2 / 4$ in Sq. meters, N= speed rpm, i= no of cylinders, n =1 for two stroke & n=2 for four stroke.

Note: 1 bar = 105 N/m2 = 100 kN/m2 = 100 kPa = 0.1 Mpa

Brake Horsepower is simply power rated at the output shaft or the power developed by the engine at shaft output.

Brake horsepower (bhp)

Brake horsepower (bhp) is the measure of an engine's horsepower without the loss in power caused by the gearbox, generator, differential, water pump, and other auxiliary components. Thus the prefix "brake" refers to where the power is measured: at the engine's output shaft, as on an engine dynamometer. The actual horsepower delivered to the driving wheels is less. An engine would have to be retested to obtain a rating in another system. The term "brake" refers to the original use of a band brake to measure torque during the test (which is multiplied by the engine RPM and a scaling constant to give horsepower).

BHP is always lesser then IHP because some of the power developed is lost to overcome the friction between moving parts like piston, connecting rod & crank.

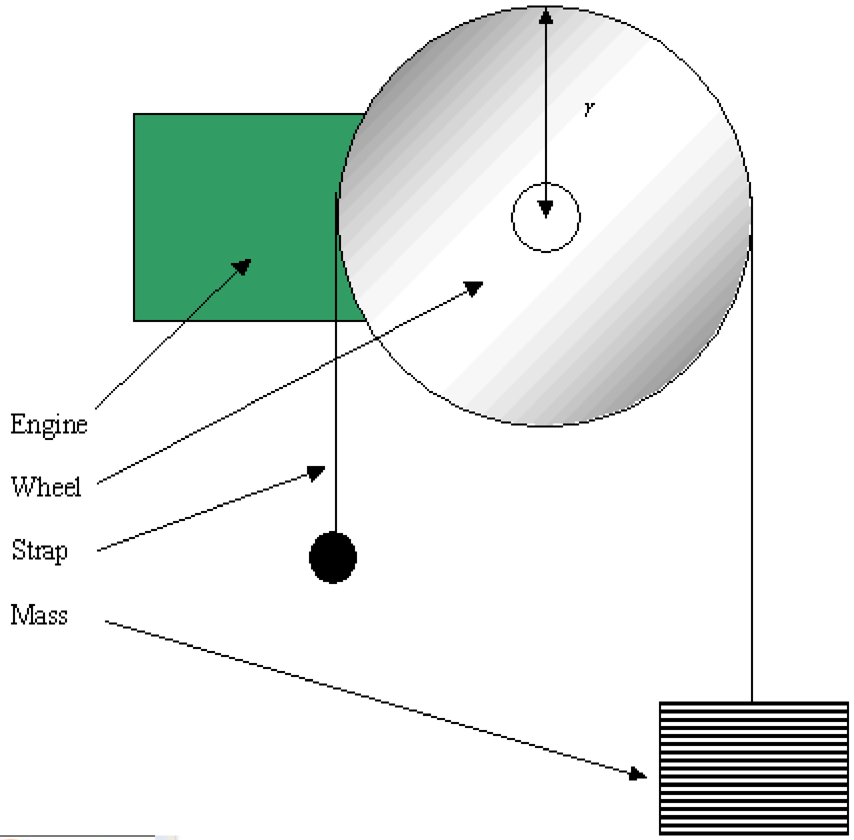
The difference between IHP & BHP is called friction power expressed in kW.

FP = IHP - BHP

The power produced by the engine is given by the formula:

$P = Tw$

[P - power (W); T - torque (Nm); w - angular velocity (rad/s)]



BHP = IHP X Mech. Efficiency

Specific fuel consumption, often shortened to **SFC**, is an engineering term that is used to describe the fuel efficiency of an engine design with respect to a mechanical output.