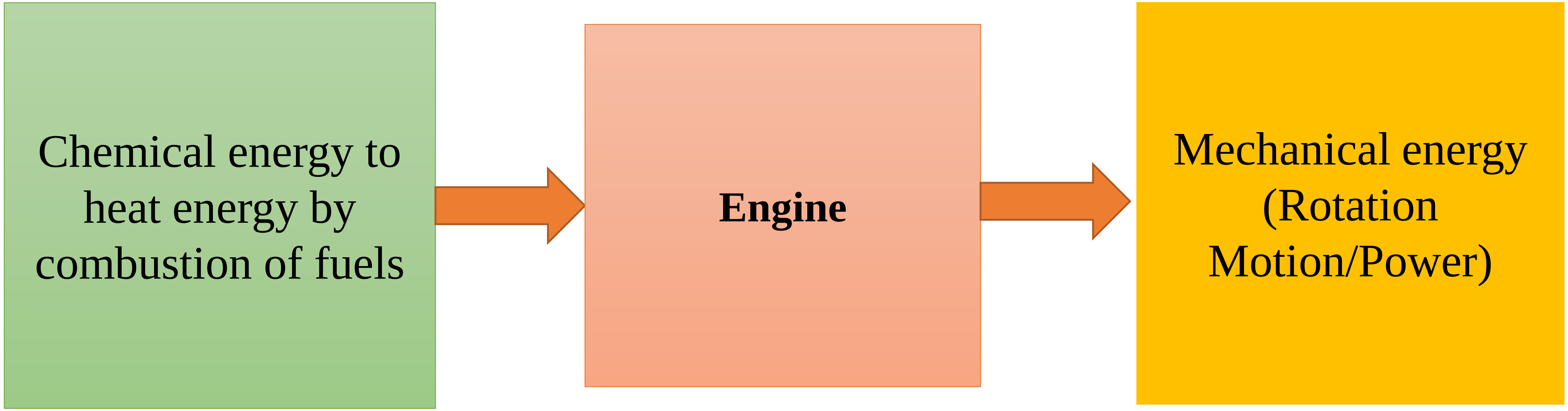
ENGINES

- A heat engine is a machine,
- which converts heat energy (Chemical energy to heat energy by combustion) into mechanical energy.
- The combustion of fuel such as coal, petrol, and diesel generates heat.

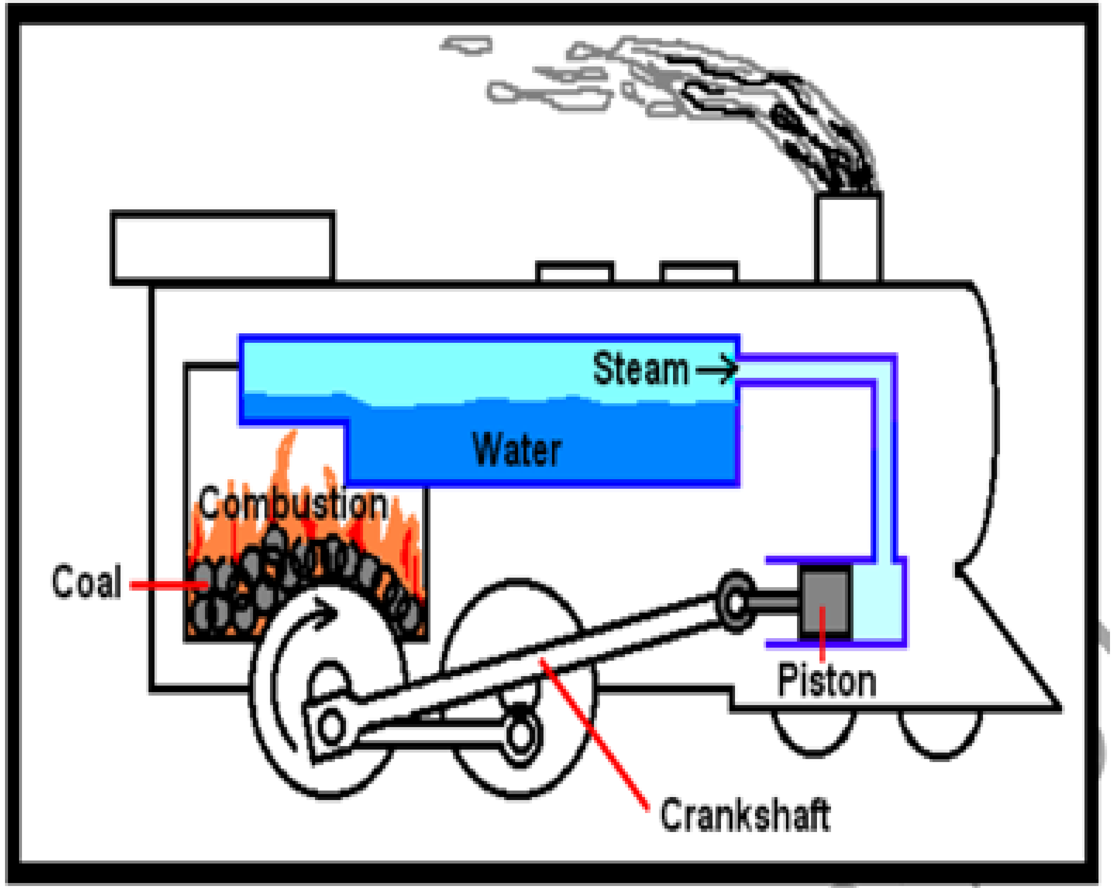


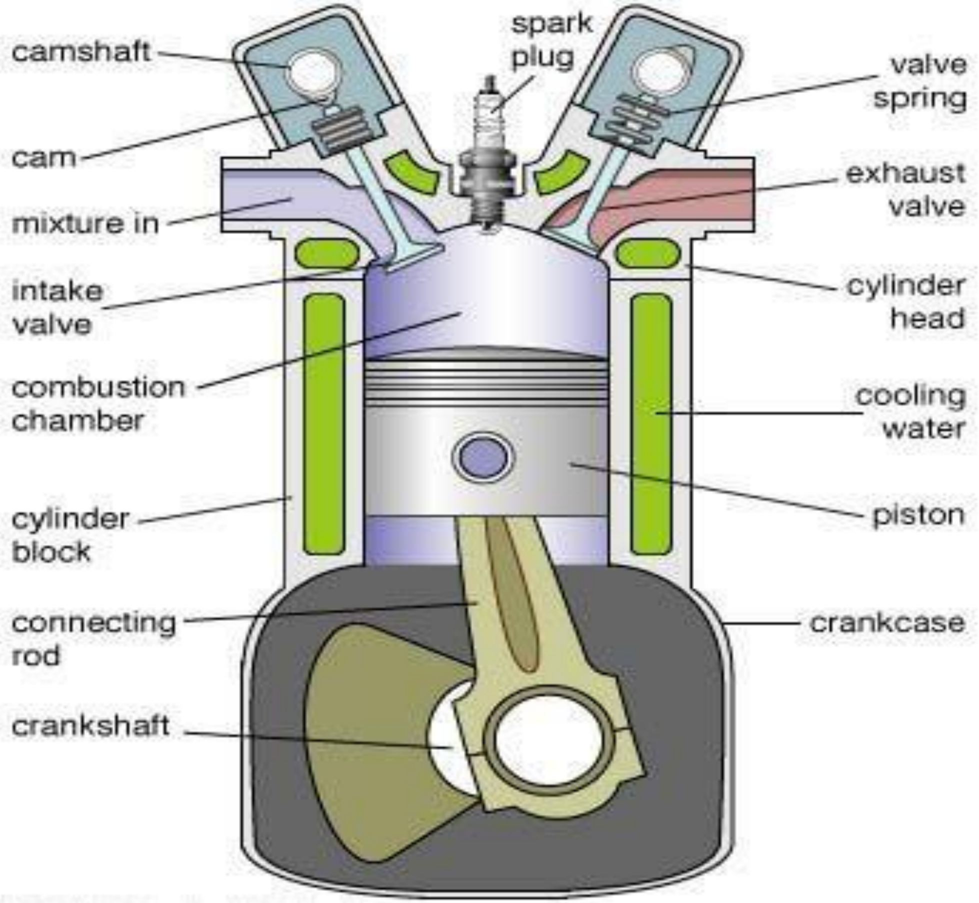
ENGINES

- Heat engines can be further divided into two types based on where the combustion of fuel take place:

(i)External combustion Engine (E C Engine)

(ii) Internal combustion (I C Engine)





ENGINES

- Difference between I C Engine and E C Engine

I.C. ENGINE	E.C. ENGINE
Combustion of fuel takes place inside the cylinder	Combustion of fuel takes place outside the cylinder
Working fluid may be Petrol, Diesel & Various types of gases	Working fluid is steam
Require less space	Require large space
Capital cost is relatively low	Capital cost is relatively high
Starting of this engine is easy & quick	Starting of this engine requires time
Thermal efficiency is high	Thermal Efficiency is low
Power developed per unit weight of these engines is high	Power Developed per unit weight of these engines is low
Fuel cost is relatively high	Fuel cost is relatively low

I C ENGINES

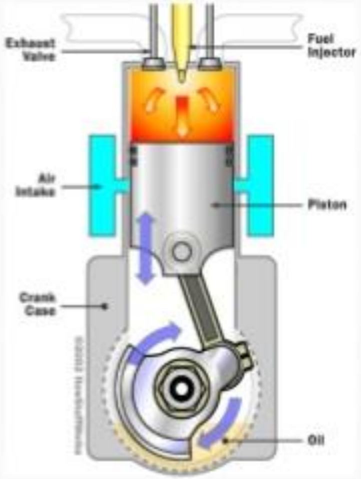
CLASSIFICATION OF IC ENGINES :

1.Type of fuel used:	(i) Petrol or Gasoline engine (ii) Diesel engine
2. Number of stroke per cycle	(i) Four stroke engine (ii)Two stroke engine
3. Type of Ignition used	(i) Spark ignition (SI) engine (ii) Compression ignition (CI) engine
4. Type of cycle of combustion	(i) Otto cycle (Constant volume combustion cycle) (ii) Diesel cycle (Constant pressure combustion cycle)
5. Number of cylinders	(i) Single cylinder engine (ii)Multiple cylinder engine
6. Type of cooling system	(i) Air cooled engine (ii) Water cooled engine
7. Based on arrangement of cylinder	(i) Vertical engine (ii) Horizontal engine (iii) Radial engine (iv) V-engine (v) Opposed cylinder & Opposed piston engine
8. Applications	(i) Stationary engine (ii) Automotive engine (iii) Marine engine (iv) Aircraft engine (v) Locomotive engine

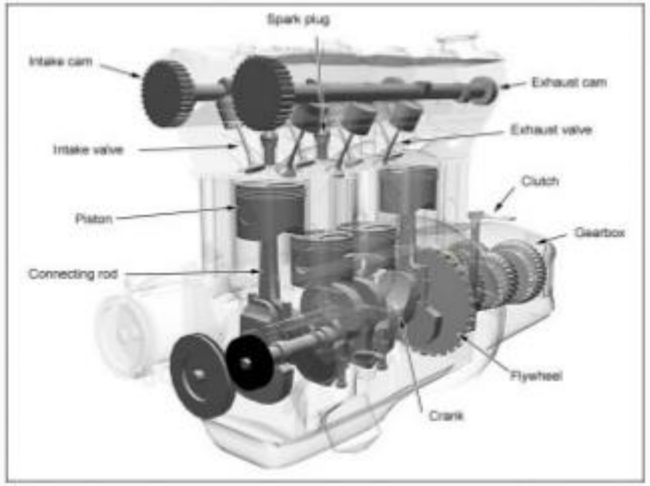
I C ENGINES

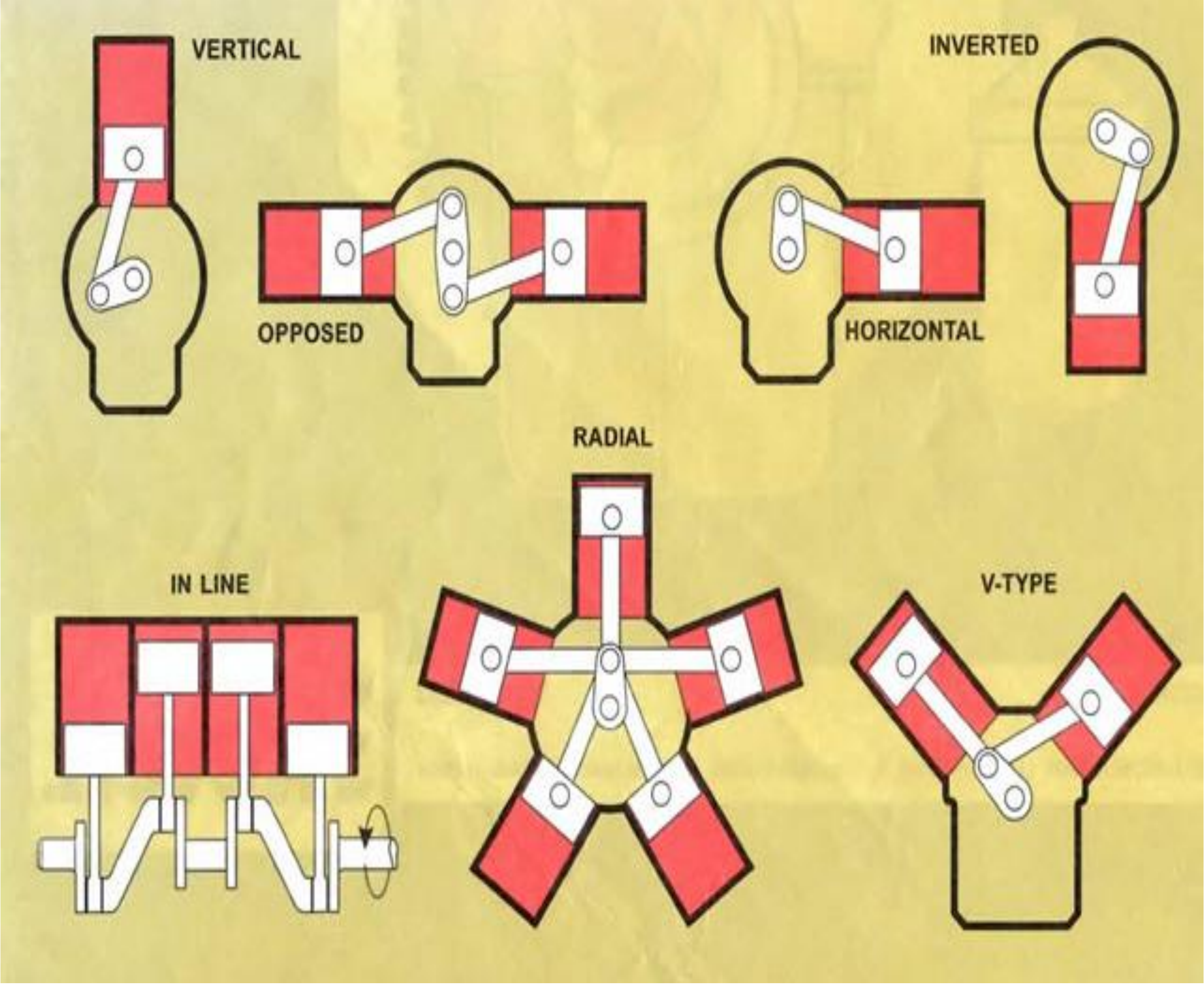
CLASSIFICATION OF IC ENGINES :

- Single cylinder Engine



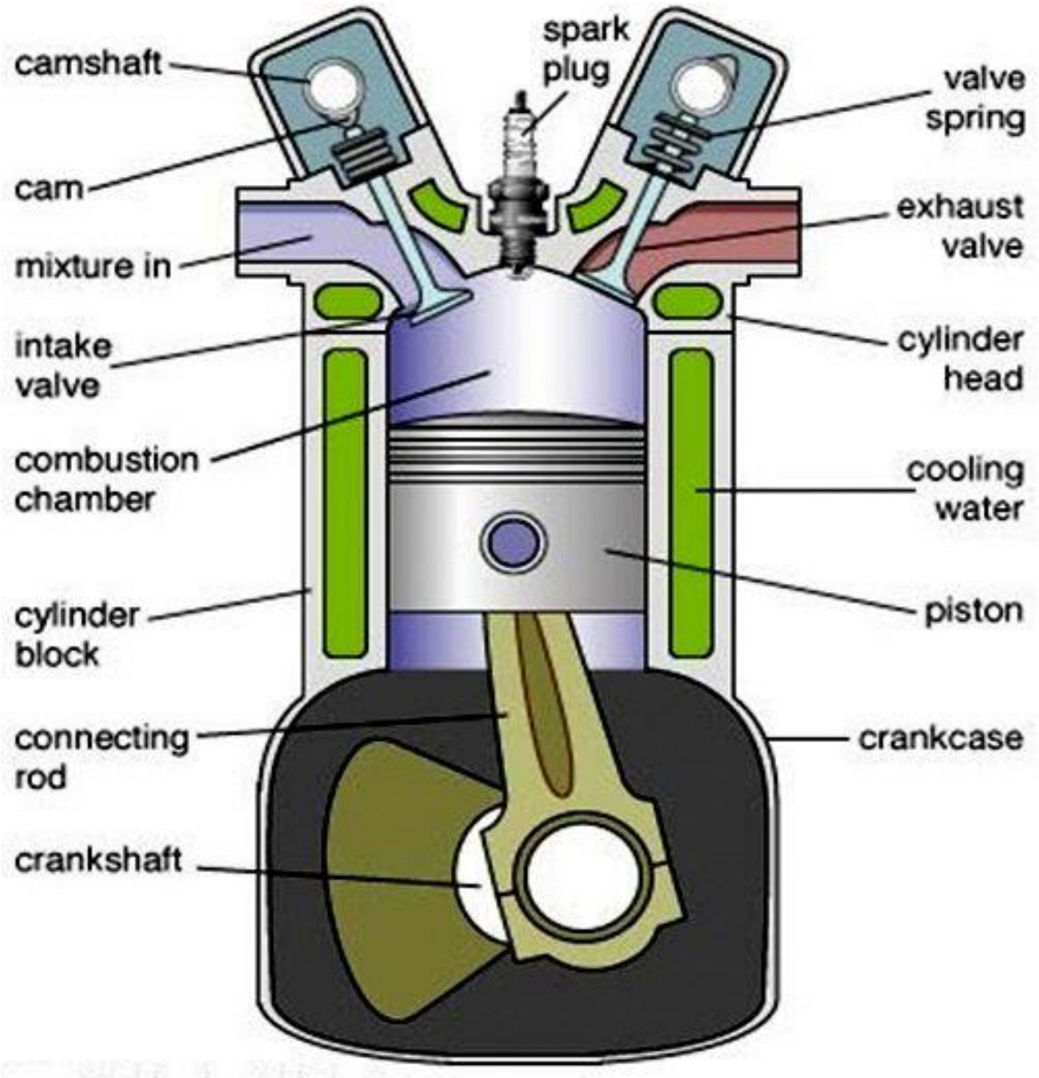
- Multi cylinder engine





I C ENGINES

PARTS OF IC ENGINES :



- Cylinder Block
- Cylinder head
- Piston
- Piston rings
- Connecting rod
- Crank
- Crankshaft
- Crank case
- Spark plug/fuel injector
- Intake/Inlet Valve
- exhaust/outlet Valve
- Combustion Chamber
- Cooling water Jackets
- Cam mechanism

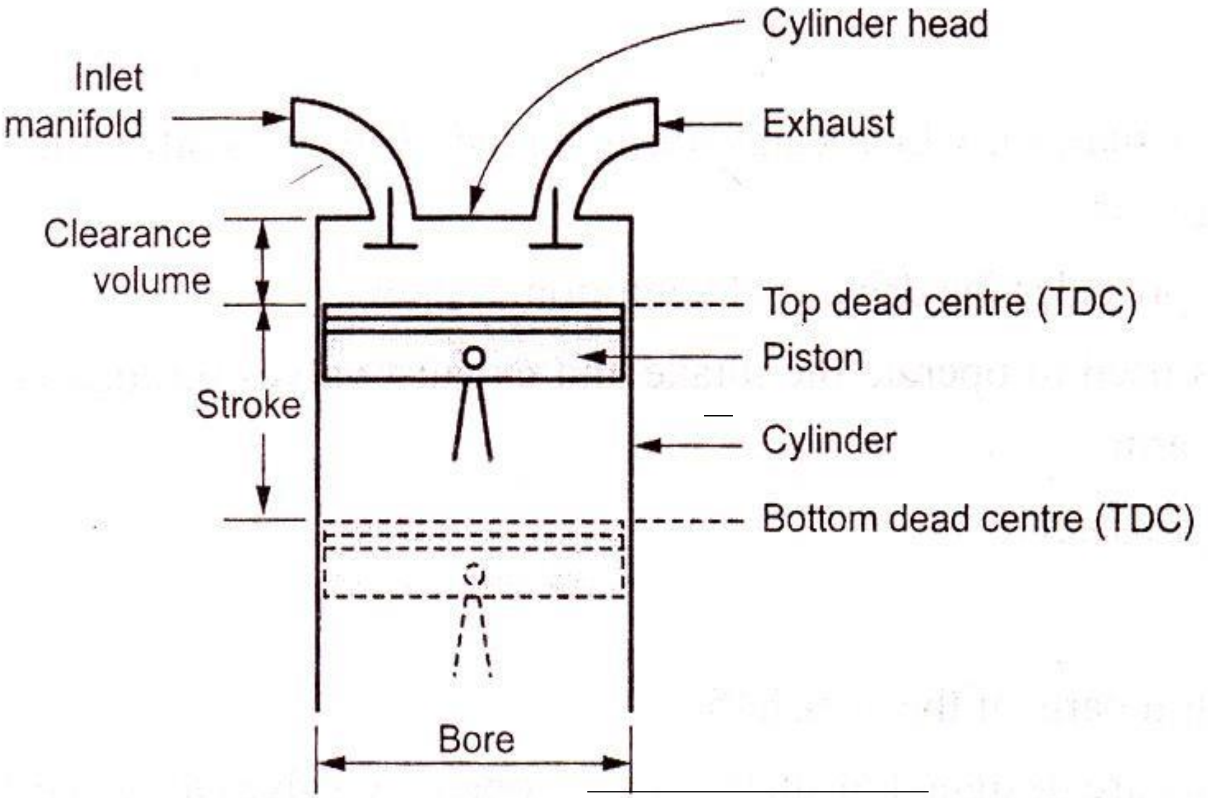
MinimumCylinderVolume

SweptVolume + ClearenceVolume

ClearenceVolume

I C ENGINES

IC ENGINE TERMINOLOGY:



Bore: The nominal inside diameter of the engine cylinder is called bore.

Top Dead Centre (TDC): The extreme position of the piston at the top of the cylinder of the
vertical engine is called top dead centre (TDC)

Bottom Dead Centre (BDC): The extreme position of the piston at the bottom of the cylinder of the vertical engine called bottom dead centre (BDC).

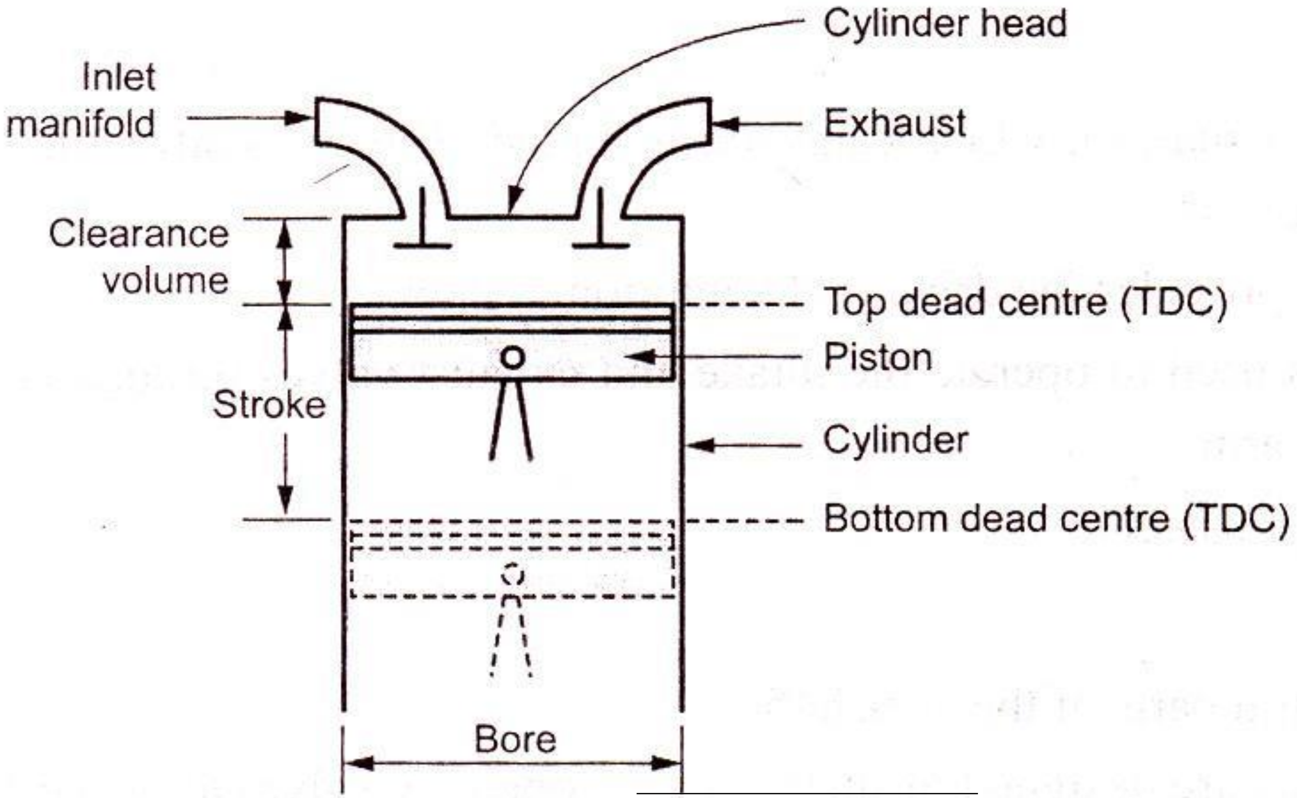
Stroke: The distance travelled by the piston from TDC to BDC is called stroke. It is equal to twice the radius of the crank.

Clearance Volume (Vc): The volume contained in the cylinder above the top of the piston, when the piston is at top dead centre is called the clearance volume.

ClearenceVolume
MinimumCylinderVolume
SweptVolume + ClearenceVolume

I C ENGINES

IC ENGINE TERMINOLOGY:



Swept Volume (Vs): The volume swept by the piston during one stroke is called the swept volume or piston displacement.

Swept volume is the volume covered by the piston while moving from TDC to BDC.

Swept volume= $V_s = A * L = (\pi 4)*D2*L$

where

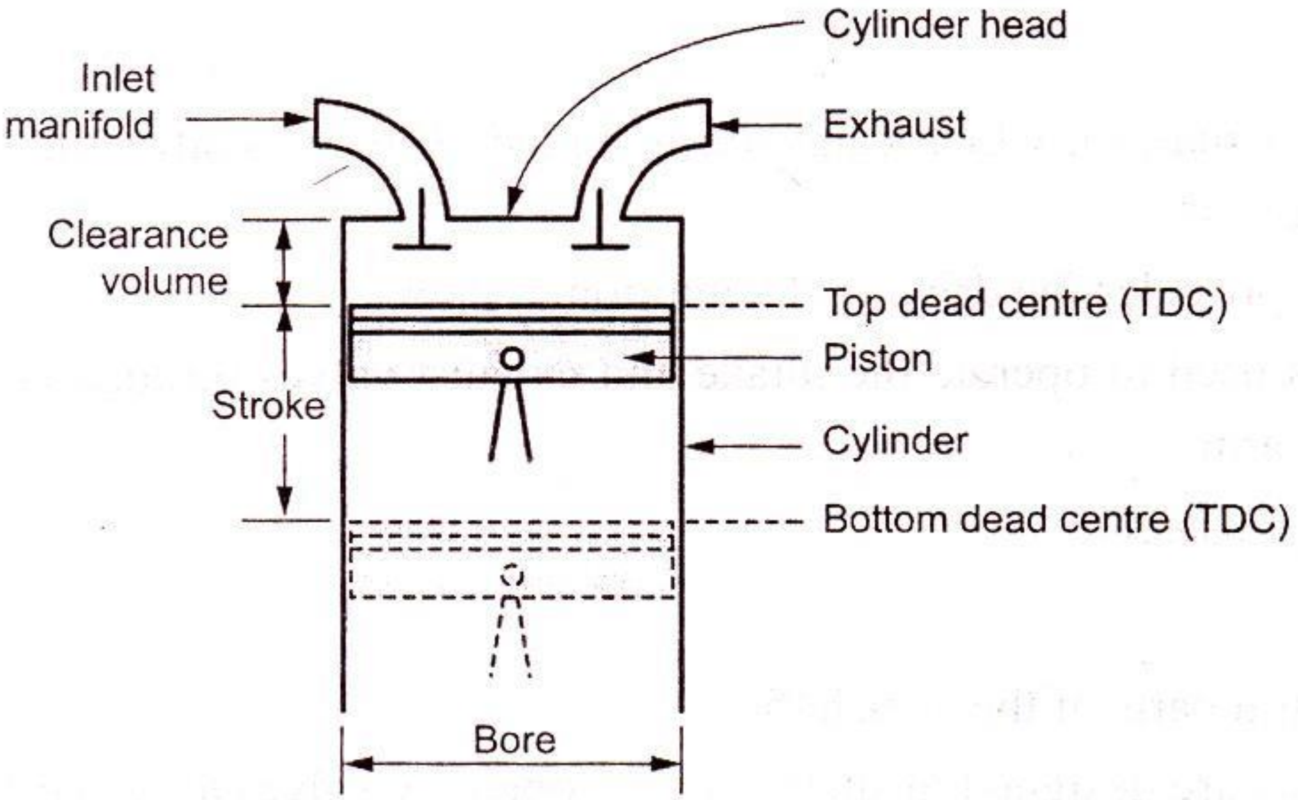
A = Cross sectional area of the piston in Sq.m,

L = Stroke in m, and

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

I C ENGINES

IC ENGINE TERMINOLOGY:



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 centre.

Mathematically,

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

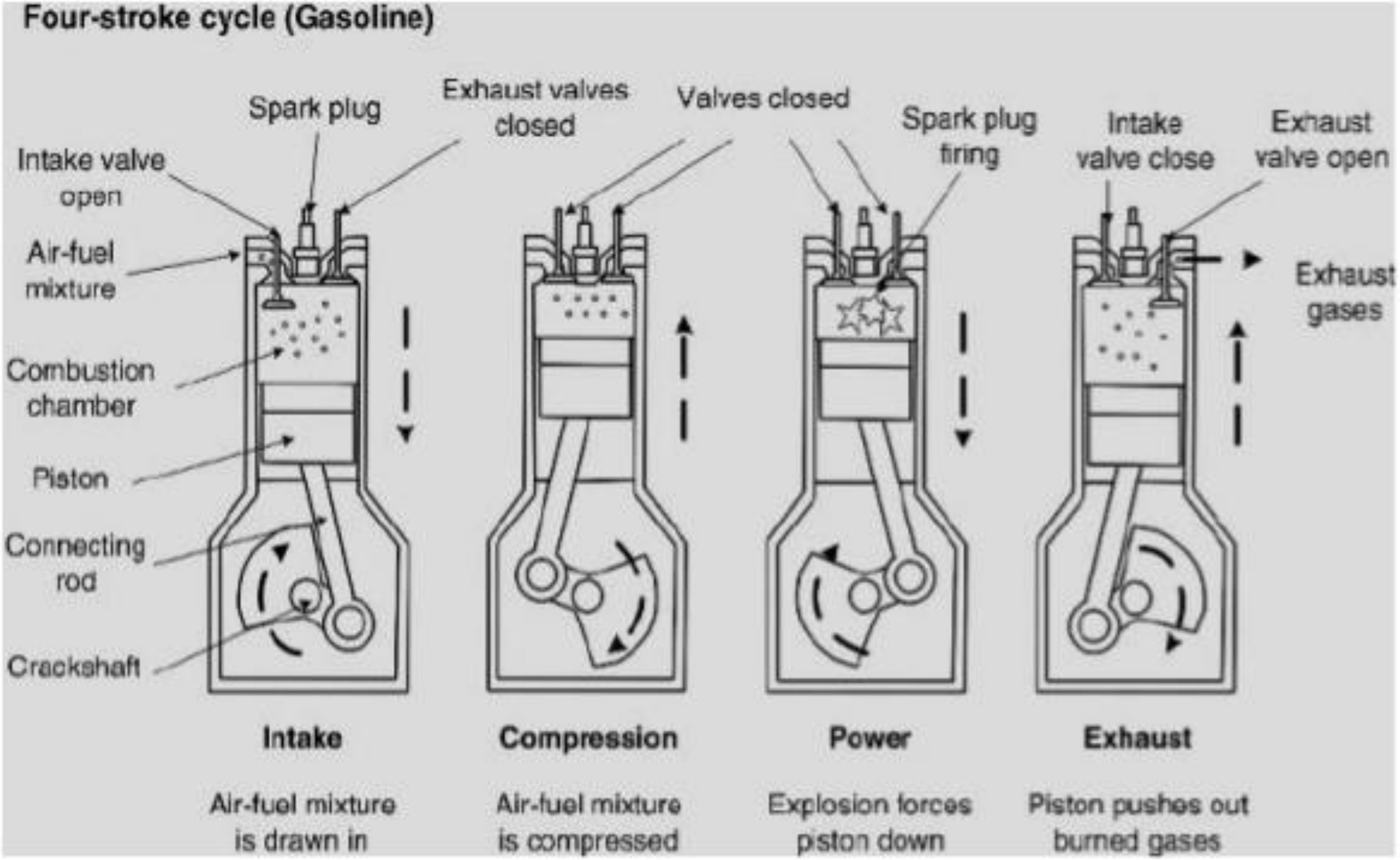
$$\text{Compression ratio} = \frac{(Swept\ volume + Clearnce\ Voume)}{Clearnce\ Voume}$$

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

I C ENGINES

4-S Petrol engine

The first practical petrol engine was built in 1876 in Germany by Nicolaus August Otto.
4-S Petrol engine works on Otto cycle.



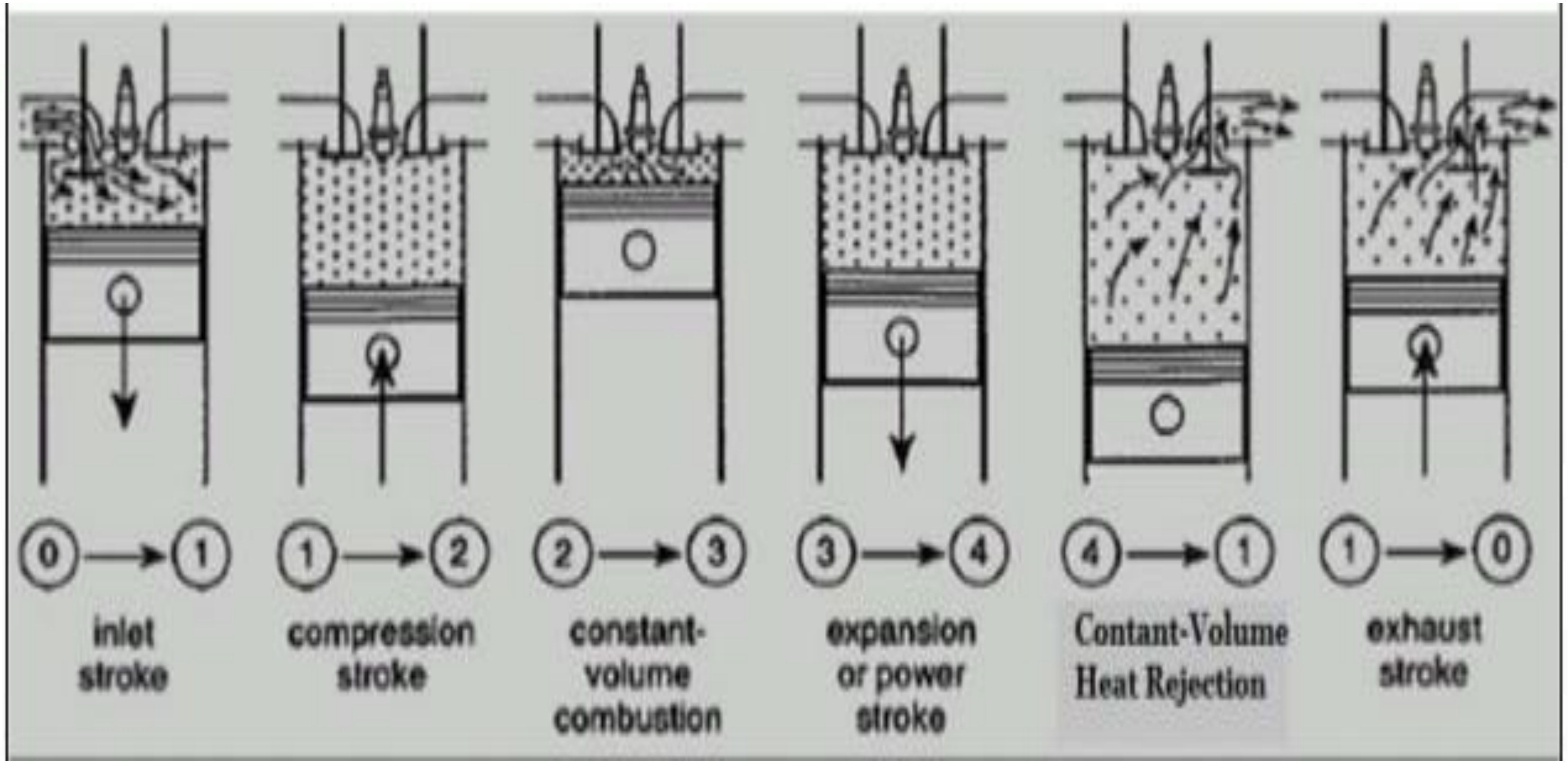
I C ENGINES

4-S Petrol engine

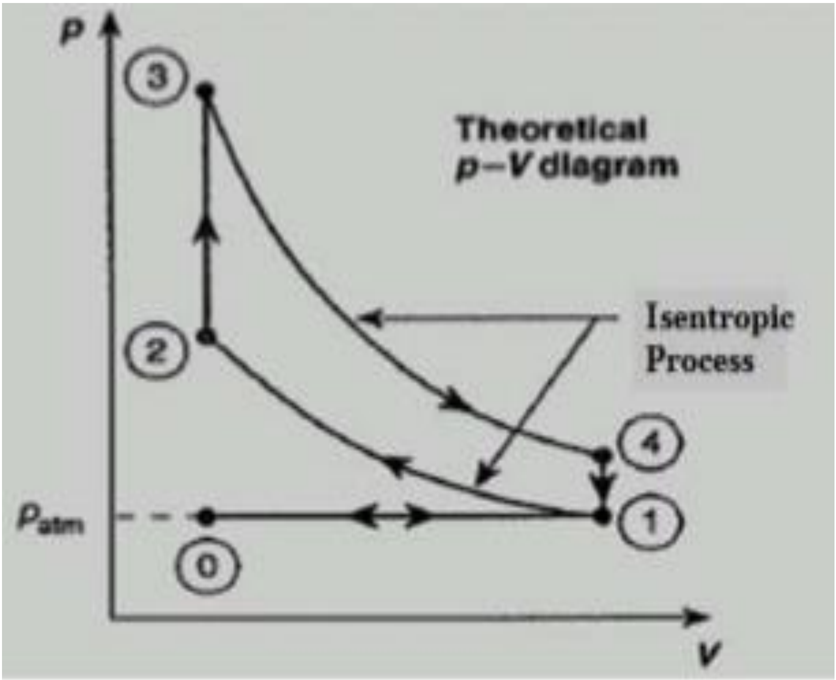
The first practical petrol engine was built in 1876 in Germany by Nicolaus August Otto.
4-S Petrol engine works on Otto cycle.

IC ENGINES
4-S Petrol engine

The first practical petrol engine was built in 1876 in Germany by [Nicolaus August Otto]



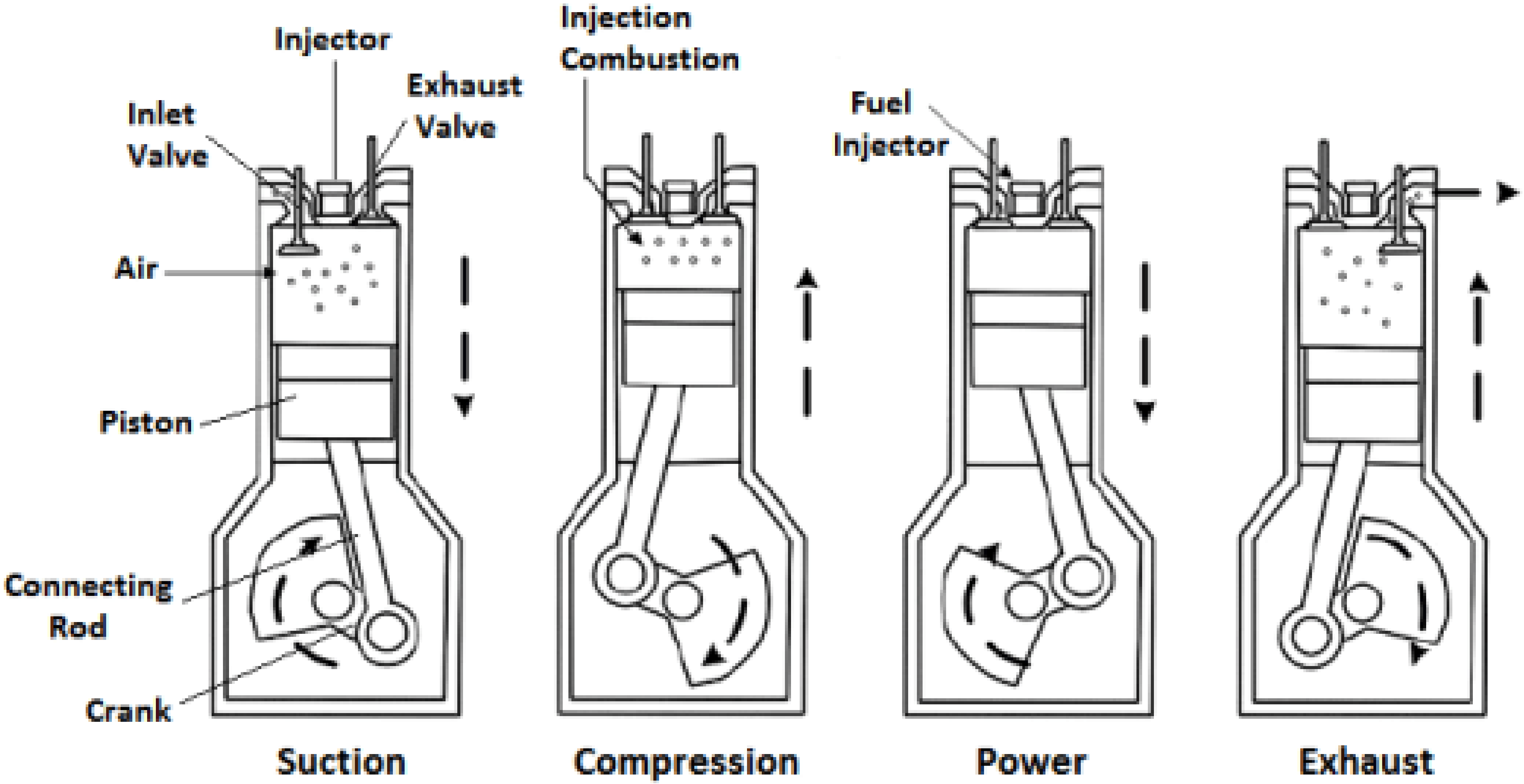
P V diagram of otto cycle



I C ENGINES

4-S Diesel engine

The first practical Diesel engine was built in 1878 in Germany by Rudolf Diesel
4-S Diesel engine works on Diesel cycle.



I C ENGINES

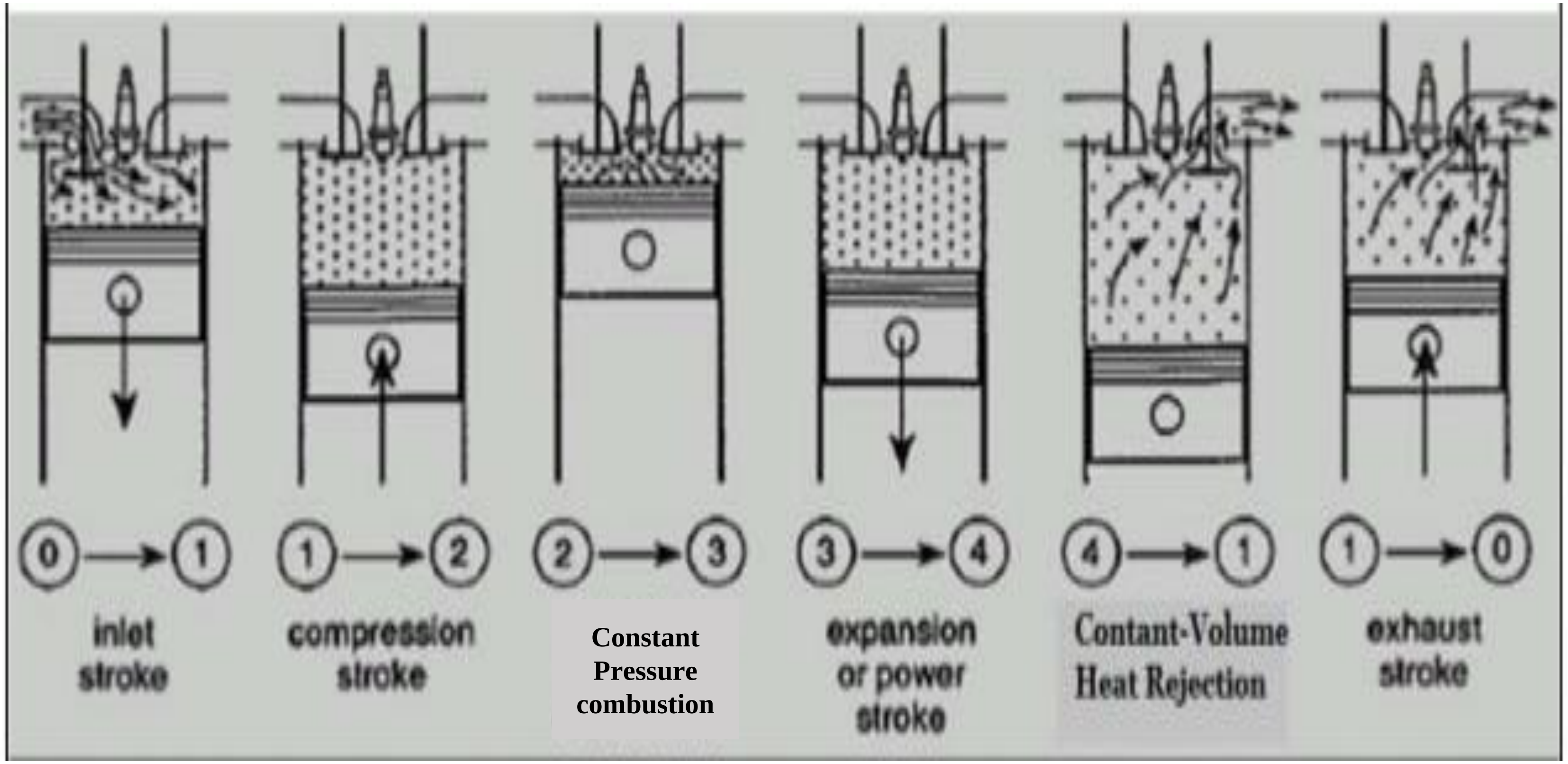
4-S Diesel engine

The first practical Diesel engine was built in 1878 in Germany by Rudolf Diesel

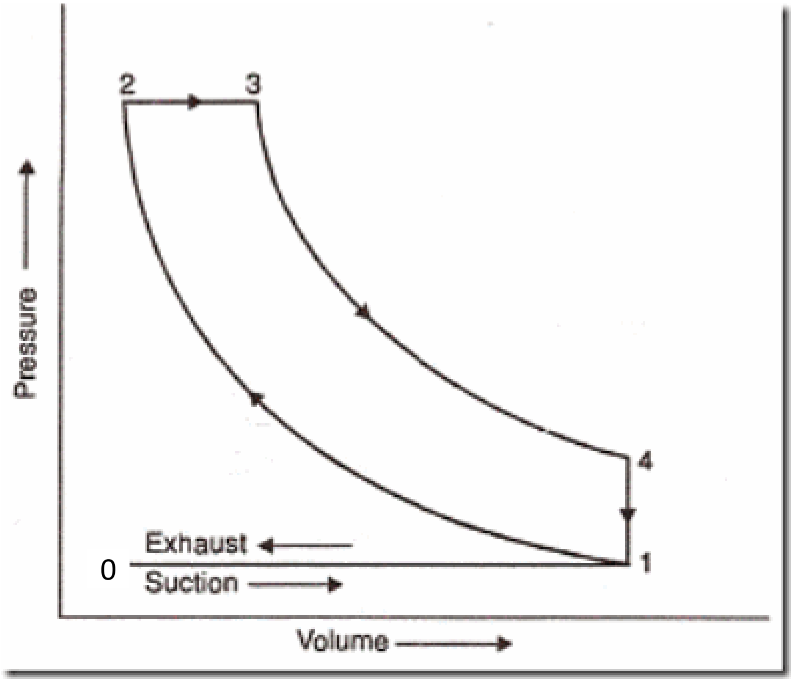
4-S Diesel engine works on Diesel cycle.

I C ENGINES
4-S Diesel engine

The first practical Diesel engine was built in 1878 in Germany by Rudolf Diesel



P V diagram of Diesel cycle



I C ENGINES

Difference between 4 stroke petrol (SI engine) and 4 stroke diesel engine (CI engine)

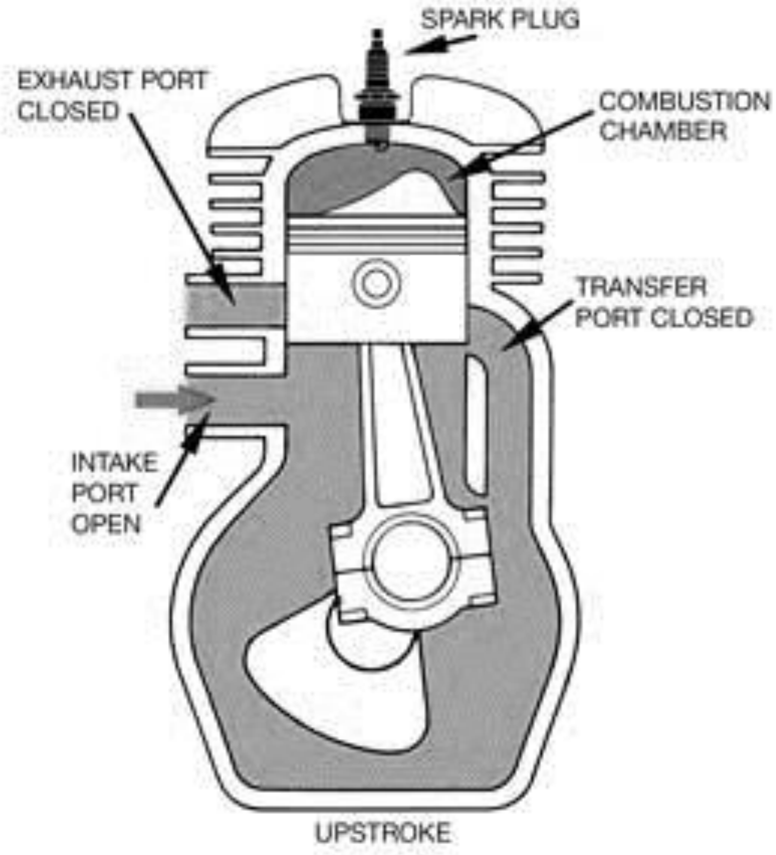
Sl No	Parameters	SI Engine (4 stroke petrol engine)	CI Engine (4 stroke Diesel engine)
1.	Cycle of operation	Otto cycle	Diesel cycle
2.	Presence of spark plug/Fuel injector	Spark Plug	Fuel injector
3.	Inlet of fresh charge to cylinder during suction stroke	Mixture of fuel & Fuel from carburetor	Only 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

I C ENGINES

2-S Petrol engine

1 cycle of heat energy to mechanical energy conversion take place in 2 Stokes

1. Downward stroke 2.Upward stroke



Comparison with 4 Stroke engine– the physical differences are

Piston – Crown shaped head Piston instead of flat head piston

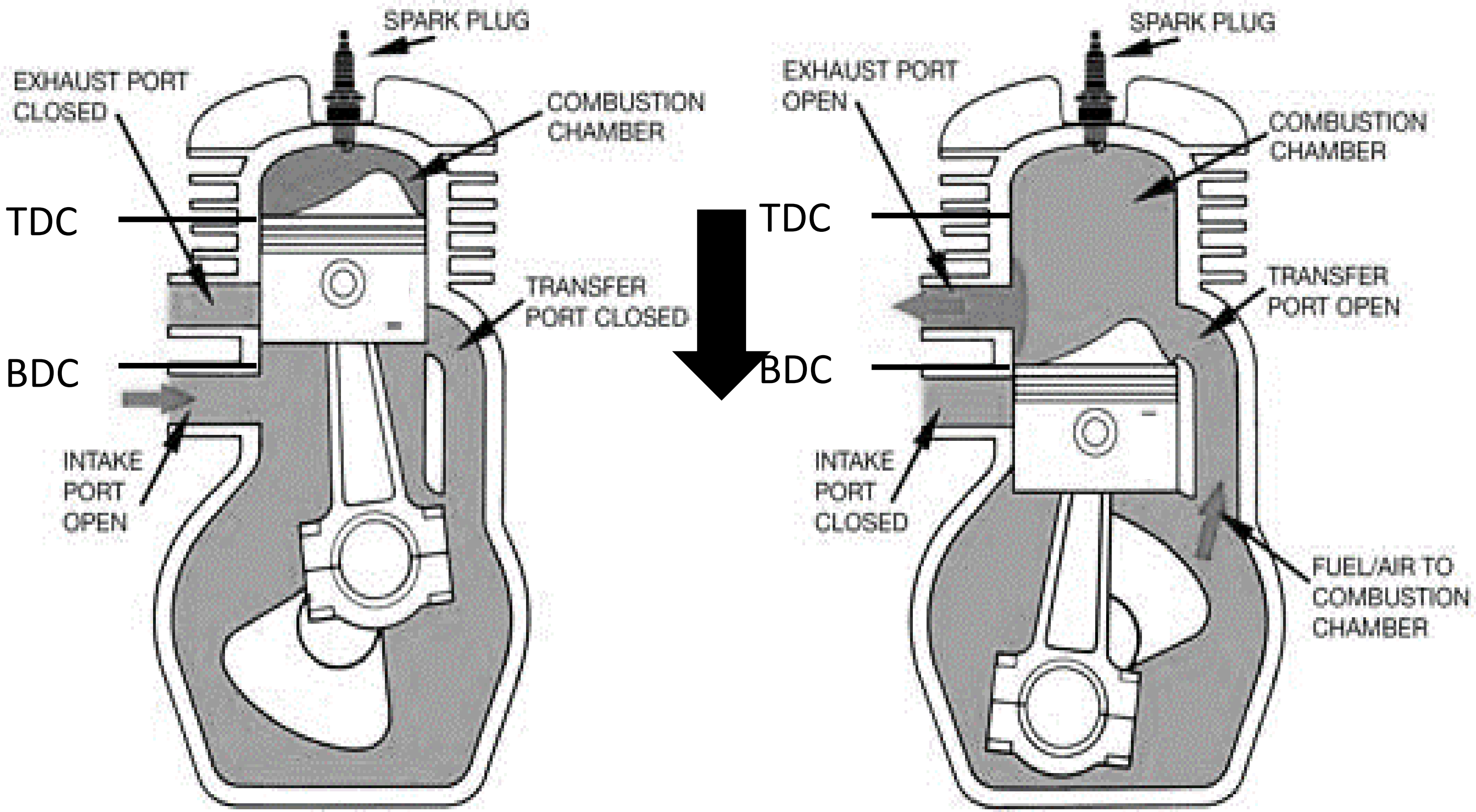
Valves – 3 ports (Intake/inlet, Exhaust/outlet, Transferport) instead of 2 valves

Cooling – Air cooling though fins

I C ENGINES

2-S Petrol engine

Downward stroke



When the piston at -TDC

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

When the piston moving from TDC to BDC

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

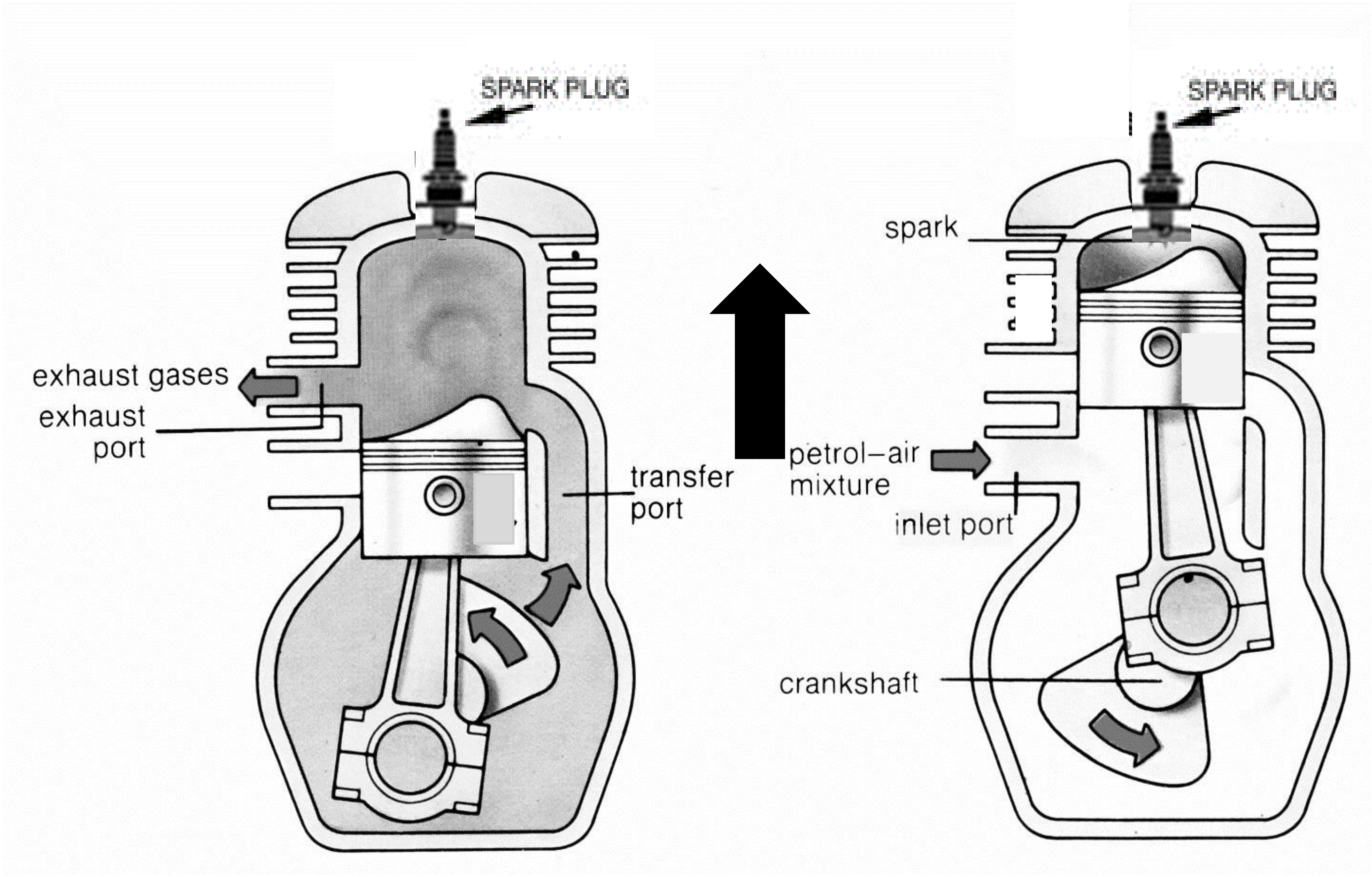
When the piston at -BDC

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

I C ENGINES
2-S Petrol engine

Upward stroke



When the piston at -BDC
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

When the piston moving from BDC to TDC
exhaust port & transfer port gradually closed, Inlet port gradually opened.

1. Stop of Exhaust of expanded hot gases & Transfer of initially compressed air fuel mixture to cylinder through transfer port
2. Secondary compression of air fuel mixture in the cylinder

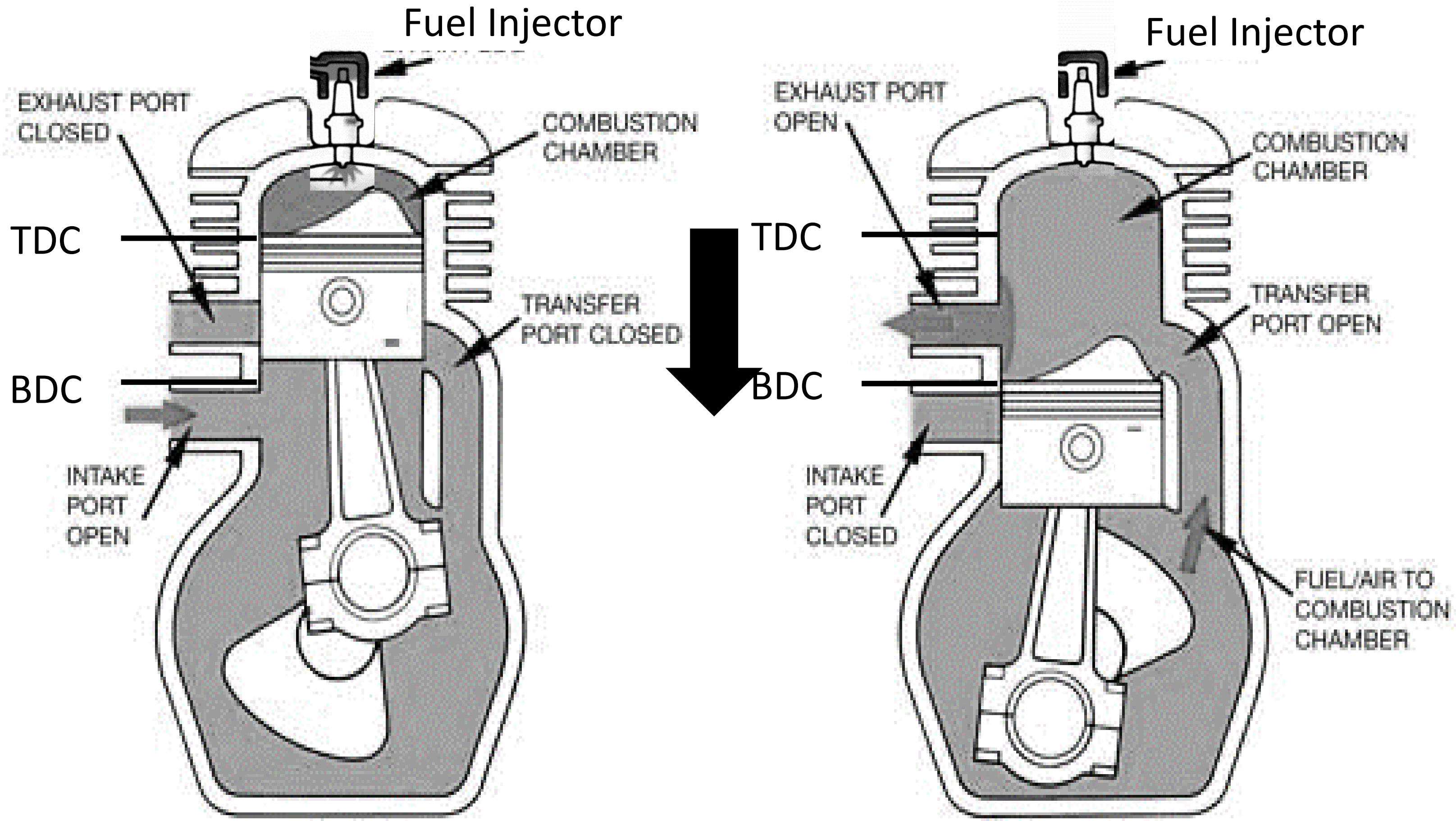
When the piston at -TDC
Inlet port opened fully, exhaust port & transfer port completely closed

1. Combustion of 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

I C ENGINES

2-S Diesel engine

Downward stroke



When the piston at -TDC

Inlet port opened fully, exhaust port & transfer port completely closed

1. Combustion of spray formed fuel injected though fuel injector mixed with previous cycle compressed air
2. Staring of power stroke
3. Inlet of only fresh air to crank case

When the piston moving from TDC to BDC

Inlet port gradually closed, exhaust port & transfer port gradually opened.

1. Power stroke
2. Initial compression of only air in the crank case
3. Exhaust of expanded hot gases
4. Transfer of initially compressed only air to cylinder through transfer port

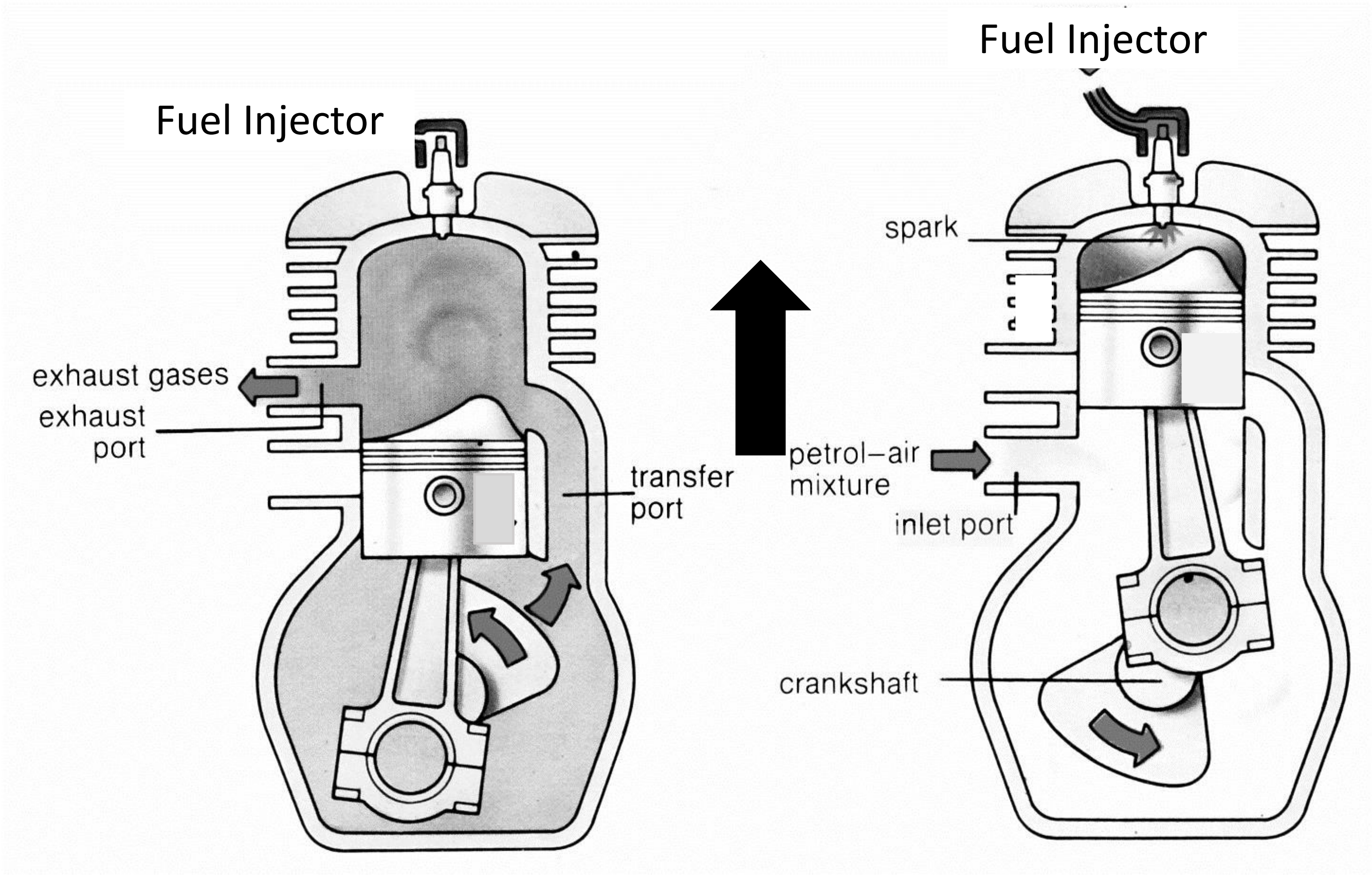
When the piston at -BDC

Inlet port completely closed, exhaust port & transfer port opened fully.

1. Exhaust of expanded hot gases
2. Transfer of initially compressed only air to cylinder through transfer port

I C ENGINES
2-S Diesel engine

Upward stroke



When the piston at -BDC
Inlet port completely closed, exhaust port & transfer port opened fully.

1. Exhaust of expanded hot gases
2. Transfer of initially compressed only air to cylinder through transfer port

When the piston moving from BDC to TDC
exhaust port & transfer port gradually closed, Inlet port gradually opened.

1. Stop of Exhaust of expanded hot gases & Transfer of initially compressed only air to cylinder through transfer port
2. Secondary compression of only air fuel in the cylinder

When the piston at -TDC
Inlet port opened fully, exhaust port & transfer port completely closed

1. Combustion of spray formed fuel injected though fuel injector mixed with previous cycle compressed air
2. Staring of power stroke
3. Inlet of fresh only fresh air to crank case

RAMAIAH Institute of Technology

I C ENGINES

Difference between 2 stroke engine and 4 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

MECHANICAL ENGINEERING

I C ENGINES

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MECHANICAL ENGINEERING

Difference between 2 stroke engine and 4 stroke engine

Sl no	Principle	Four-stroke engine	Two-stroke engine
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..

Mean effective pressure (MEP): P_m

- mean or average pressure acting on a piston throughout the power stroke.
- It is also the developed inside the engine cylinder of an IC engine. It is expressed in Bar.
- The mean effective average pressure of an engine is obtained from indicator diagram (p –V diagram diagram), which is get by indicator fitted on the engine.

$$\mathbf{P_m} = \frac{\left(\begin{matrix}\boldsymbol{Spring\ value\ or\ spring\ stiffness\ of\ the} \\ \boldsymbol{spring\ used\ in\ the\ indicator\ (S) in\ bar\ per\ mt}\end{matrix}\right) * \boldsymbol{Net\ are\ of\ the\ indicator\ digram\ (a)\ in\ m^2}}{\boldsymbol{(Length\ of\ the\ indicator\ diagram\ (l) in\ m}}$$

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

I C ENGINES

Performance of IC Engines

Indicated Power (IP) : 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, $\mathbf{IP} = \dfrac{\mathbf{nPmLANK}}{\mathbf{60 * 1000}}$ in Kw

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

I C ENGINES

Performance of IC Engines

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.

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

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

Friction power (FP) = Indicated power – Brake power. (FP=IP-BP) in Kw

I C ENGINES

Performance of IC Engines

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.

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

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 heat supplied 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

Indicated Thermal Efficiency (η_{ITH}): Indicated thermal efficiency can be defined as the ratio of indicated power to the heat supplied by the burning fuel.

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

Brake Thermal Efficiency (η_{BTH}): Indicated thermal efficiency can be defined as the ratio of indicated power to the heat supplied by the burning fuel.

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

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

I C ENGINES

Performance of IC Engines

Specific fuel consumption (SFC): SFC is defined as the amount of fuel consumed by an engine for one unit of power 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 (ISFC): ISFC is defined as the amount of fuel consumed by an engine for one unit of indicated power that is produced.

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

Brake Specific fuel consumption (BSFC): ISFC is defined as the amount of fuel consumed by an engine for one unit of brake power that is produced.

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