Chapter 4 – Prime Movers

Session 2 – IC Engines
Working of
2 Stroke Petrol and Diesel Engines

Topic Learning Outcomes:

1. Discuss Steam as a working medium in prime movers and heat engines and its characteristic properties

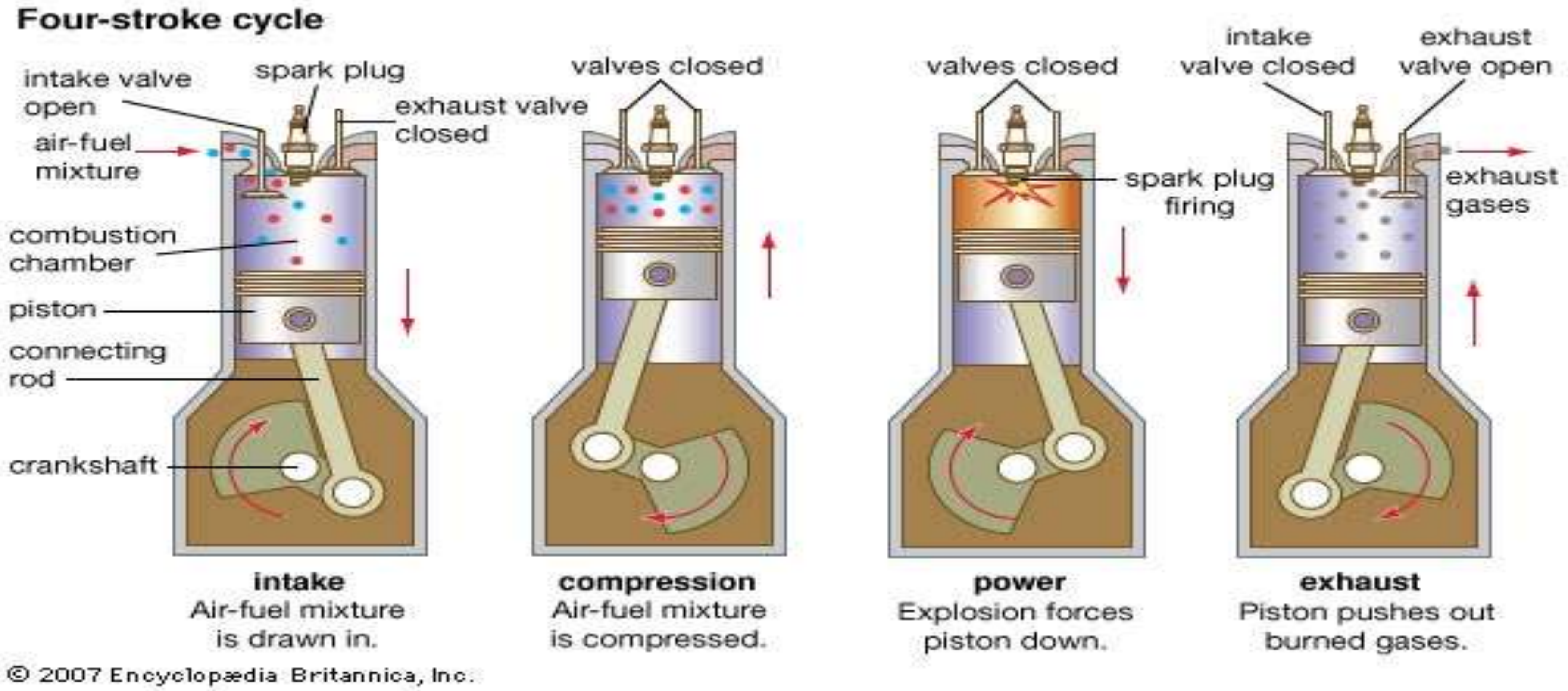
2. Explain the working principle of impulse and reaction steam turbine

3. **Outline the basic operating principles behind two-stroke and four-stroke internal combustion engines.**

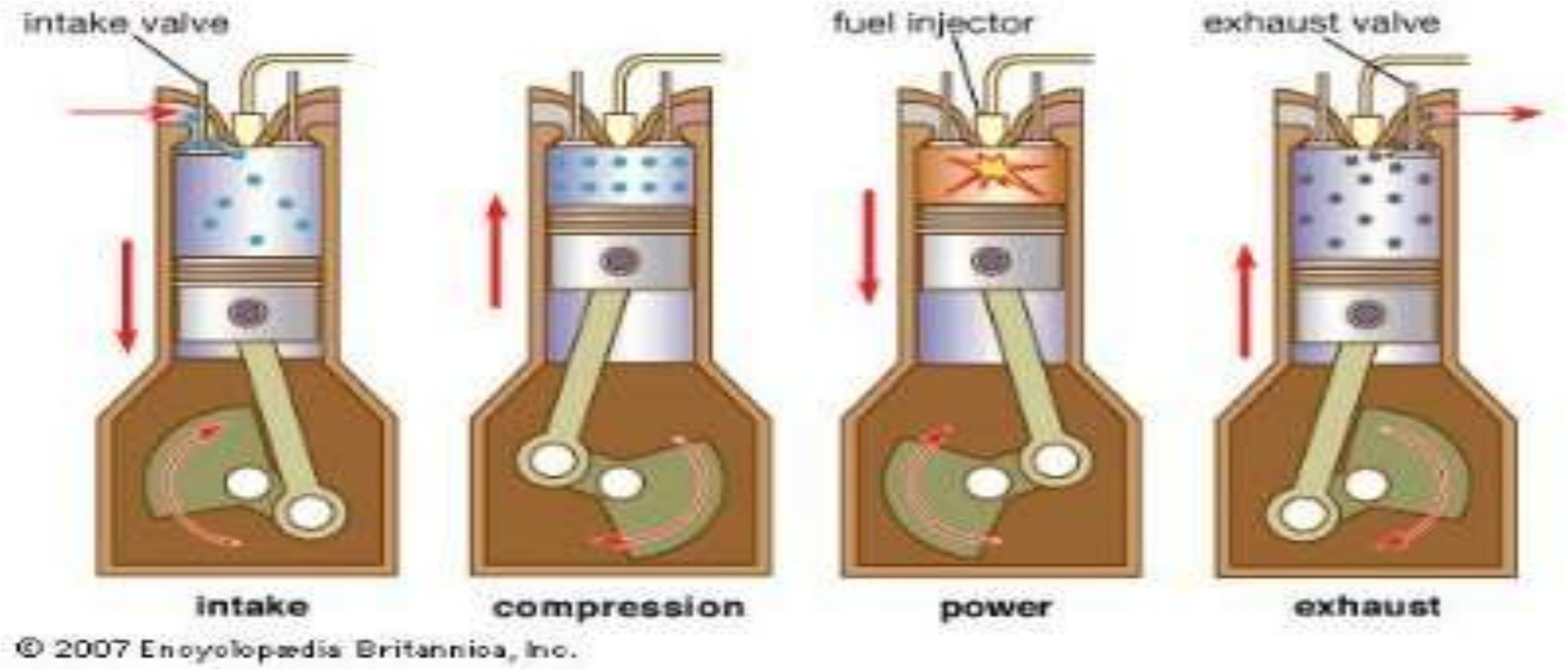
Lesson Schedule

1.1. Introduction, classification and parts of an IC Engine
1.2. Working principle of 4 stroke petrol and diesel Engine
2.1. Working principle of 2 stroke petrol and diesel Engine
2.2. Comparison of 2 stroke and 4 stroke engine, Comparison of diesel and petrol engine
3.1. Numerical problems on engine performance
4.1. Steam- Formation of steam, Properties of steam
4.2. Applications of steam, Steam turbines: Working principle of impulse and reaction steam turbines

Summary of 4 Stroke Petrol Engine



Summary of 4 Stroke Diesel Engine



COMPARISON BETWEEN PETROL ENGINE AND DIESEL ENGINE

Comparison between SI and CI Engines

Description	SI Engine (Petrol Engine)	CI Engine (Diesel Engine)
Cycle of operation	Otto Cycle	Diesel Cycle
Fuel used	Petrol	Diesel
Fuel Supply	Using carburetor	Using Fuel Injection Pump
Charge drawn during suction stroke	Mixture of Petrol & Air	Only Air is drawn in.
Ignition of charge	Using Spark plug	Self ignition

Comparison between SI and CI Engines

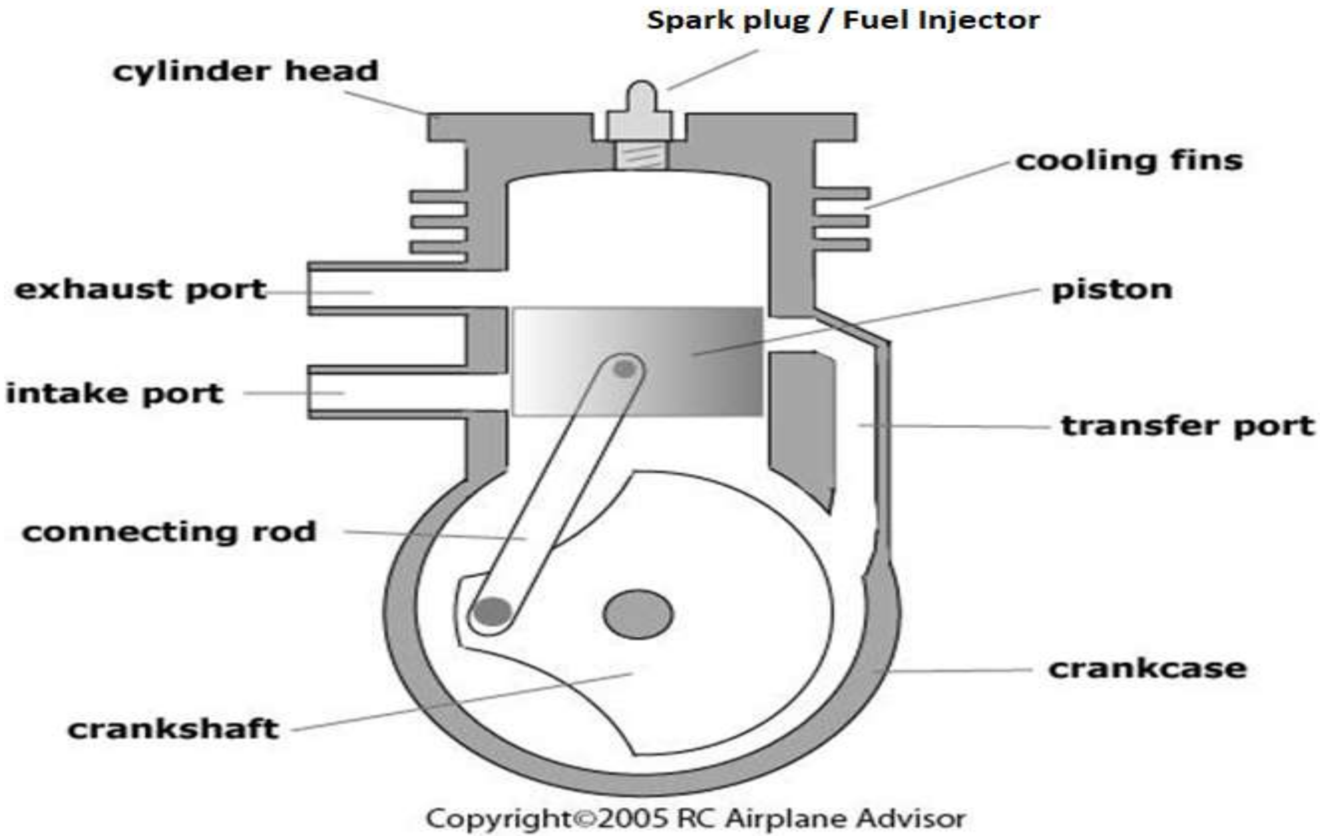
Description	SI Engine (Petrol Engine)	CI Engine (Diesel Engine)
Compression Ratio	7:1 to 11:1	14:1 to 22:1
Power output	Less (low CR)	High
Thermal Efficiency	Less (low CR)	High
Starting of Engine in cold condition	Easy to start	Difficult to start

Comparison between SI and CI Engines

Description	SI Engine (Petrol Engine)	CI Engine (Diesel Engine)
Exhaust gas pollution	**More** (Incomplete Combustion due to limited air availability)	**Less** (Excess air available for complete Combustion)
Operating cost	**High** (fuel is costlier)	**Low**
Initial cost	**Less** (light weight)	**More**
Noise and Vibration	**Less** (Low working pressure)	**More** (High working pressure)

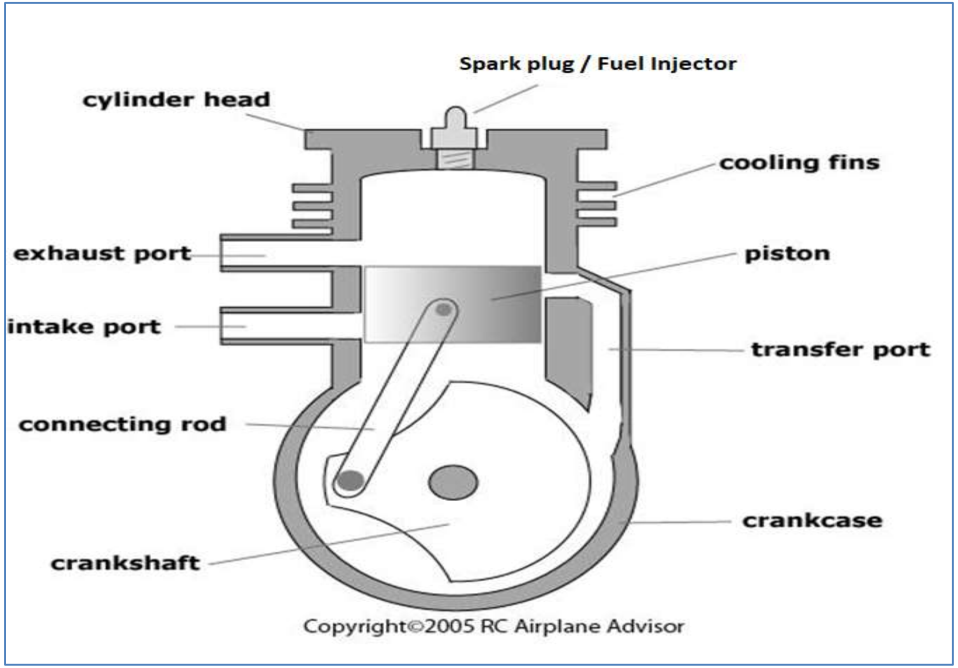
2 STROKE ENGINES

2 Stroke Engine Parts



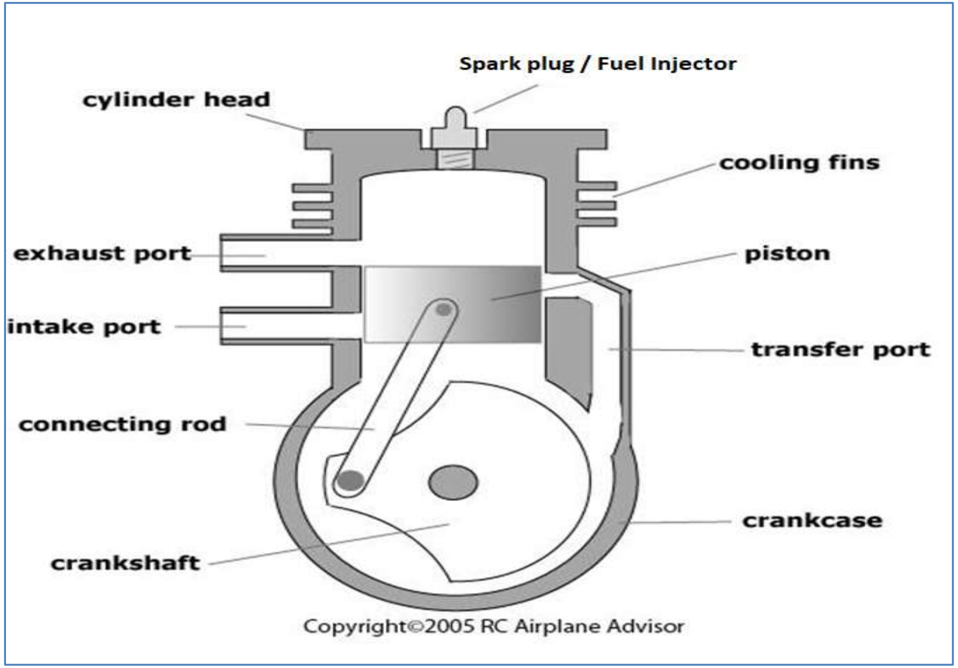
Some important points to remember

- In two stroke engines, the whole sequence of events i.e. suction, compression, power and exhaust are completed in two strokes of the piston (i.e. in one revolution of the crankshaft)



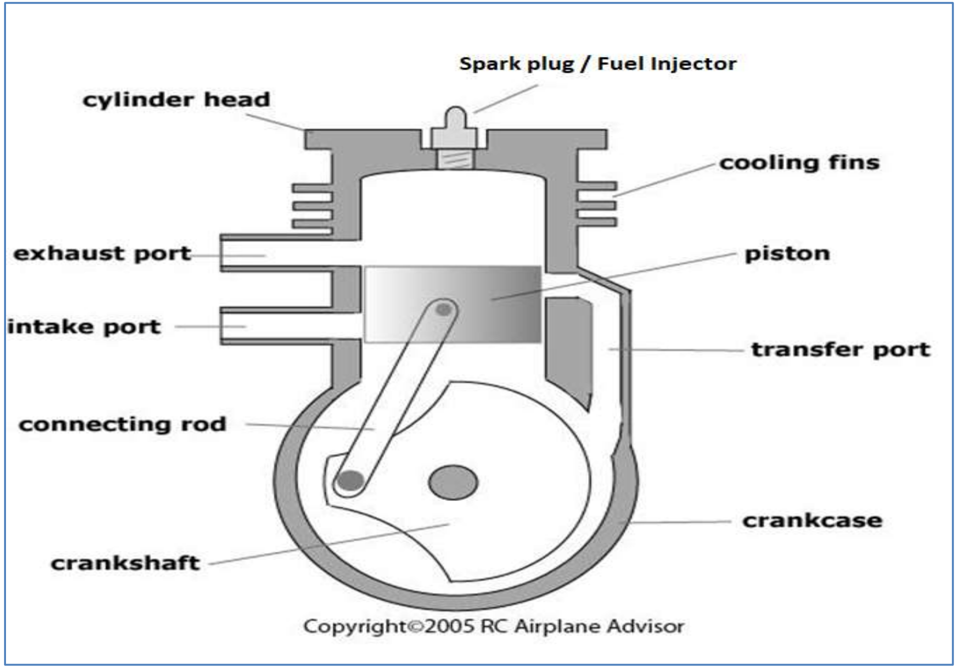
Some important points to remember

- There are no valves in this type of engine.
- Gas movement takes place through holes called as ports in the cylinder.



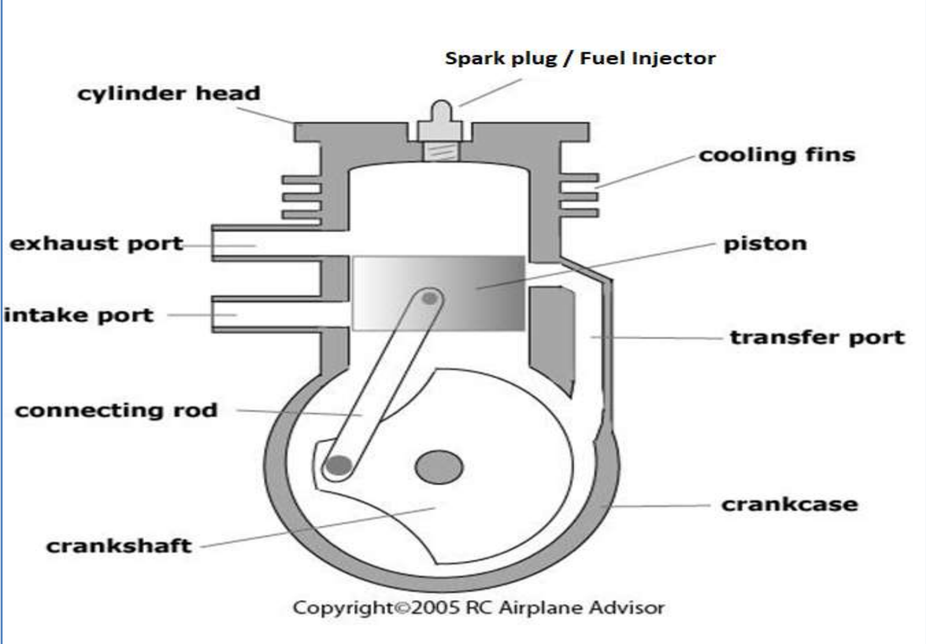
Some important points to remember…

- The covering and uncovering of the ports is done by the movement of the piston.
- The crankcase of the engine is air tight in which the crankshaft rotates.



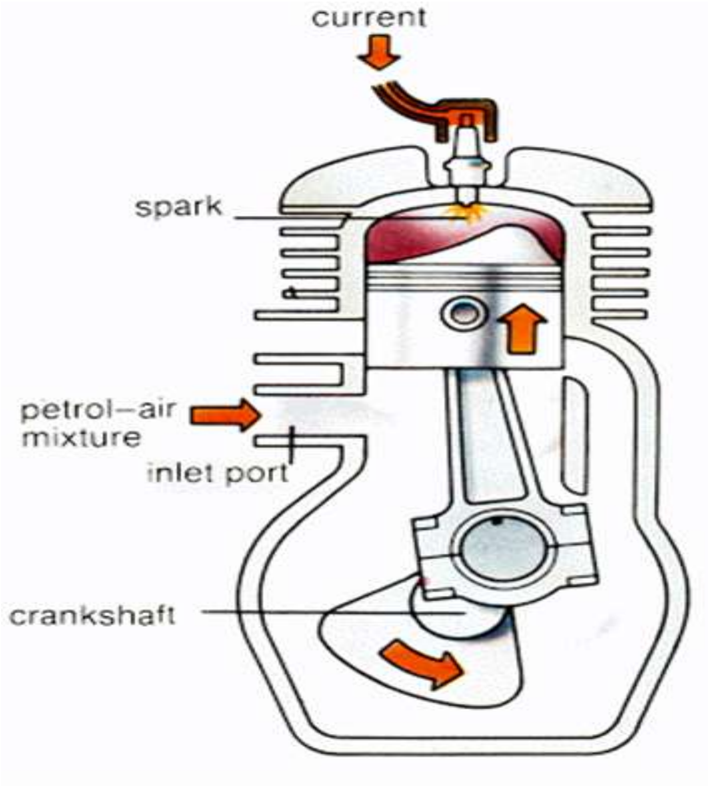
Some important points to remember…

- In a two-stroke engine, more than one function occurs at any given time during the engine's operation.
- Upward stroke
  - Suction + Compression
- Downward stroke
  - Power + Exhaust

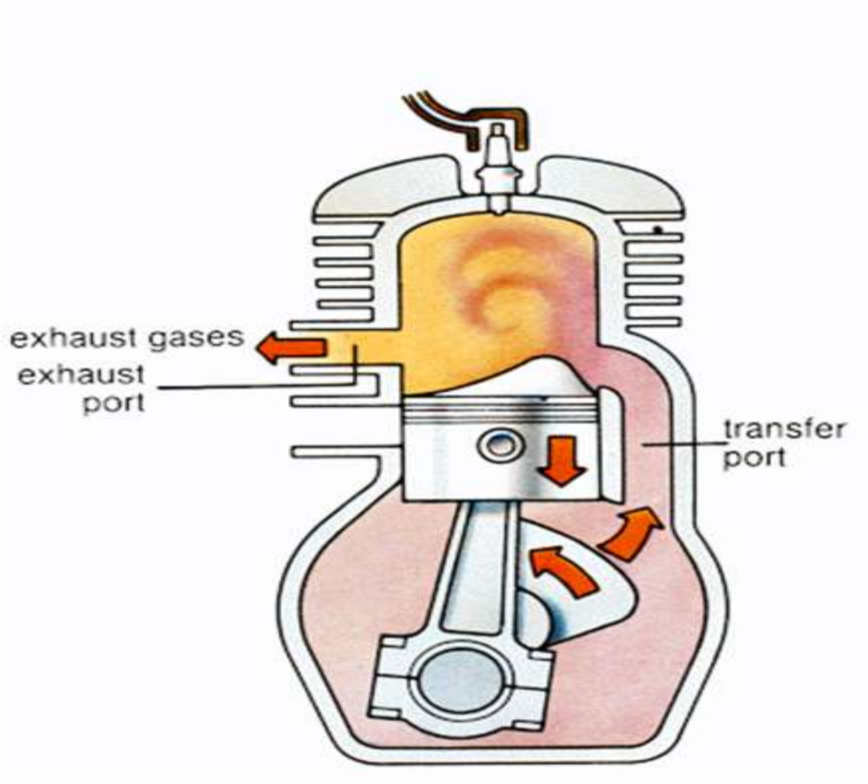


2 STROKE PETROL ENGINES

2 Stroke Petrol Engine

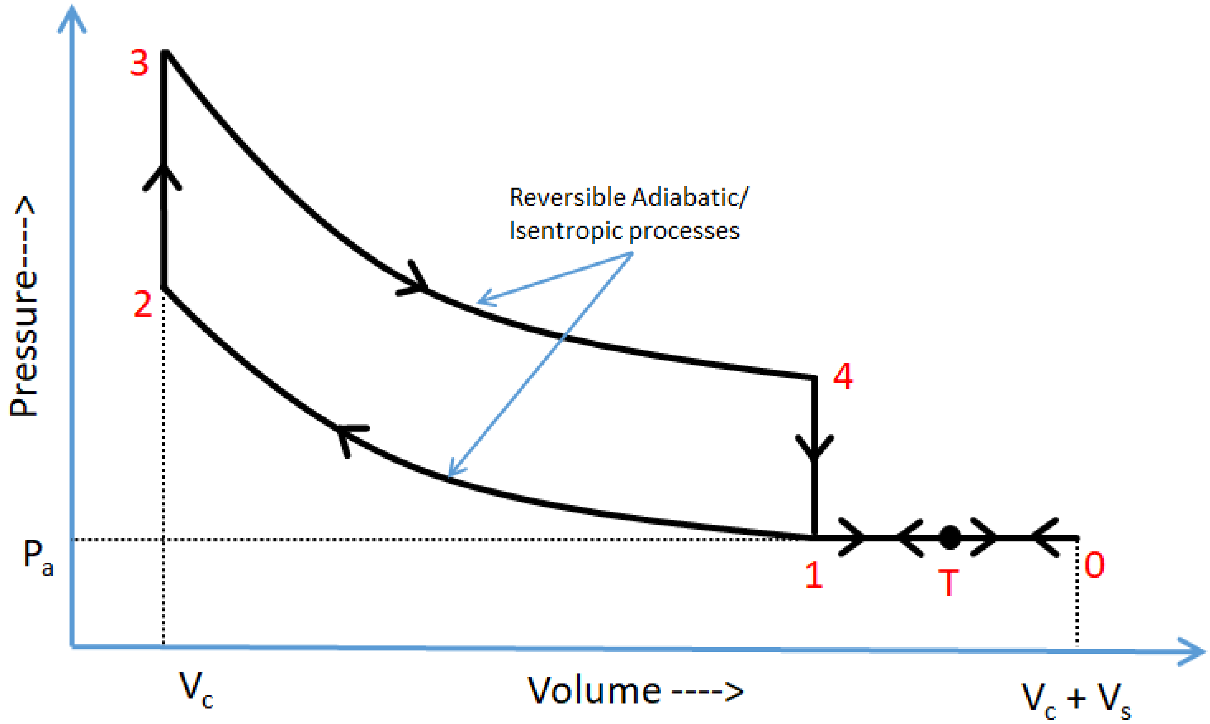


Upward Stroke



Downward Stroke

Otto Cycle PV Diagram for 2Stroke Engines



Theoretical Otto Cycle for 2 Stroke Petrol Engine

Otto Cycle (PV Diagram) for 2Stroke Engines

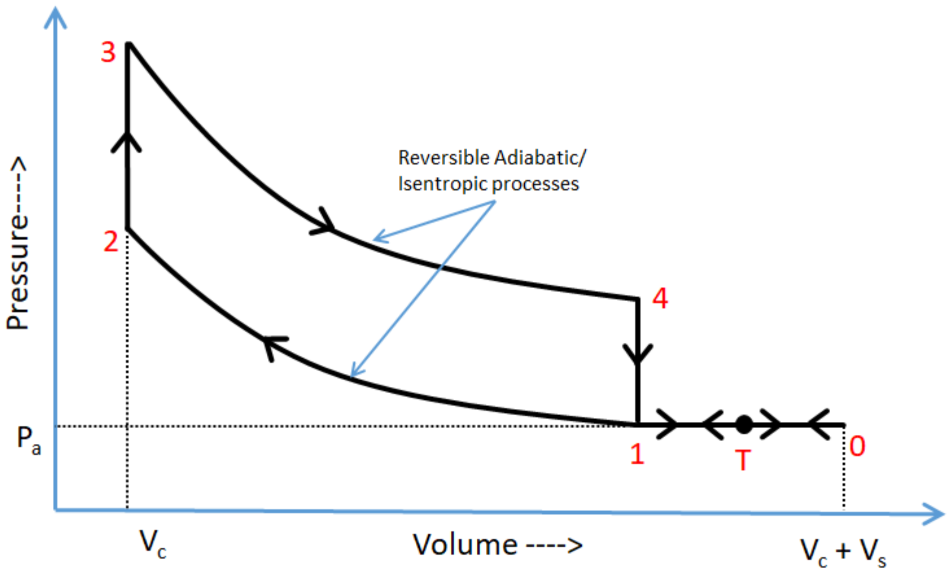
It has four processes:

- 1 -2 : Isentropic Compression
- 2 -3 : Constant Volume Heat Addition
- 3 -4 : Isentropic Expansion
- 4 -1 : Constant Volume Heat Rejection

Note:

- 0-1 : Suction Stroke
- 1-0 : Exhaust Stroke

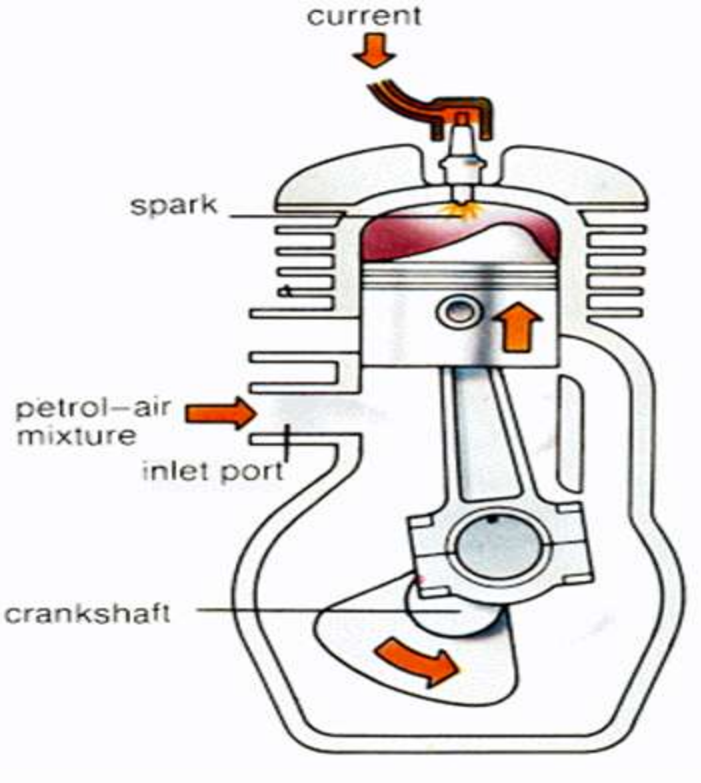
All Petrol Engines operate on basis of Thermodynamic Otto Cycle



Theoretical Otto Cycle for 2 Stroke Petrol Engine

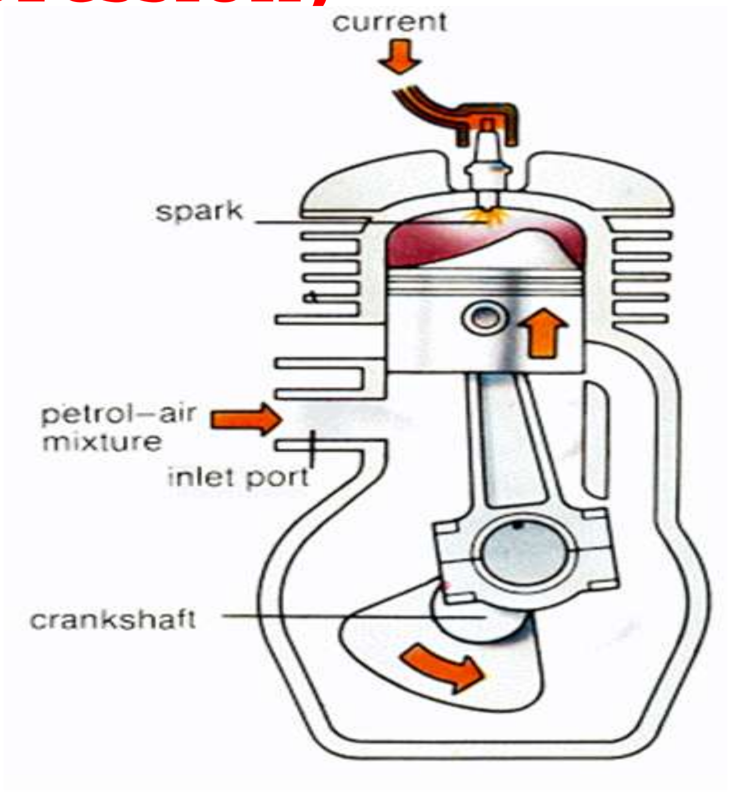
Upward stroke (Suction + Compression)

- When the piston moves upward it covers two of the ports, the exhaust port and transfer port, which are normally almost opposite to each other.
- This traps the charge of **air- fuel mixture** drawn already in to the cylinder.



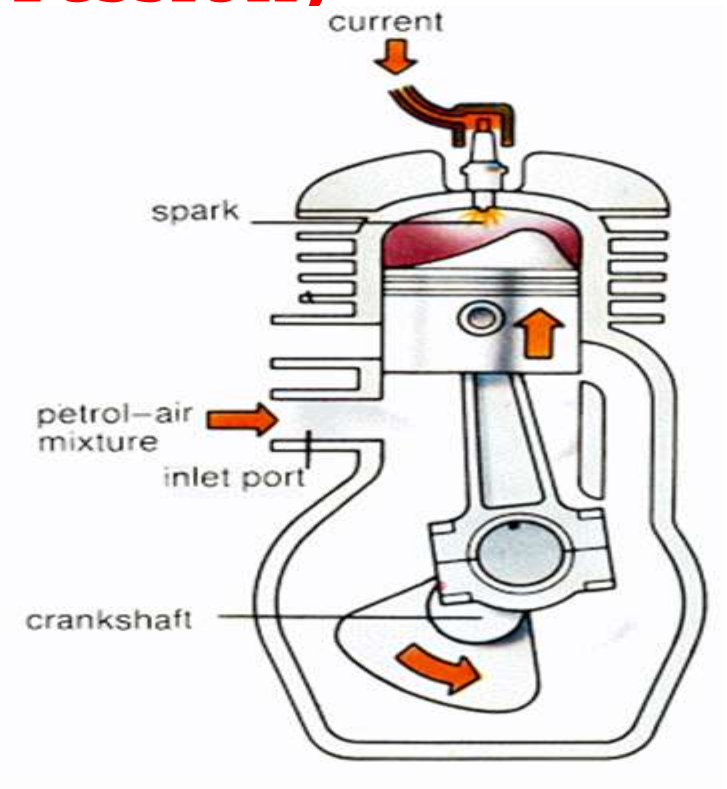
Upward stroke…
(Suction + Compression)

- Further upward movement of the piston compresses the charge and also uncovers the suction port.
- Now fresh mixture is drawn through the suction port into the crankcase.



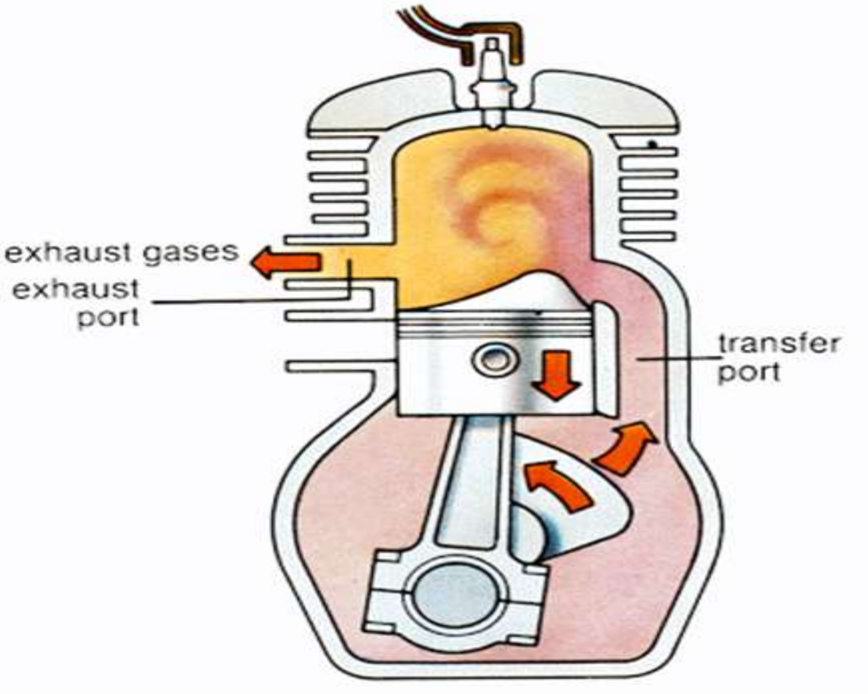
Upward stroke…
(Suction + Compression)

- Just before the end of this stroke, the mixture in the cylinder is ignited by a **spark plug**. Thus, during this stroke both suction and compression events are completed.



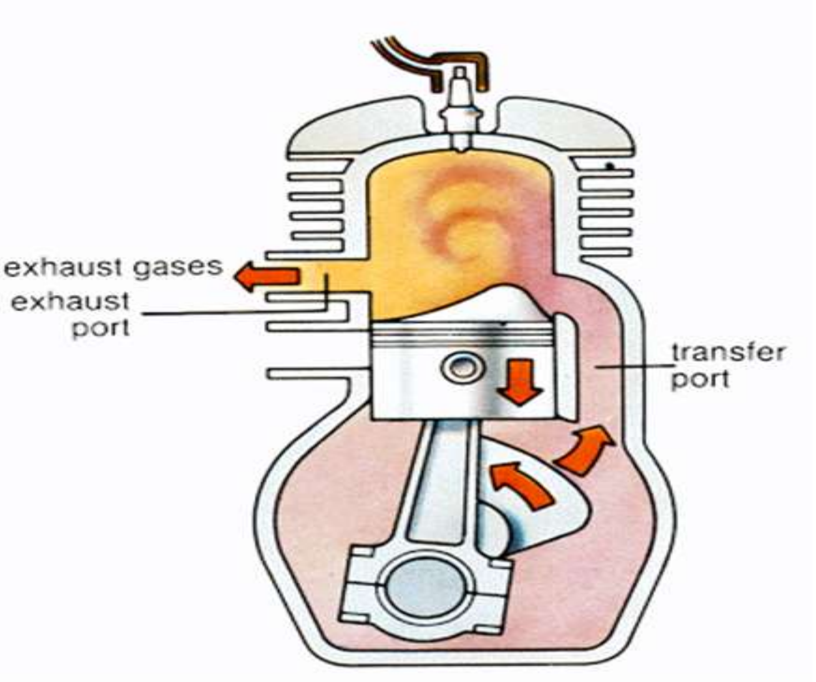
Downward stroke (Power + Exhaust)

- Burning of the fuel raises the temperature and pressure of the gases which forces the piston to move down the cylinder.
- When the piston moves down, it closes the suction port, trapping the fresh charge drawn into the crankcase during the previous upward stroke.



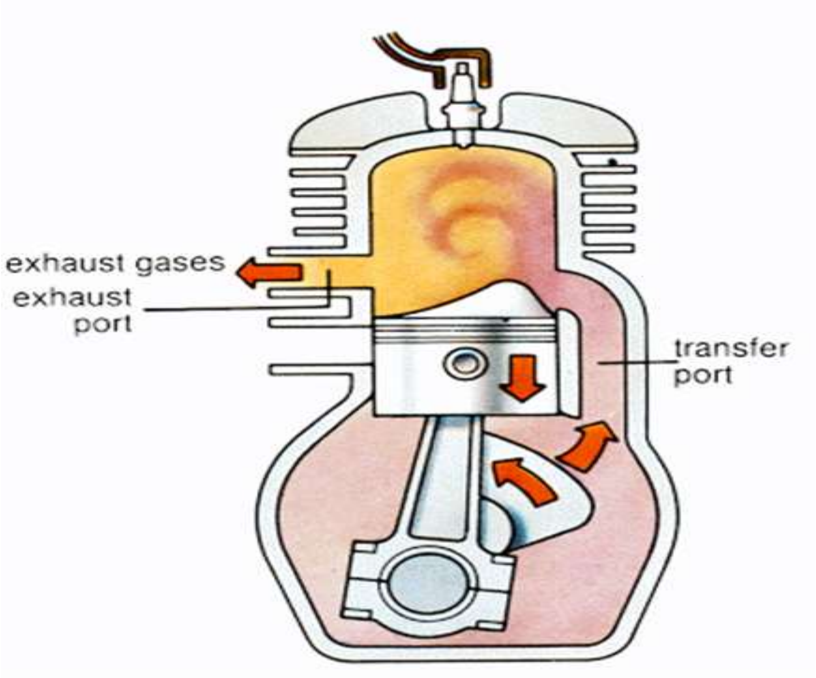
Downward stroke…
(Power + Exhaust)

- Further downward movement of the piston uncovers first the exhaust port and then the transfer port.
- Now fresh charge in the crankcase moves in to the cylinder through the transfer port driving out the burnt gases through the exhaust port.



Downward stroke…
(Power + Exhaust)

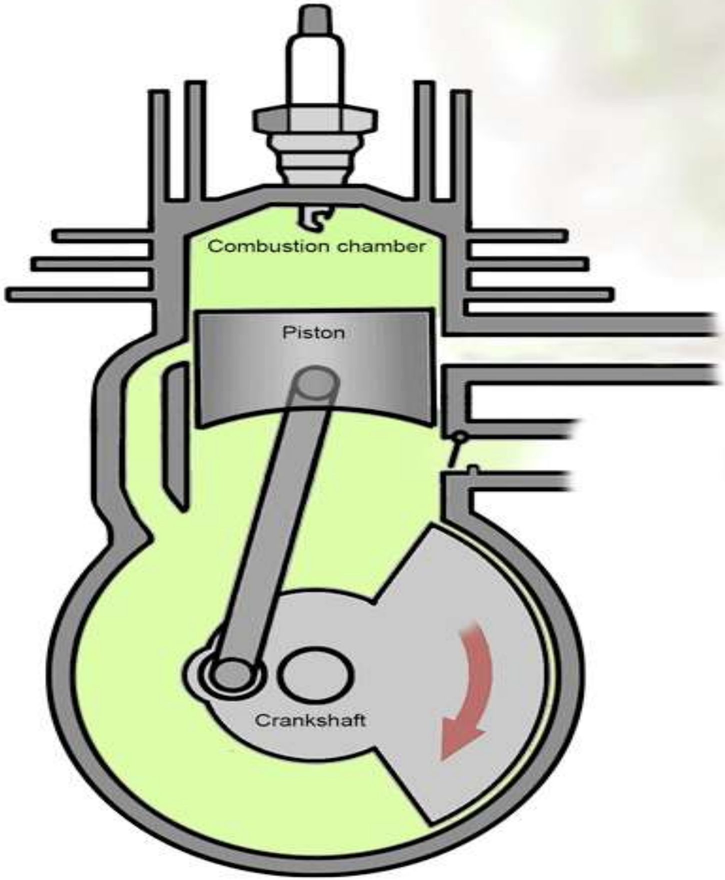
- Special shaped piston crown deflect the incoming mixture up around the cylinder so that it can help in driving out the exhaust gases.
- During the downward stroke of the piston power and exhaust events are completed.



Working of 2 Stroke Petrol Engine

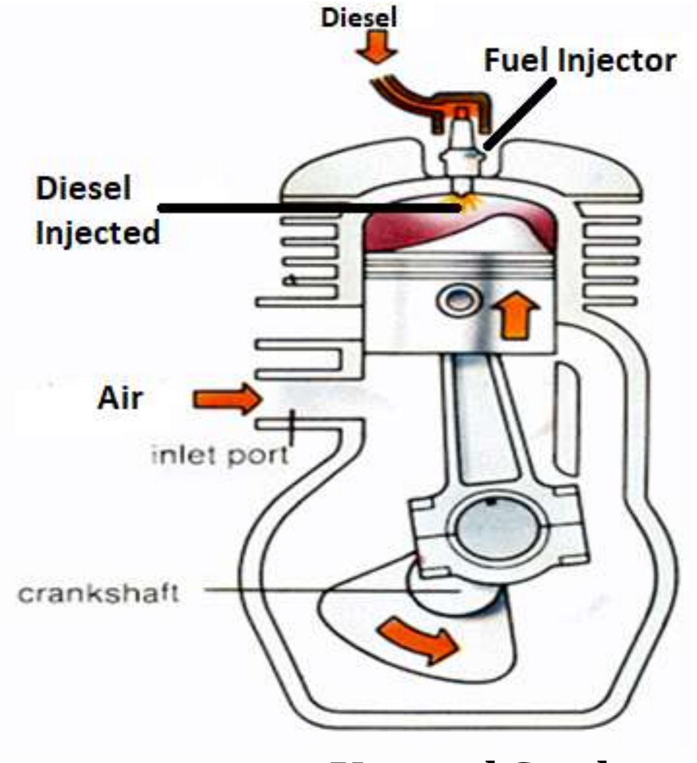
- Upward stroke
  - Suction
  - Compression

- Downward stroke
  - Power
  - Exhaust

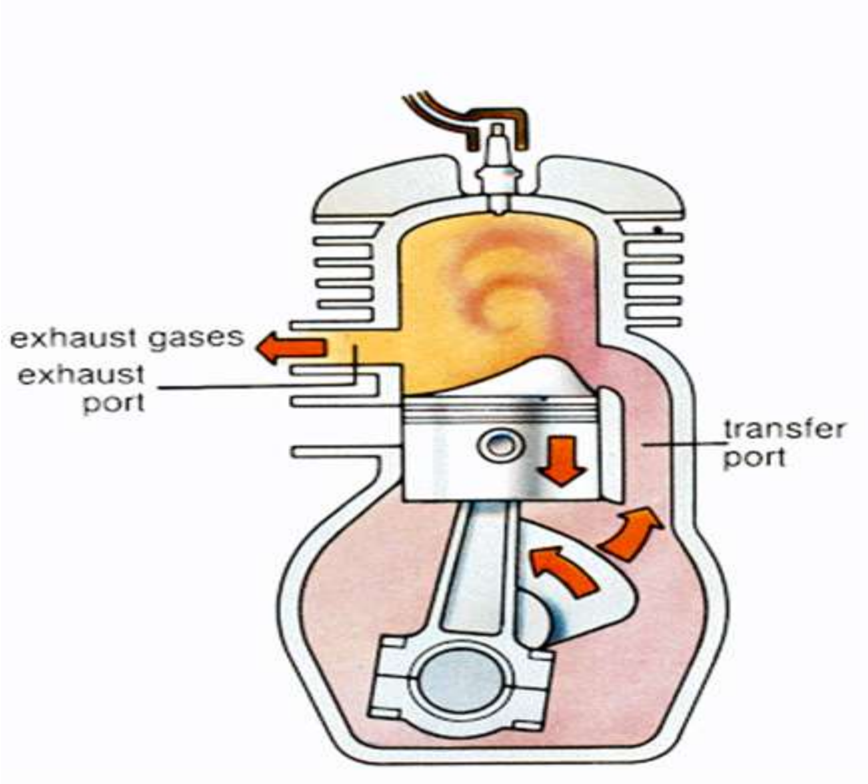


2 STROKE DIESEL ENGINE

2 Stroke Diesel Engine

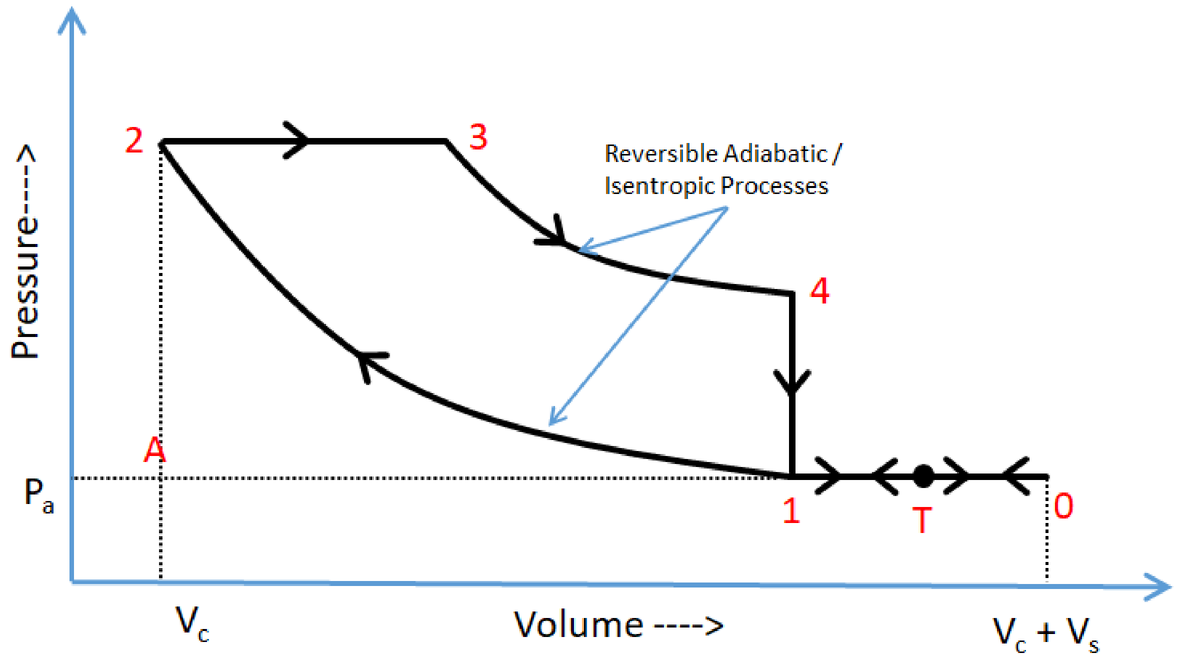


Upward Stroke



Downward Stroke

Diesel Cycle PV Diagram for 2Stroke Engines



Theoretical Otto Cycle for 2 Stroke Diesel Engine

Diesel Cycle (PV diagram)

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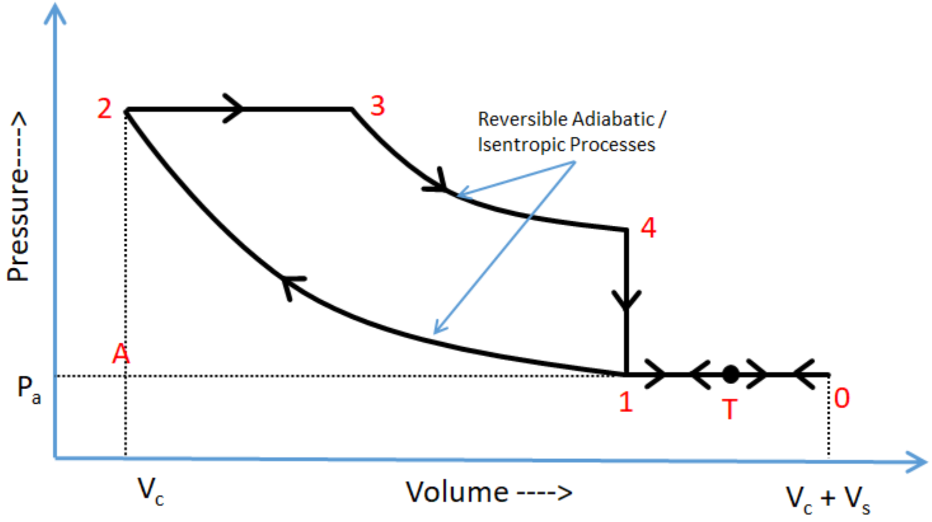

Theoretical Otto Cycle for 2 Stroke Diesel Engine

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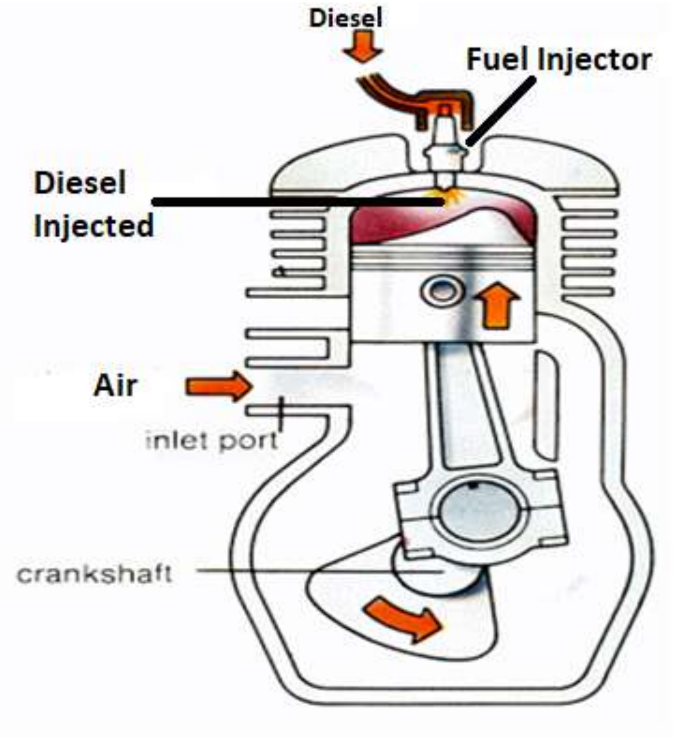
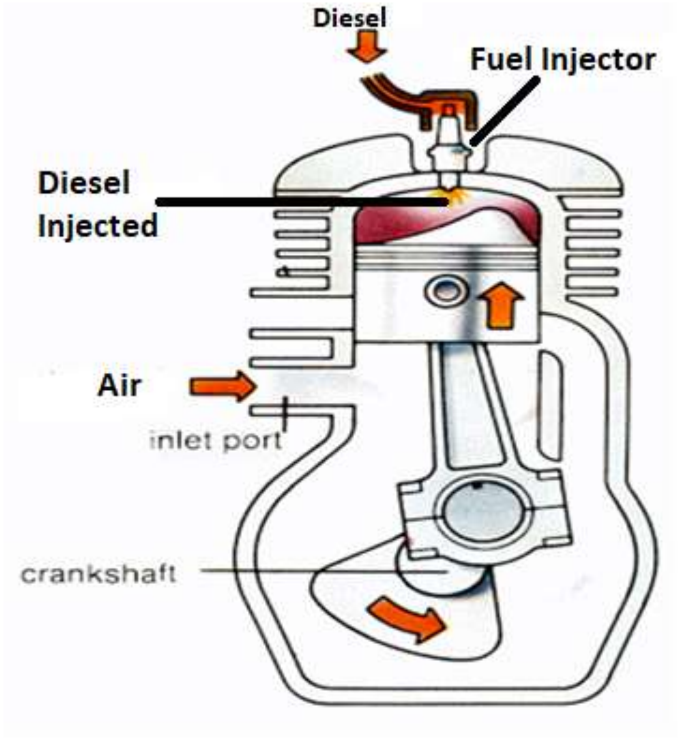


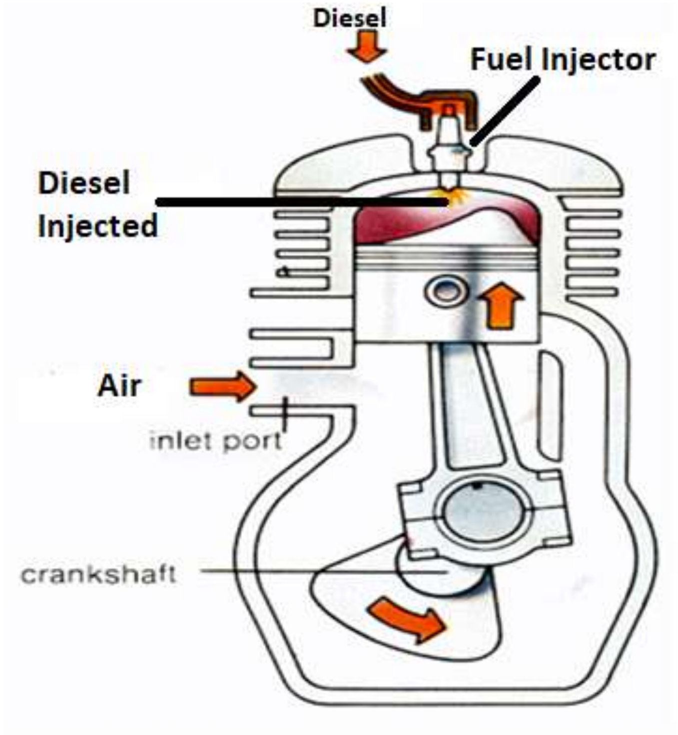
Upward stroke…
(Suction + Compression)

- Further upward movement of the piston compresses the air and also uncovers the suction port.
- Now fresh air is drawn through the suction port into the crankcase.



Upward stroke…
(Suction + Compression)

- Just before the end of this stroke, Diesel fuel is injected in to the combustion chamber by the fuel injector.
- Injected fuel mixes with high temperature air and auto-ignites.



Downward stroke (Power + Exhaust)

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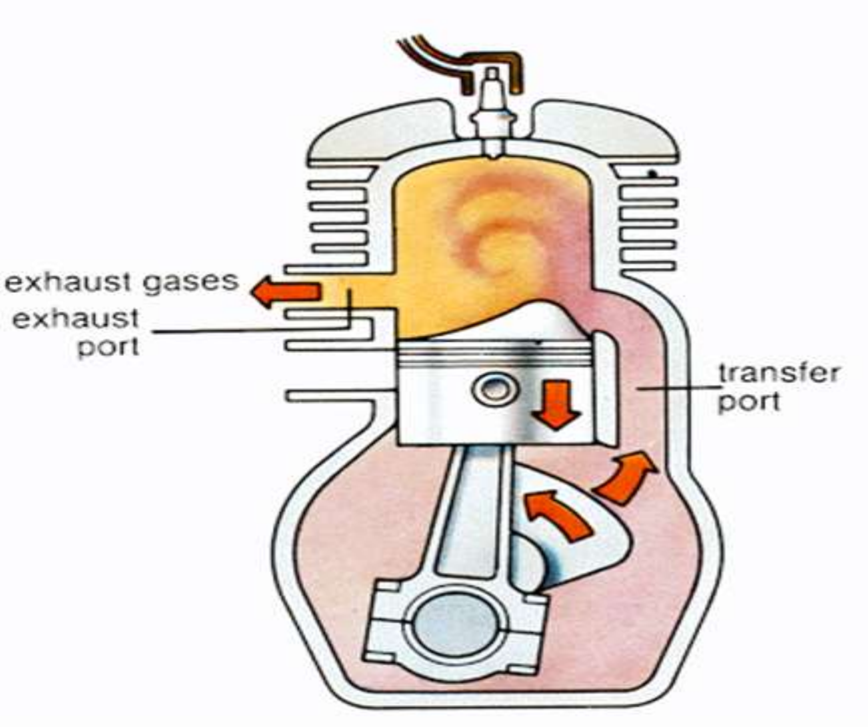

Downward stroke…
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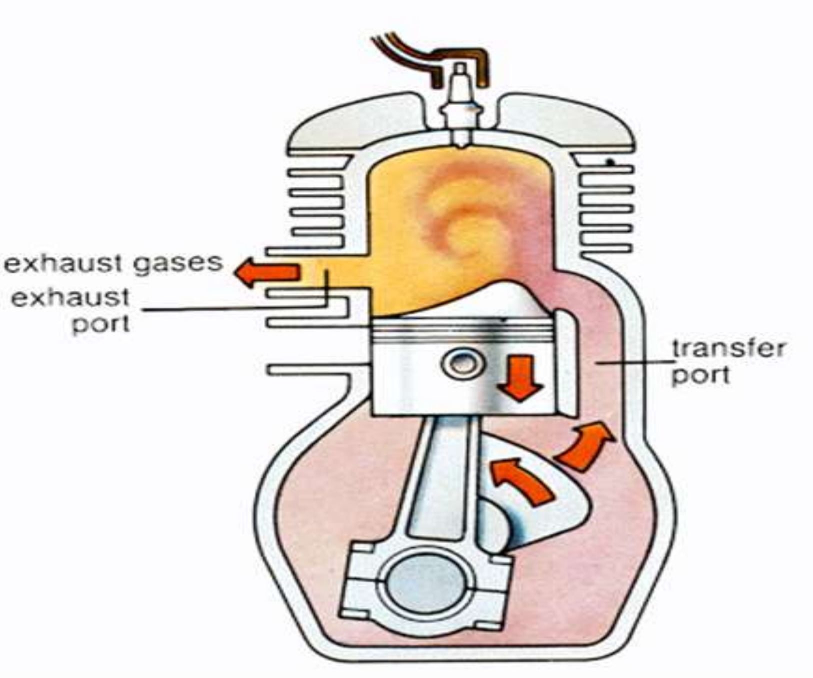

Downward stroke…
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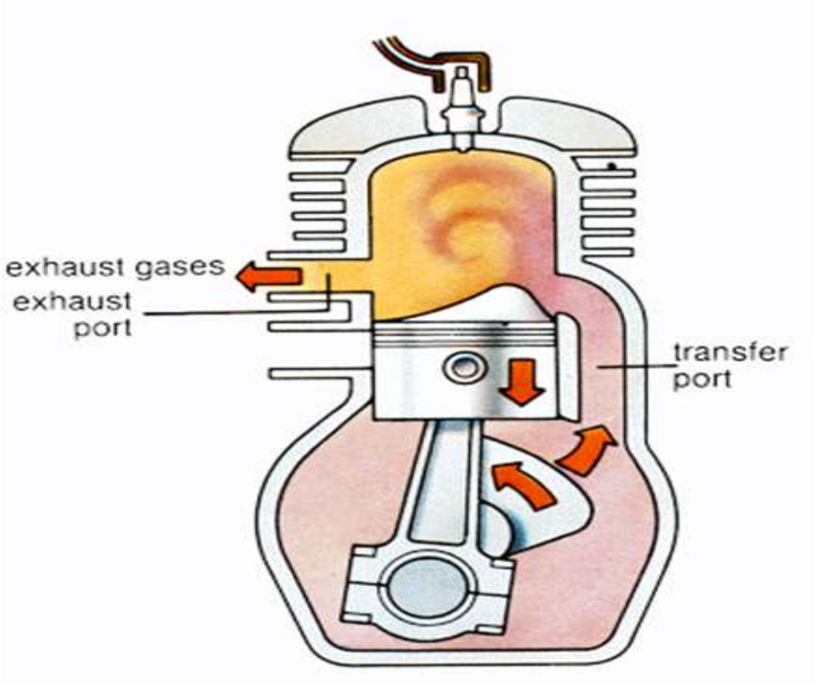


COMPARISON BETWEEN
4 STROKE AND 2 STROKE ENGINES

Comparison between 4-S and 2-S Engines

Description	4-stroke Engine	2-stroke Engine
No. of strokes/cycle	Requires 4 separate strokes to complete 1 cycle of operation	Requires only 2 strokes
No. of cycles/min	n = N/2 N = Engine speed	n = N
Power developed	Every alternate revolution	Every revolution
Admission of charge	Directly in to cylinder during suction stroke	First in to crank case & then to the cylinder

Comparison between 4-S and 2-S Engines

Description	4-stroke Engine	2-stroke Engine
Valves	Passages are opened & closed by inlet & exhaust valves	Piston itself opens & closes ports.
Engine cooling	Moderate cooling, as power is produced in alternate revolution.	High rate of cooling. Power is produced in every revolution.
Direction of crank shaft rotation	Rotates in only one direction.	Rotates in either direction.

Comparison between 4-S and 2-S Engines

Description	4-stroke Engine	2-stroke Engine
Fuel consumption	Less. No mixing of fresh charge & exhaust gases	More. Mixing of fresh charge & exhaust gases.
Lubricating oil consumption	Less.	More.
Volumetric efficiency	High, due to high rate of induction.	Low, due to low rate of induction.

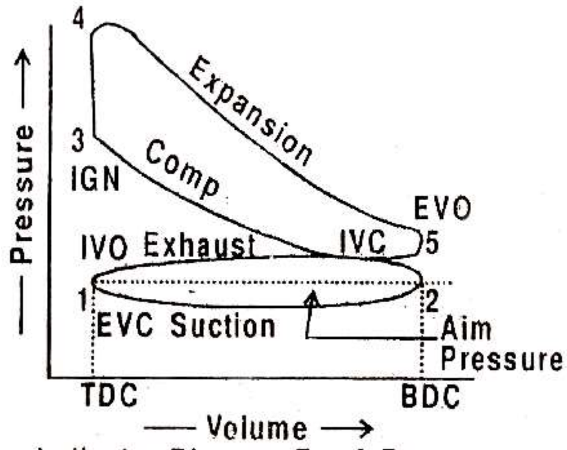
FORMULAE FOR IC ENGINES PERFORMANCE CHARACTERISTICS

Important Formulae

- Indicated Power (IP)
- Brake Power (BP)
- Friction Power (FP)
- Mechanical Efficiency (η_{Mech})
- Thermal Efficiency ($\eta_{Thermal}$)

1. Indicated Power

- It is the power produced inside the cylinder and calculated by finding the actual mean effective pressure. The actual mean effective pressure is found as follows.



Indicator Diagram For A Four Stroke Cycle Petrol Engine.

1. Indicated Power

- Let a = Area of the actual indicator diagram, Sq.cm

  I = Base width of the indicator diagram, cm

  s = Spring value of the spring used in the indicator, $N/m^2/cm$

If, P_m = Actual mean effective pressure, N/m^2

$$Pm = \frac{s\,a}{l}\ ,\ N/m^2$$

- Let a = Area of the actual indicator diagram, Sq.cm

  I = Base width of the indicator diagram, cm

  s = Spring value of the spring used in the indicator, $N/m^2/cm$

If, P_m = Actual mean effective pressure, N/m^2

$$Pm = \frac{s\,a}{l}\ ,\ N/m^2$$

1. Indicated Power

- The indicated power of the four stroke and two stroke engines are as follows,
- **Indicated power (4 stroke) =** $\frac{P_m\, L\, A\, N\, k}{60\ x\ 2\ x\ 1000}$, kW
- **Indicated power (2 stroke) =** $\frac{P_m\, L\, A\, N\, k}{60\ \ x\ 1000}$, kW

Where:

P_m *is Mean Effective Pressure (Pa) ,* ***L*** *is Stroke length (m) ,*

A *is internal cross-section area of the cylinder (m2) ,*

N *is crankshaft speed (rpm) ,* ***k*** *is number of cylinders*

1. Indicated Power

If the engine is having a single cylinder,

Then, k=1

- Indicated power (4 stroke) = $\frac{P_m L\, A\, N}{60\ x\ 2\ x\ 1000}$, kW
- Indicated power (2 stroke) = $\frac{P_m L\, A\, N}{60\ \ x\ 1000}$, kW

Note: 1 bar (Pressure) = 1x10^5 Pa

2. Brake Power

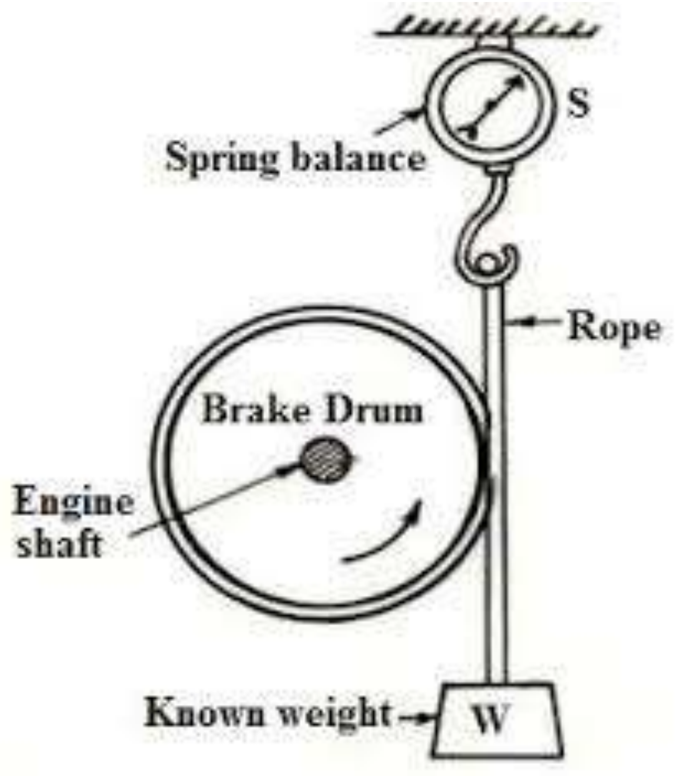
- The indicated power produced inside the IC engine cylinder will be transmitted through the piston, connecting rod and crank. Since these mechanical parts are moving relative to each other, they will have to encounter resistance due to friction.
- Therefore a certain fraction of the indicated power produced inside the will be lost due to the friction of the moving parts of the engine.

2. Brake Power

- Therefore the net power available at the crankshaft will be equal to the difference between the indicated power produced inside the engine cylinder and the power lost due to the friction.
- The net power available at the crankshaft is measured by applying the brake and is therefore called brake power.

2. Brake Power

- The Brake Power is determined experimentally using Brake Drum Dynamometer



2. Brake Power

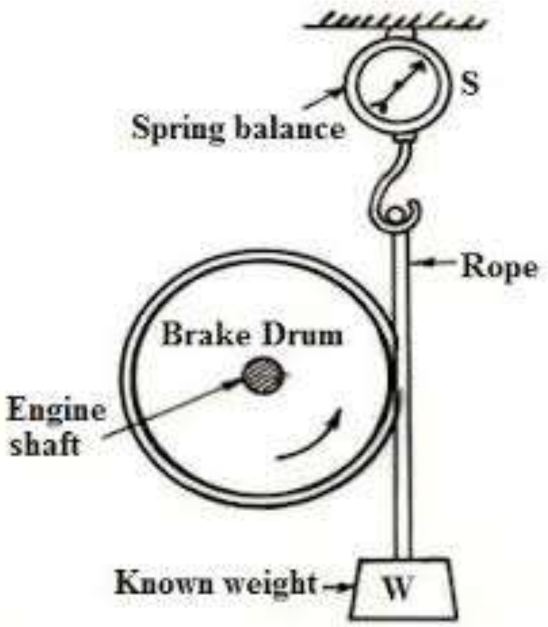
- The brake power is calculated as follows :

Let W = Net load acting on the brake drum, kg

R = Radius of the brake drum. M

N = R.P.M of the crankshaft

T = Torque applied due to the net load W on the brake drum.



$$\textbf{Torque} = T = \frac{9.81}{1000} W\,R, \text{ kNm}$$

$$\textbf{B. P} = \frac{2\pi\, NT}{60}, \text{ kW}$$

3. Friction Power

- The amount of power lost in friction is called friction power.
- The friction power is the difference between the indicated power and the brake power.
- Friction power = Indicated power – Brake power

(FP = IP – BP)

4. Mechanical Efficiency

- It is the efficiency of the moving parts of the mechanism transmitting the indicated power to the crankshaft.
- Therefore it is defined as the ration of the brake power and the indicated power. It is expressed in percentage.
- Therefore, $\eta_{\mathrm{Mech}} = \dfrac{Brake\ Power}{Indicated\ Power} \times 100$

5. Thermal Efficiency

It is the efficiency of 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 the power developed by the engine to the heat supplied by the fuel in the same interval of time. It is expressed in percentage.

- Therefore, $\eta_{Thermal} = \frac{\textit{Power Output}}{\textit{Heat energy supplied by the fuel}} \times 100$

5. Thermal Efficiency

- In the thermal efficiency formula, the numerator is Power output.
- We have two powers, IP and BP.
- Hence, if IP is used in numerator, then the formula is referred as Indicated Thermal Efficiency
- And, if BP is used in the numerator, then the formula is referred as Brake Thermal Efficiency.

5.1 Indicated Thermal Efficiency

- The Indicated Thermal Efficiency is defined as the ratio of Indicated power to the heat supplied by the fuel.

- Therefore, $\eta_{\text{IThermal}} = \dfrac{Indicated\ Power}{Heat\ energy\ supplied\ by\ the\ fuel}$ x 100

- i.e, $\eta_{\text{IThermal}} = \dfrac{I\ P}{CV\ x\ m}$ x 100

  Where, I P = Indicated Power, kW

  CV = Calorific value of the fuel, kJ/kg

  m = mass of fuel supplied, kg/s

5.2 Brake Thermal Efficiency

- The Brake Thermal Efficiency is defined as the ratio of Brake power to the heat supplied by the fuel.

- Therefore, $\eta_{\text{BThermal}} = \dfrac{Brake\ Power}{Heat\ energy\ supplied\ by\ the\ fuel} \times 100$

- i.e, $\eta_{\text{BThermal}} = \dfrac{B\ P}{CV\ x\ m} \times 100$

Where, B P = Brake Power, kW

CV = Calorific value of the fuel, kJ/kg

m = mass of fuel supplied, kg/s

Today's Learnings

- Principle of working of a 2 Stroke Petrol Engine
- Principle of working of a 4 Stroke Diesel Engine
- Comparison between 4S and 2S Engines
- Formulae for IC Engines:
  - *Indicated Power*
  - *Brake Power*
  - *Friction Power*
  - *Mechanical Efficiency*
  - *Thermal Efficiency (Indicated and Brake Thermal Efficiencies)*

Q & A

- If you have any queries, post them in the chat box of MS Teams.

Thank You