



Unit IV: Part - A

2023-24 (Odd): 1st Semester

BE in CV, CY, EC, EI, IM

ME113AT: Fundamentals of Mechanical Engineering

(Category: Engineering Science)

(Theory)

ESC: 'C' Section

Unit – IV
MECHANICAL DRIVES AND
ELECTRICAL DRIVES

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Mechanical Drives >>

- Classification of IC Engines
- Working of 4-S direct injection Engines
- Performance characteristics
- Classification of Gears
- Velocity Ratio for:
 - Simple Gear Trains
 - Compound Gear Train

Electrical Drives>>

- History
- Well to Wheels Analysis
- Electric Vehicles
- Configurations
- EV / ICEV Comparison
- Performance
- Traction Motors Characteristics
- Concept of Hybrid Electric Drive Trains
- Classification of Hybrid Electric Vehicles

| Unit -IV | 08 Hrs |
|---|---------------|
| Mechanical Drives: Classification of IC Engines, Working of 4-S direct injection engines, Performance characteristics, Classification of gears, velocity ratio for simple and compound gear trains. Electrical Drives: History, Well to Wheel analysis, Electric vehicles, Configurations, EV/ICEV comparison, Performance, Traction Motor Characteristics, Concept of Hybrid Electric Drive Trains, Classification of hybrid electric vehicles. | |

Mechanical Drives>>

- Classification of IC Engines
- Working of 4-S direct injection engines

| Unit -IV | 08 Hrs |
|--|--------|
| <p>Mechanical Drives: Classification of IC Engines, Working of 4-S direct injection engines, Performance characteristics, Classification of gears, velocity ratio for simple and compound gear trains.</p> <p>Electrical Drives: History, Well to Wheel analysis, Electric vehicles, Configurations, EV/ICEV comparison, Performance, Traction Motor Characteristics, Concept of Hybrid Electric Drive Trains, Classification of hybrid electric vehicles.</p> | |

Introduction

Any type of engine which derives heat energy from the combustion of fuel and converts it in to mechanical work is termed as a **Heat Engine**.

Heat engines may be classified in to **two main types**:

- External Combustion engines (**EC** engines)
- Internal combustion engines (**IC** engines)

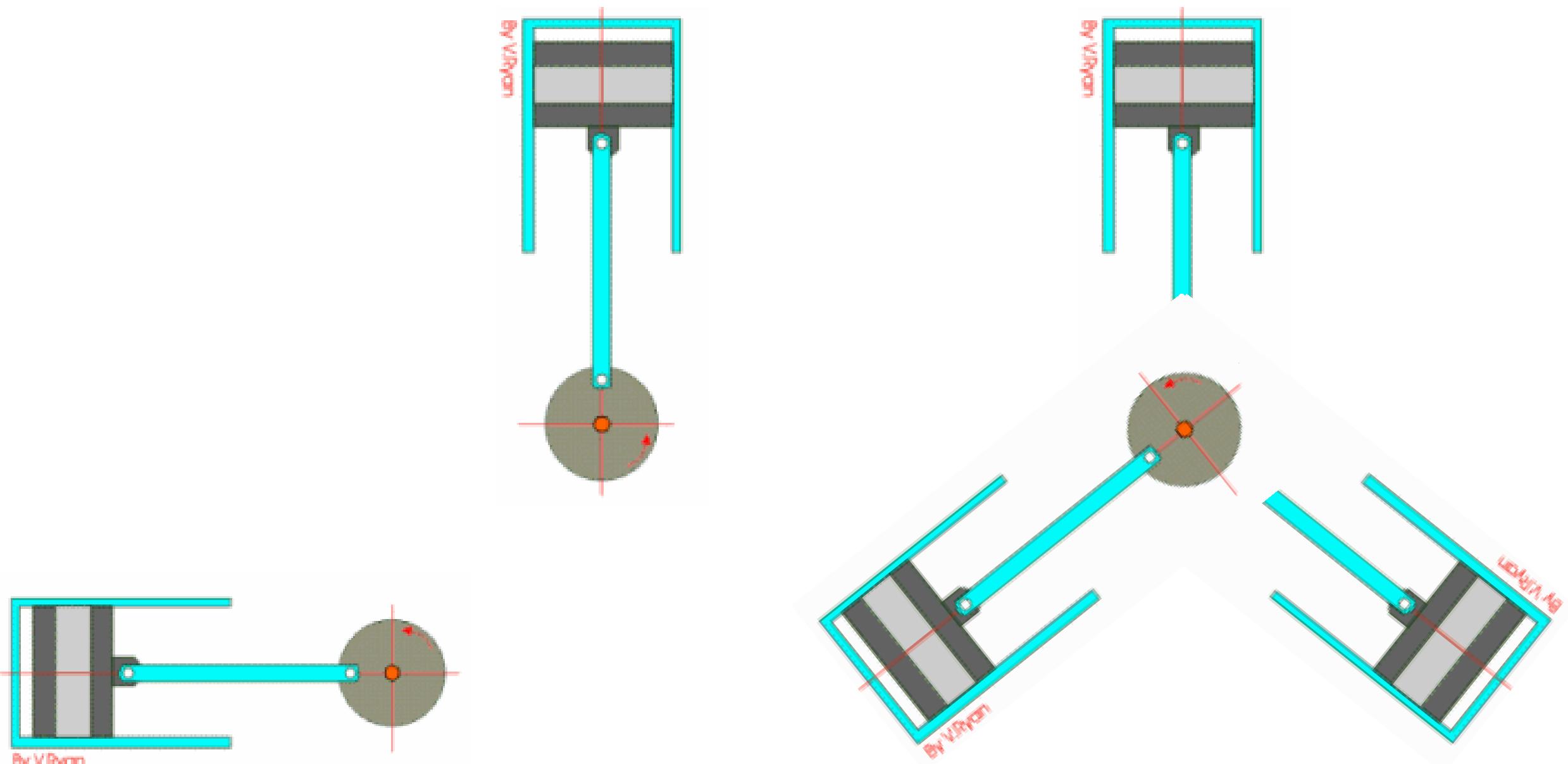
In an external combustion engine, the combustion of fuel takes place outside the engine cylinder.

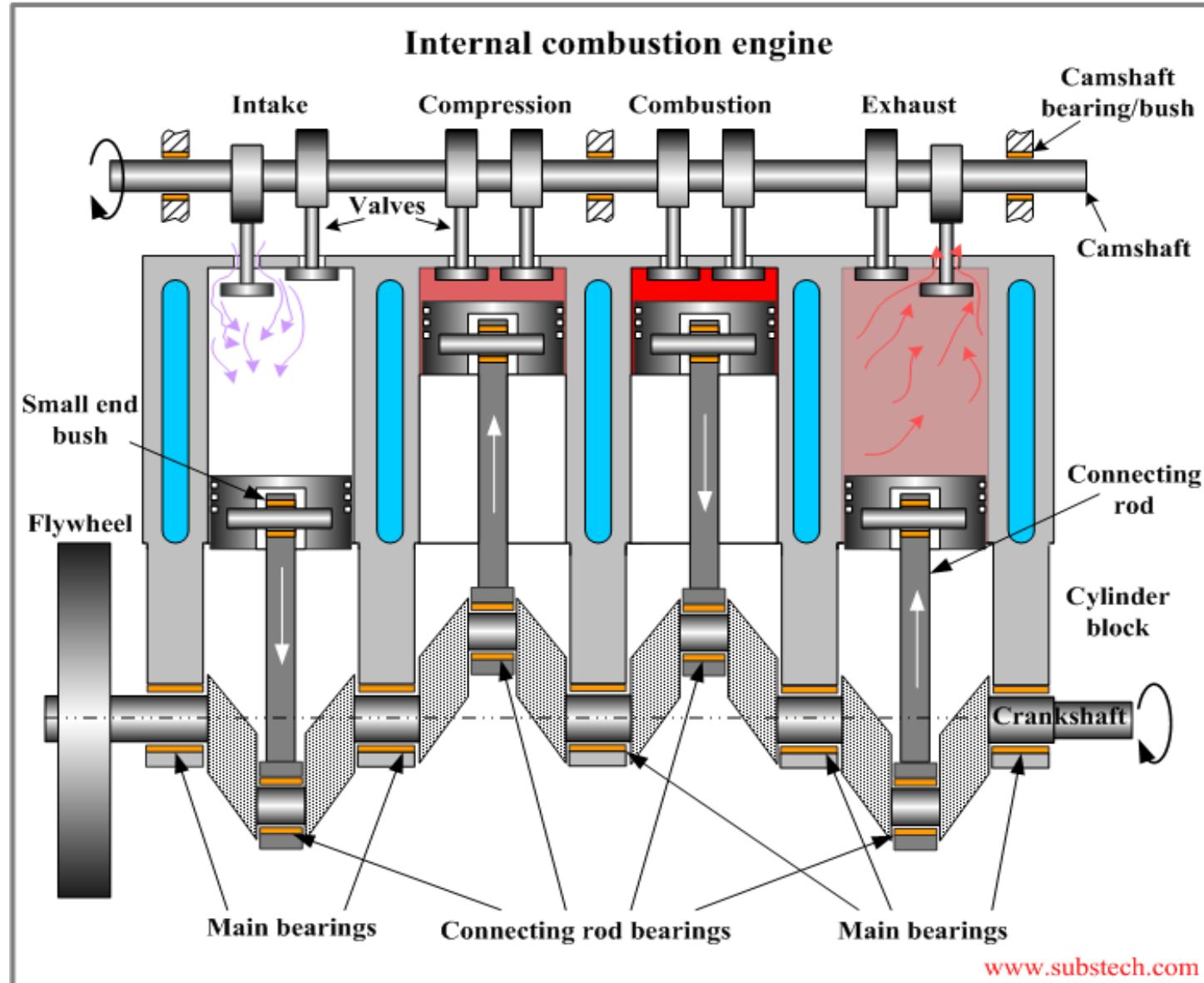
Ex: Steam engines

In an internal combustion engine, the combustion of fuel takes place inside the engine cylinder.

Ex: Petrol engines, Diesel engines.

Classifications of IC Engines >>





Classifications of IC Engines >>

I.C. Engines are classified according to:

1. Nature of thermodynamic cycle

- Otto cycle engine
- Diesel engine
- Dual combustion cycle engine

2. Type of the Fuel used

- Petrol engine
- Diesel engine
- Gas engine
- Bi-fuel engine

3. Number of strokes

- Two stroke engine
- Four stroke engine

4. Type of Ignition

- Spark ignition engine, known as SI Engine
- Compression ignition engine, known as CI engine

5. Number of Cylinder

- Single cylinder engine
- Multi cylinder engine

6. Position of the Cylinder

- Horizontal engine
- Vertical engine
- Radial engines
- In-line engines

7. Method of Cooling

- Air cooled engine
- Water cooled engine

Classifications of IC Engines >>

Advantages of IC Engines over EC Engines>>

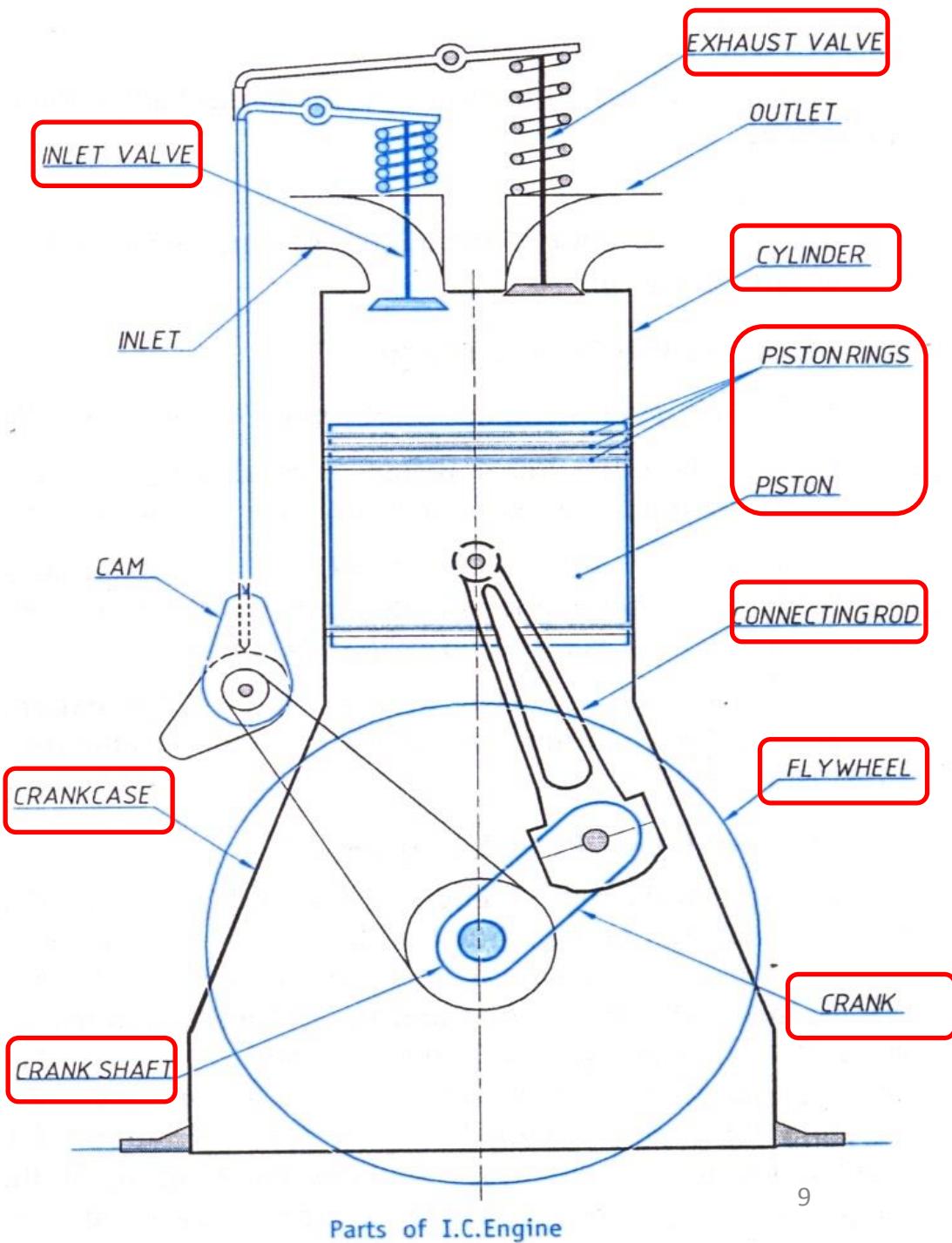
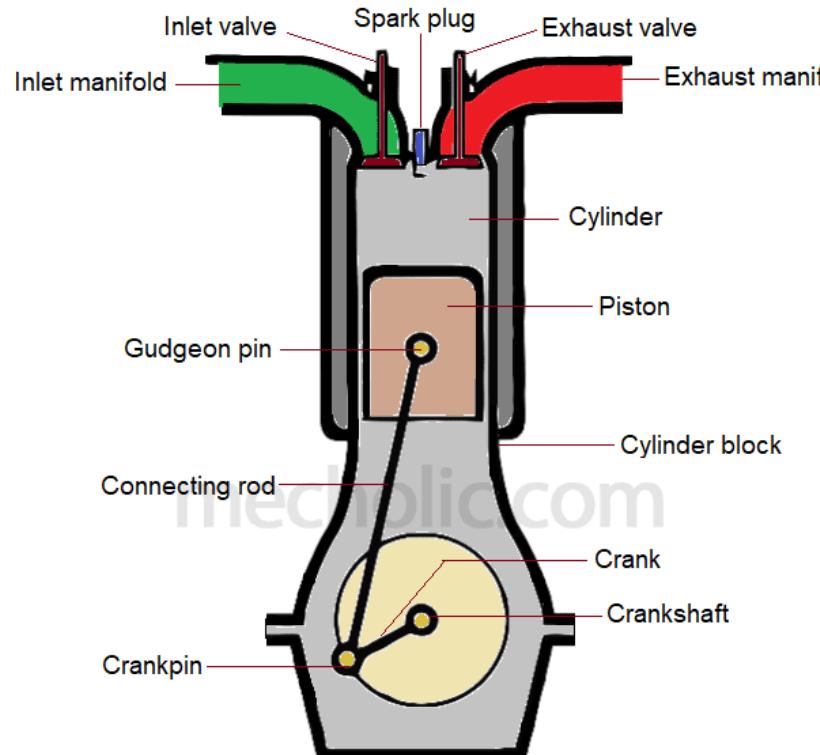
The following advantages of ICE are observed over ECE:

- High efficiency
- Simplicity
- Compactness
- Light weight
- Easy starting
- Comparatively low cost

Parts of IC Engines>>

The main parts of an IC Engine are:

- Cylinder
- Piston and Piston rings
- Connecting rod
- Crank and crankshaft
- Valves
- Flywheel
- Crankcase



Parts of IC Engines>>

1.Cylinder:

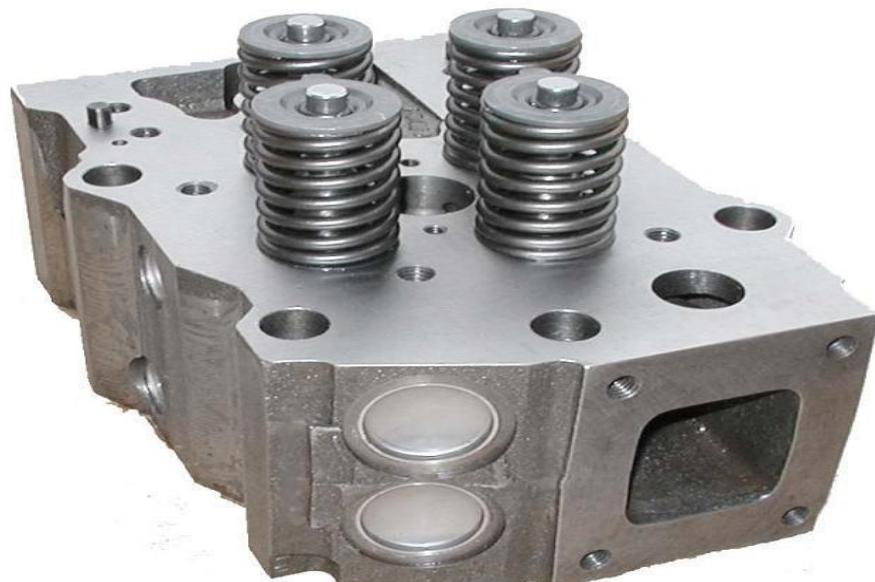
- Fuel is burnt inside the cylinder and
- Power is developed by action of hot gases on the piston
- It is made of grey cast iron



Cylinder

2.Cylinder head:

- One end of the cylinder is closed by means of movable head
- Cylinder head houses the inlet & exhaust valves.
- Cylinder head is made of cast iron with alloying elements such as nickel, chromium, molybdenum, etc.



Cylinder head

Parts of IC Engines>>

3. Piston:

- It is a close fitting hollow cylindrical plunger moving to & fro inside the cylinder.
- The power developed by the combustion of fuel is transmitted by the piston to the crankshaft through the connecting rod.
- It is made of aluminium alloys for light weight.



Piston

4. Piston rings:

- They are inserted in to the circumferential grooves provided at the top end of the piston.
- Piston rings maintain a gas tight seal between the cylinder & the piston.
- They also help in conducting the heat from piston to cylinder.
- These are metallic rings made of cast iron.



Piston Rings

Parts of IC Engines>>

5. Connecting rod:

- It is the link that connects the piston and the crankshaft by means of pin-joints.
- It converts the linear motion of the piston in to rotary motion of the crankshaft.
- It is generally made of alloy steels



Connecting rod

6. Crank & Crankshaft:

- Crank is a lever that is connected to the end of the connecting rod by a pin joint.
- The other end of the crank is rigidly connected to a shaft known as '**Crankshaft**'.
- As the connecting rod oscillates, the crank and hence the crankshaft rotate about an axis.
- It is made of carbon steel

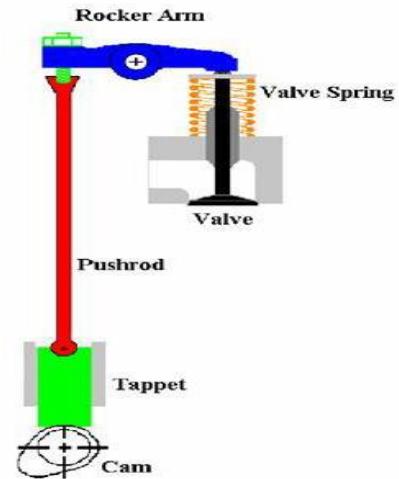


Crank and
Crank Shaft

Parts of IC Engines>>

7. Valves:

- Valves are devices which control the flow of intake & exhaust gases to & from the cylinder.
- They are operated by means of cams driven by the crankshaft through belt or gears
- They are also called as '**Poppet Valves**'



Valves

8. Flywheel:

- It is a heavy wheel mounted on the crankshaft of the engine
- It helps to maintain uniform rotation of the crankshaft
- It absorbs kinetic energy during power stroke and delivers energy during other strokes.
- Fly wheel is made of cast iron



Flywheels

9. Crankcase:

- It is the lower part of the engine
- It serves as an enclosure for the crankshaft
- It also serves as a sump or reservoir for lubricating oil

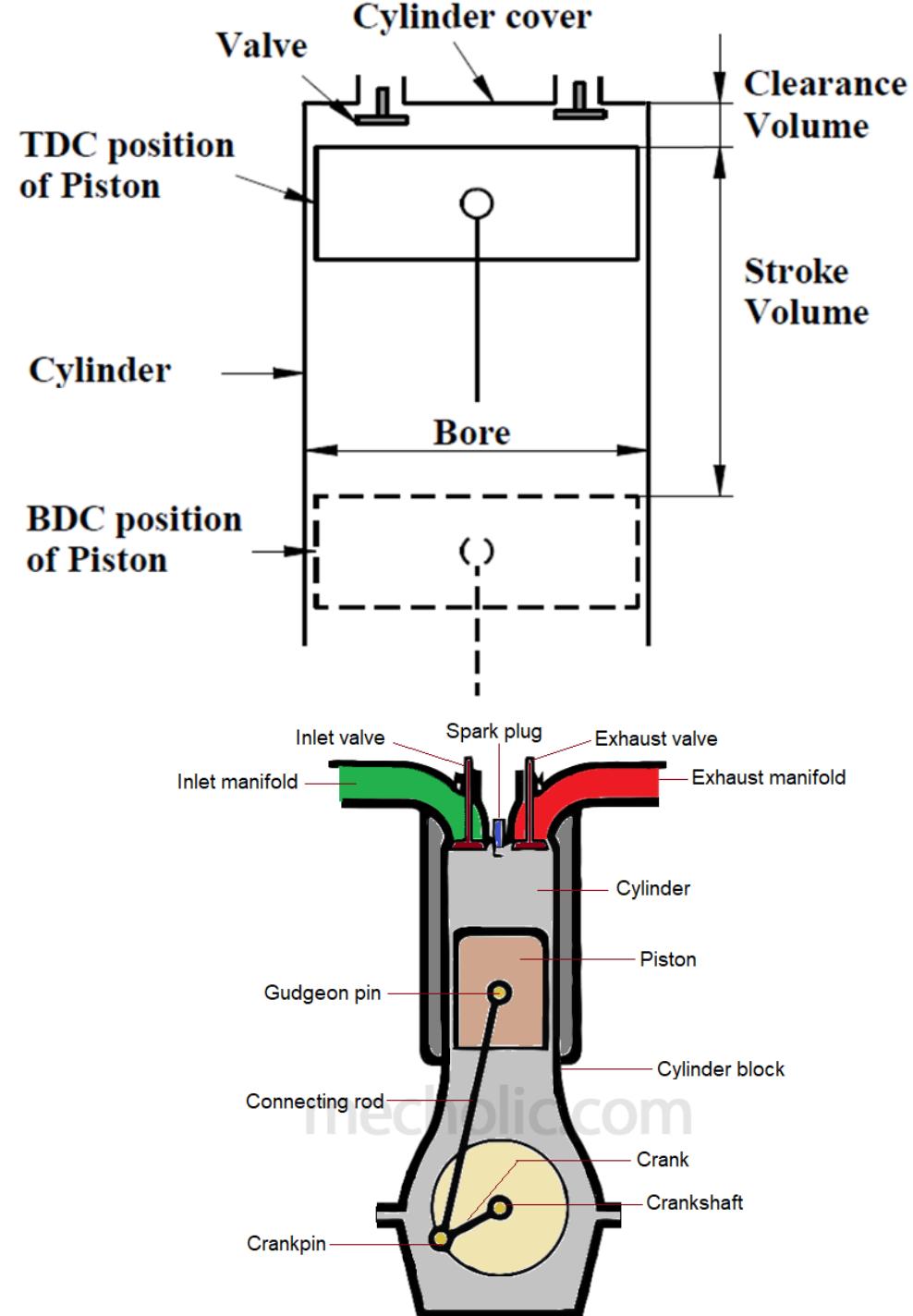


Crank case

Terminologies of IC Engines>>

Main terminologies of an IC Engine are as follows:

- Bore
- Top Dead Centre / Inner Dead Centre
- Bottom dead centre / Outer Dead centre
- Stroke ($L=2r_c$)
- Crank radius ($r_c = L/2$)
- Swept volume
- Clearance volume (V_c)
- Compression Ratio
- Piston Speed
- Cycle of Operation



Terminologies of IC Engines>>

➤ **Bore:**

It is the inside diameter of the cylinder.

➤ **Top Dead centre / Inner dead centre:**

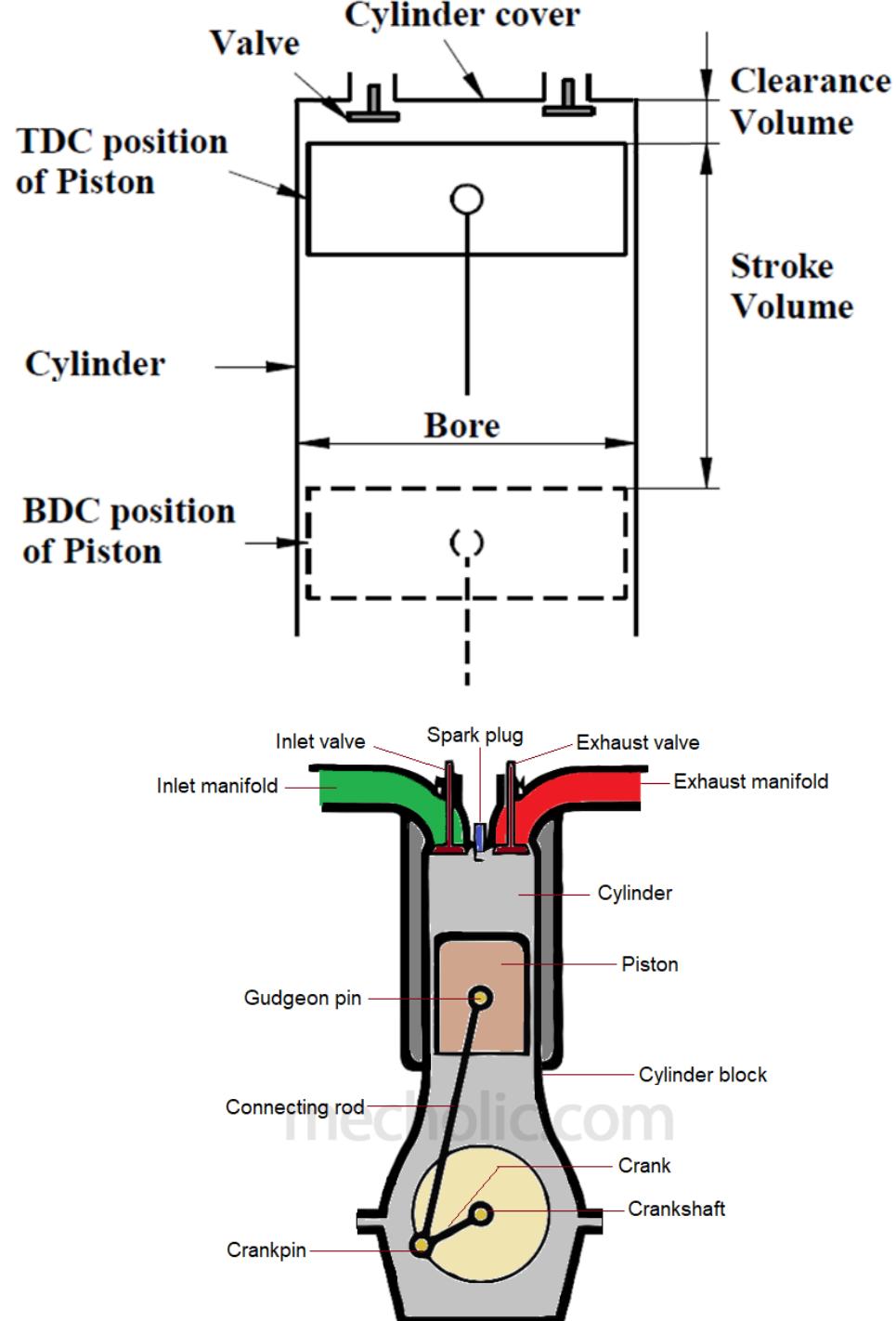
It is the extreme position of the piston towards cover end side of the cylinder.

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.



Terminologies of IC Engines>>

➤ Stroke ($L=2r_c$):

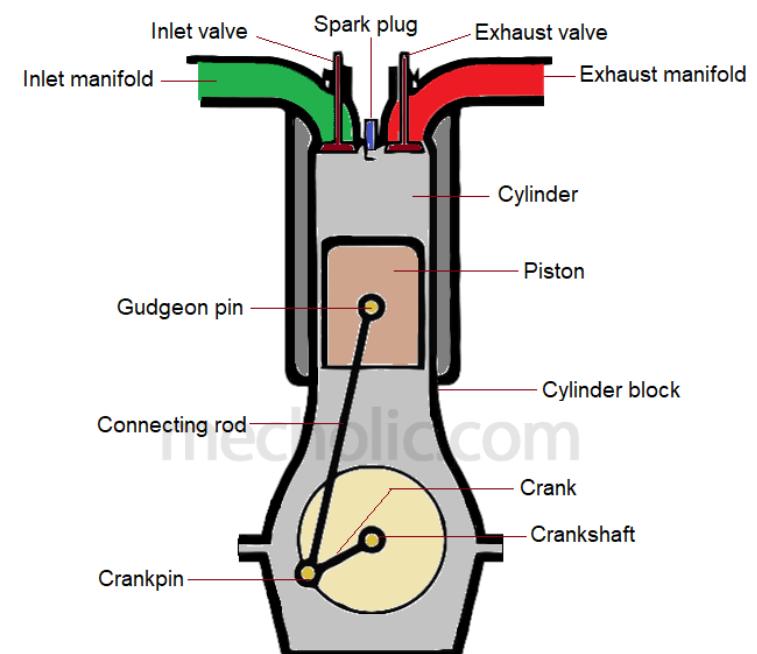
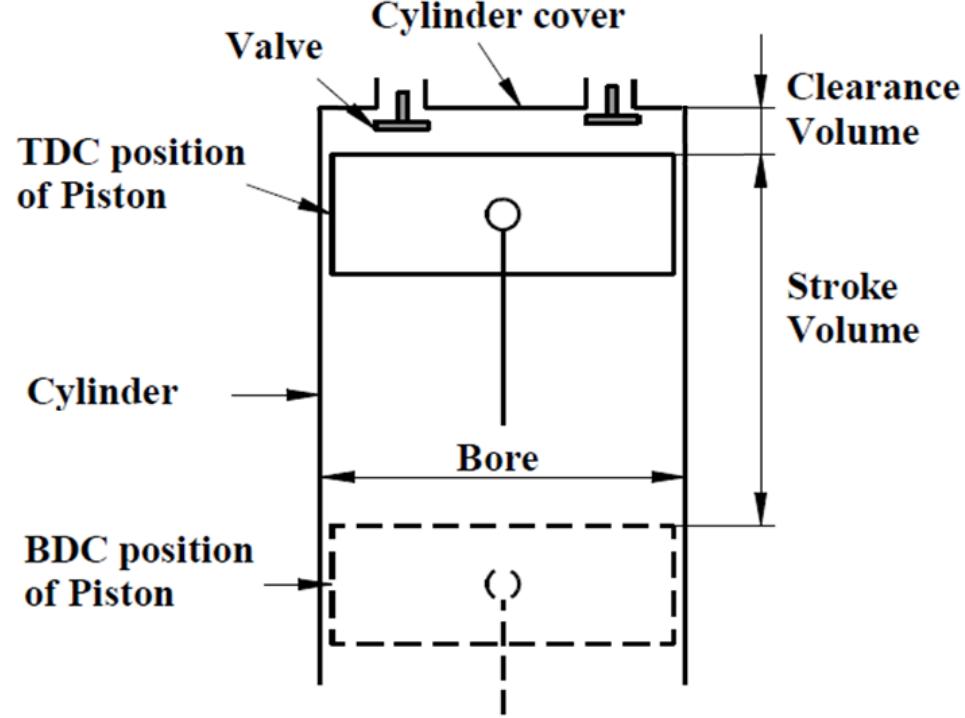
It is the linear distance travelled by the piston from one dead centre position to the another dead centre position.

It is equal to twice the crank radius

➤ Crank radius ($r_c = L/2$):

It is the linear distance between the shaft centre and crank pin centre.

It is equal to half the stroke length



Terminologies of IC Engines>>

➤ Swept volume (V_s) :

It is the volume through which the piston sweeps during a stroke.

It is equal to the product of surface area of piston and its stroke length.

➤ Clearance volume (V_c) :

The piston never touches the cylinder head.

It is the volume included between the top of the piston and the cylinder head when the piston is at TDC .

It is expressed as a percentage of the swept volume .

➤ Compression Ratio (CR):

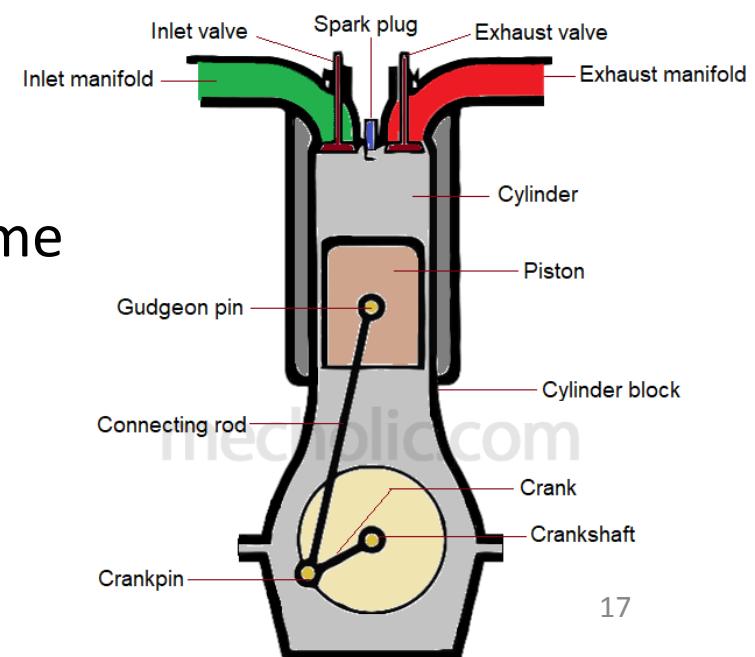
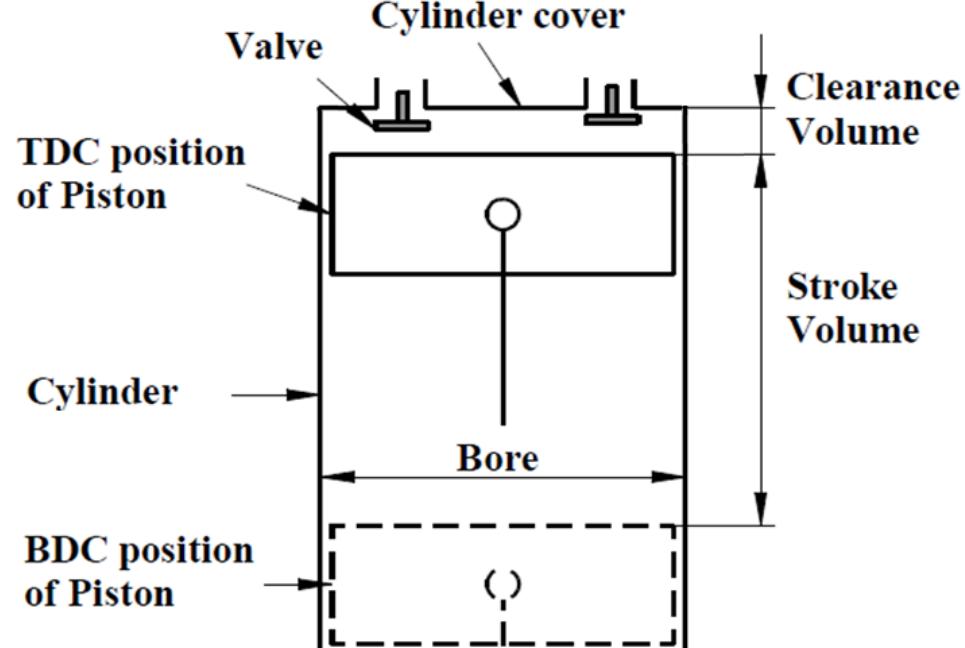
It is the ratio of the total cylinder volume to the clearance volume

For petrol engine CR varies from **4:1 to 10:1**

For diesel engine CR varies from **12:1 to 22:1**

➤ **Piston Speed:** It is the distance travelled by the piston per unit time.

➤ **Cycle of Operation:** It is complete series of events



Fundamentals of Mechanical Engineering

MECHANICAL DRIVES

Assignment – Unit 4a - 01

<<for Practice>>

1. Define Heat Engine and specify the types.
2. Classify the IC Engines.
3. State the advantages of IC Engines over EC Engines
4. Sketch a neat diagram and name the significant part of an IC Engine.
5. List and define various terminologies in the context of IC Engines.
6. Illustrate with the help of neat sketch, the IC Engine terminologies.

Note:

- i) Use new A4 size sheets, provide 1" left and top margin for each sheet.
- ii) Write Roll No., Name (at right top), Topic and Assignment No. (at top Middle) in the 1st sheet.
- iii) Use red pen to write the questions and blue or black pen for answer
- iv) Draw neat sketches using instruments (avoid free hand sketching)

Mechanical Drives>>

➤ Working of 4-S direct injection engines

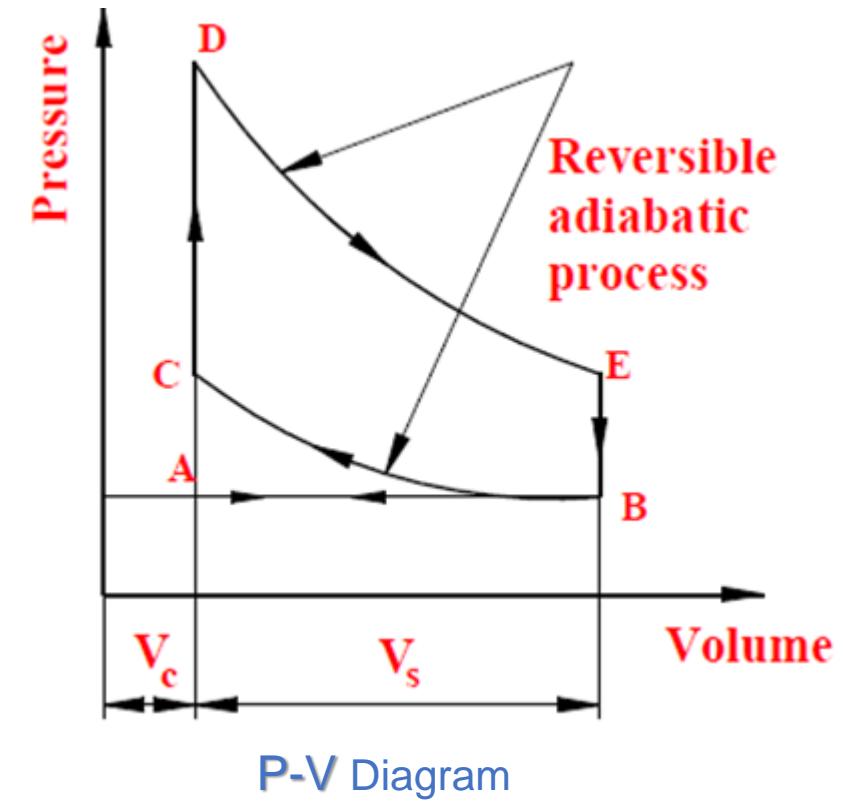
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Working Principle of 4-S Direct Injection Engine >>

Four Stroke cycle >> Petrol Engine
>> Diesel Engine

Four Stroke cycle >> Petrol Engine

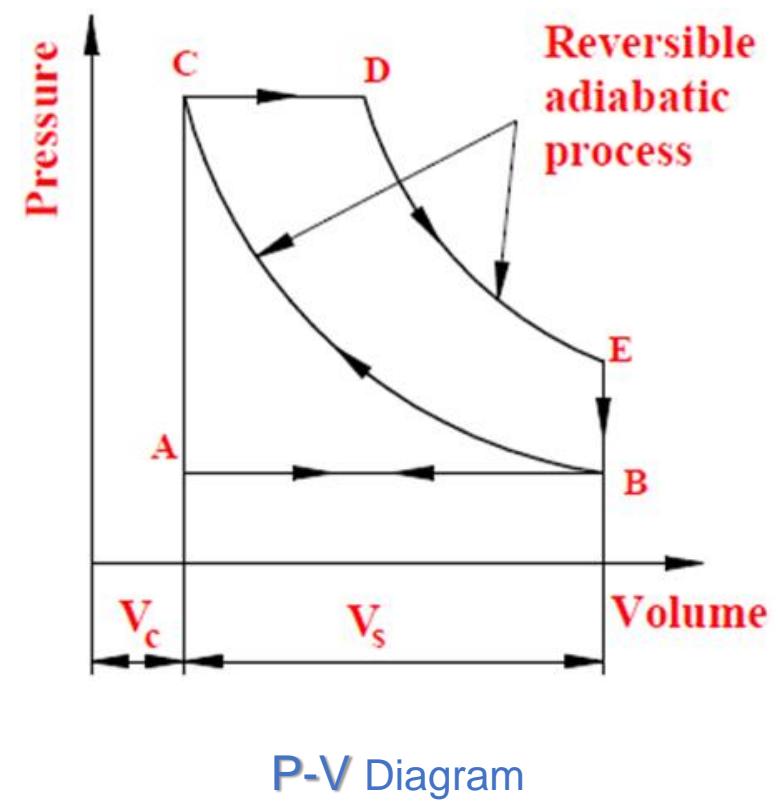
➤ Otto Cycle



Petrol Engine

Four Stroke cycle >> Diesel Engine

➤ Diesel Cycle



Diesel Engine



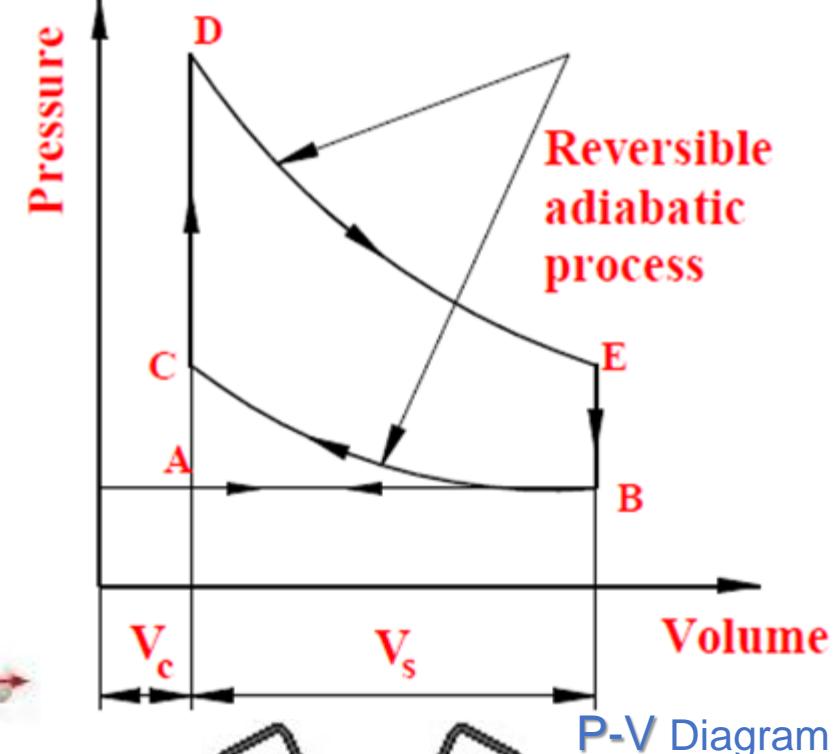
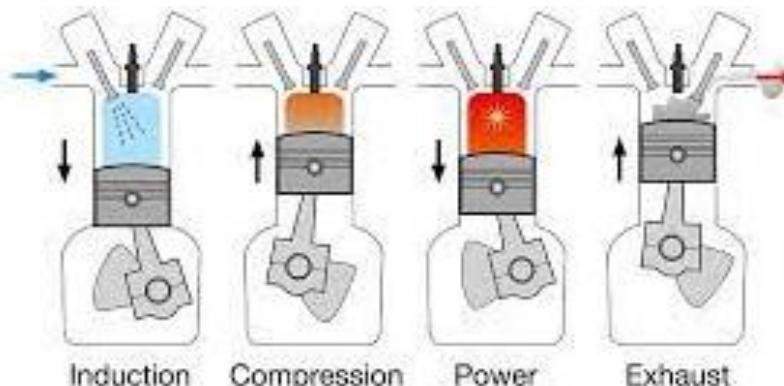
By V.Ryan

Working Principle of 4-S Direct Injection Engine >>

Four Stroke cycle >> Petrol Engine

Petrol engines work on the principle of theoretical Otto cycle.

- It is also known as Constant Volume Cycle, shown in figure
- The piston performs four strokes (one each in half revolution of crankshaft) to complete the working cycle (in 2 revolutions of crank or crank shaft)
- The four strokes are:
 - i) Suction
 - ii) Compression
 - iii) Working (or) Power stroke
 - iv) Exhaust stroke



Note:

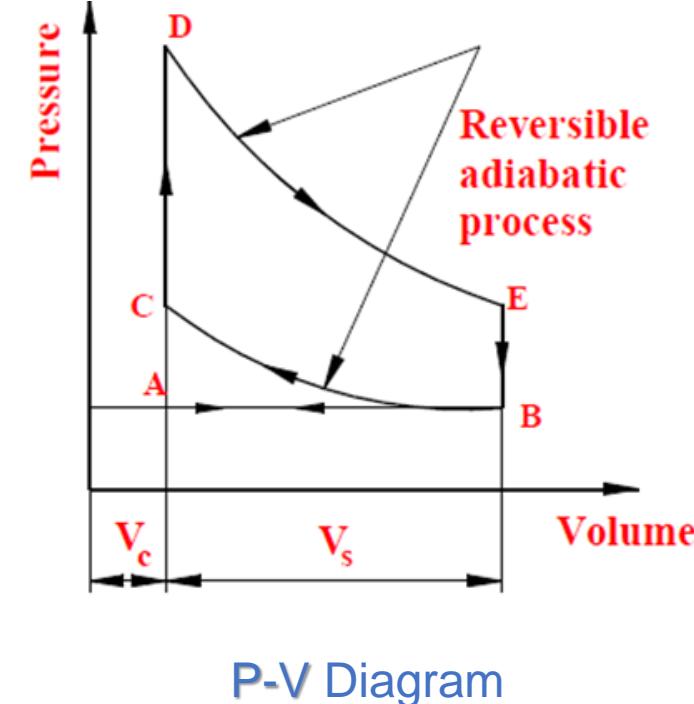
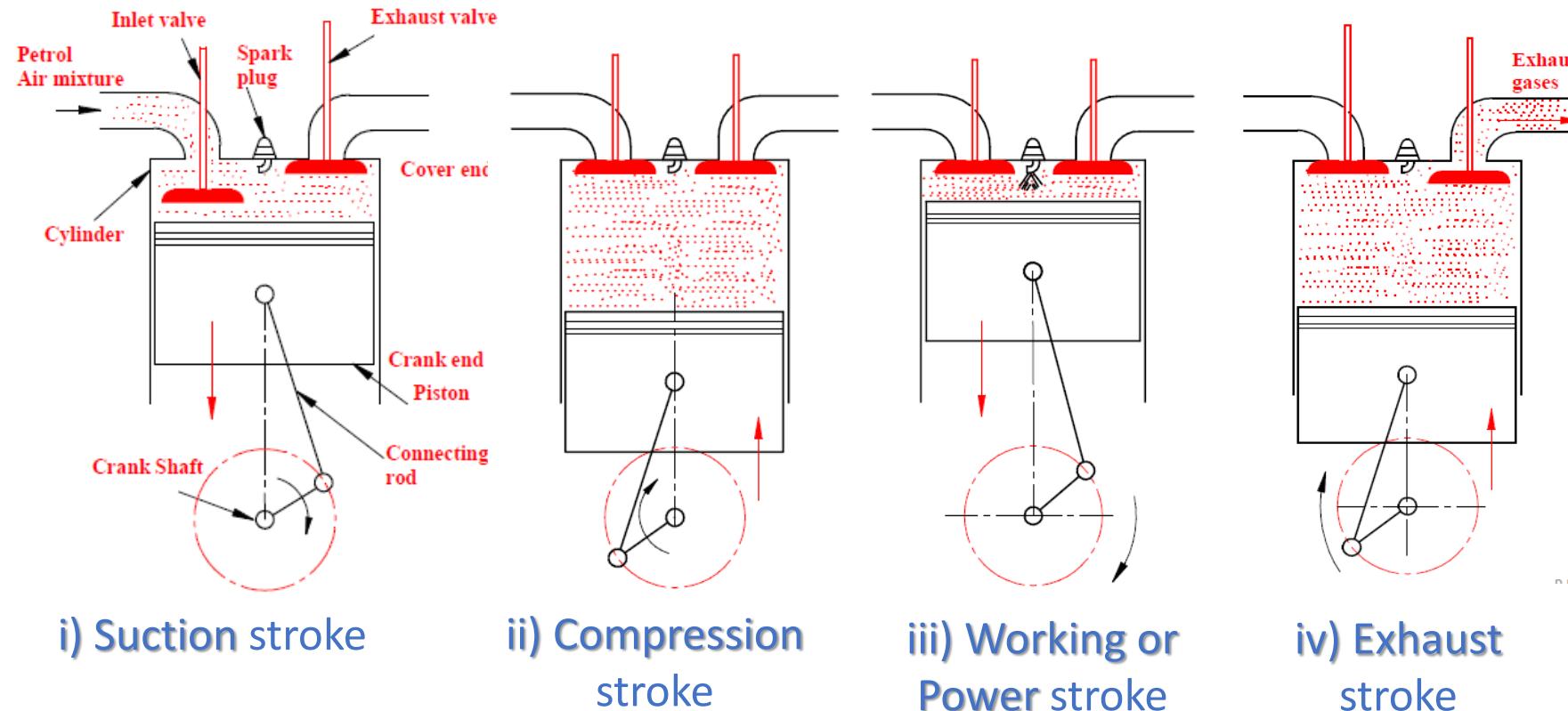
An **adiabatic process** is a thermodynamic change whereby no heat is exchanged between a system and its surroundings ($q = 0$)

The **reversible adiabatic process** is also called [an Isentropic Process](#).

It is an idealized thermodynamic process that is adiabatic and in which the work transfers of the system are frictionless; there is **no transfer of heat or of matter**, and the process is reversible.

Working Principle of 4-S Direct Injection Engine >>

Four Stroke cycle: Petrol Engine >>

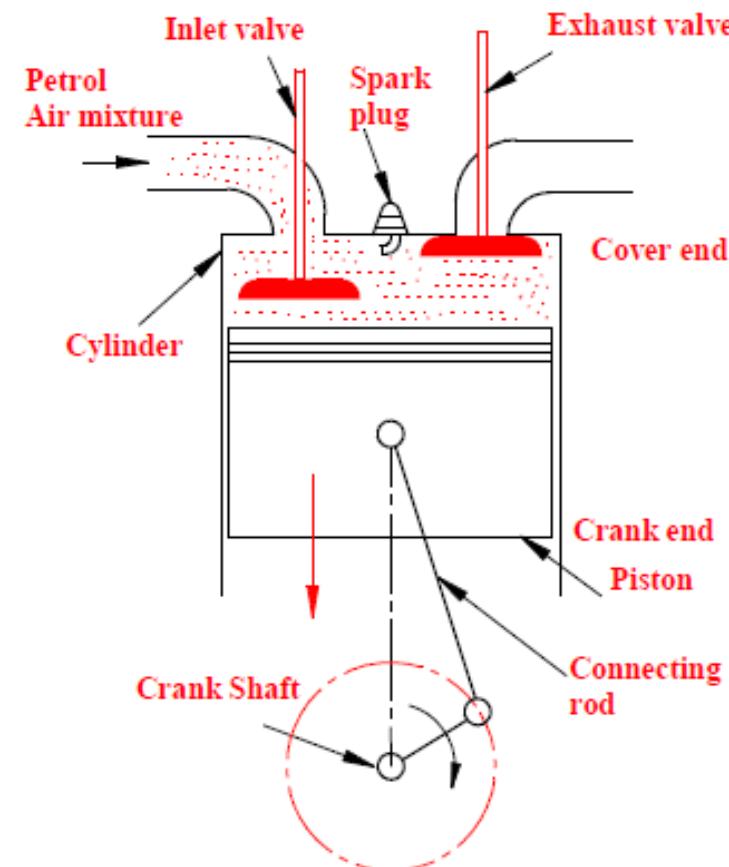


Working Principle of 4-S Direct Injection Engine >>

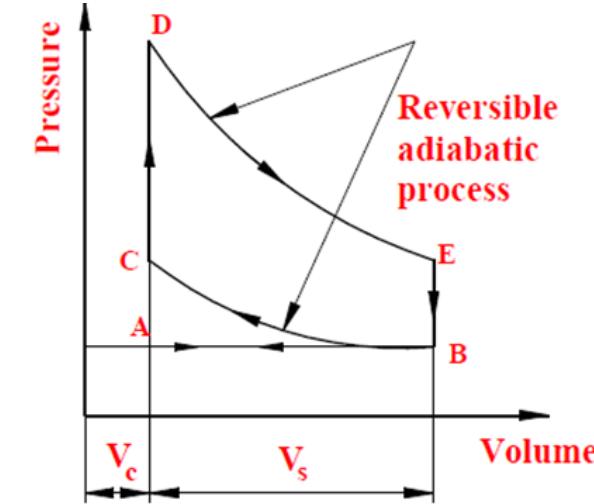
Four Stroke cycle: Petrol Engine >>

i) Suction stroke:

- During suction stroke, the inlet valve is open and exhaust valve is closed.
- The piston moves from cover end to crank end during half revolution of crankshaft.
- The air-petrol mixture is drawn into the cylinder and completely fills the cylinder.
- Suction takes place at atmospheric pressure and is indicated by horizontal line AB in the P-V diagram.
- The process is initiated by 'cranking' using external energy source.



Diesel Engine
- Suction Stroke



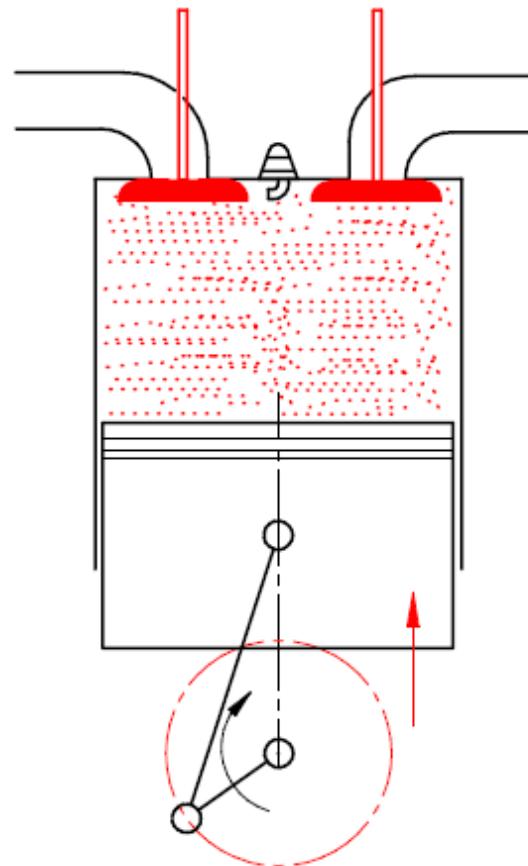
P-V Diagram

Working Principle of 4-S Direct Injection Engine >>

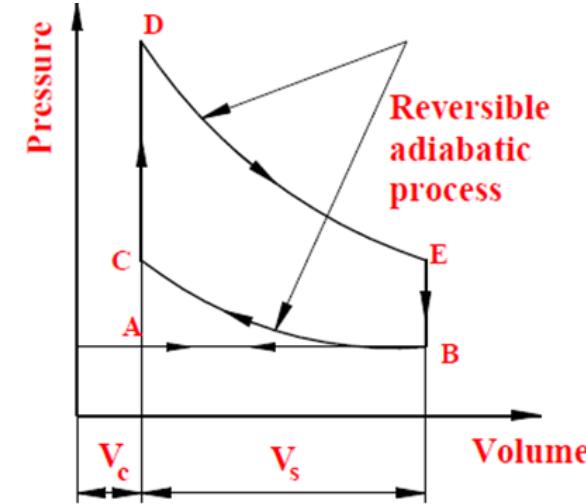
Four Stroke cycle: Petrol Engine >>

ii) Compression stroke:

- During this stroke, both inlet & exhaust valves are closed.
- The piston moves from crank end to cover end during half revolution of crankshaft.
- The air fuel mixture in the cylinder will be compressed adiabatically as shown by **curve BC in the P-V diagram**.
- At the end of compression stroke, the air-petrol mixture is ignited by an **electric spark** given out by the spark plug.
- The combustion of the mixture causes increase in pressure as shown by **line CD in P-V diagram**.



Diesel Engine
- Compression Stroke



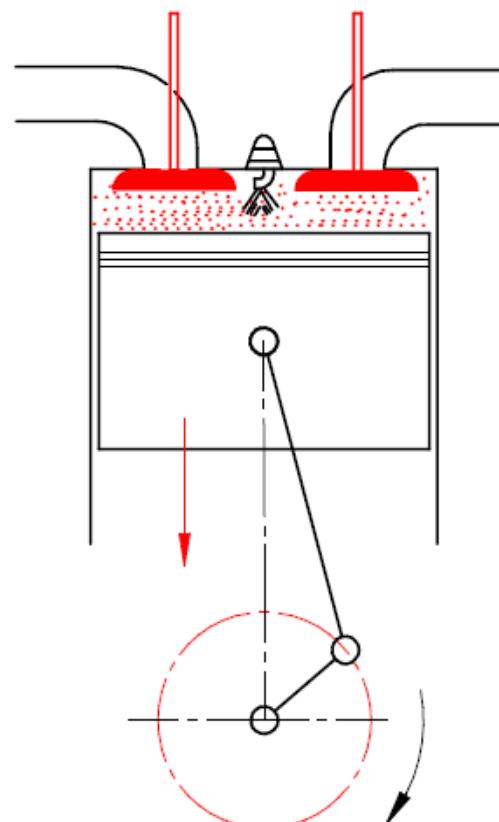
P-V Diagram

Working Principle of 4-S Direct Injection Engine >>

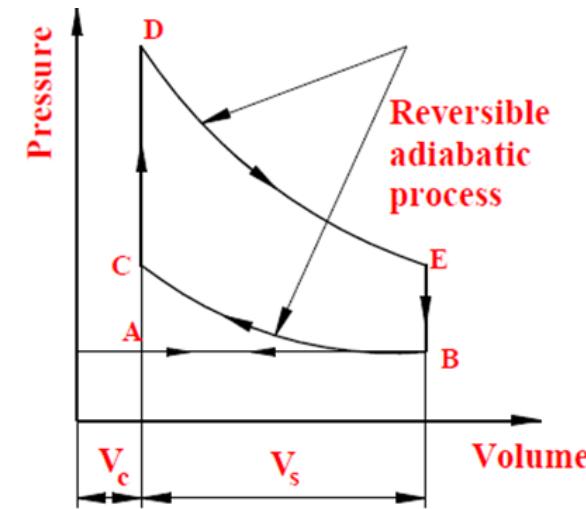
Four Stroke cycle: Petrol Engine >>

iii) Working or Power stroke:

- During this stroke, both inlet & exhaust valves are closed.
- The expansion of gases due to heat of combustion exerts a pressure on the piston **forcing it to move towards** the crank end.
- The expansion of gases is indicated by adiabatic process **DE** in the P-V diagram.
- At the end of this stroke, the exhaust valve will open release the burnt gases to the atmosphere thus bringing down the pressure as indicated by vertical line **EB** in the P-V diagram



Diesel Engine
- Working or Power Stroke



P-V Diagram

Working Principle of 4-S Direct Injection Engine >>

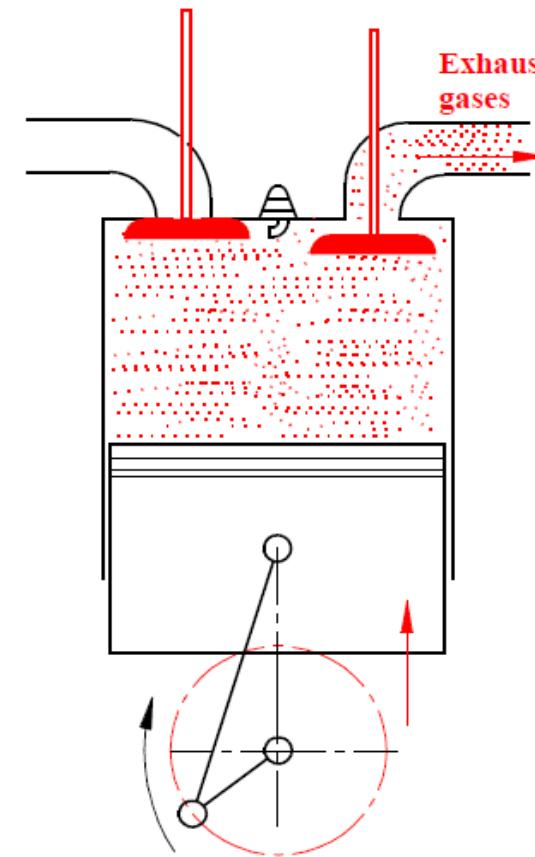
Four Stroke cycle: Petrol Engine >>

iv) Exhaust stroke:

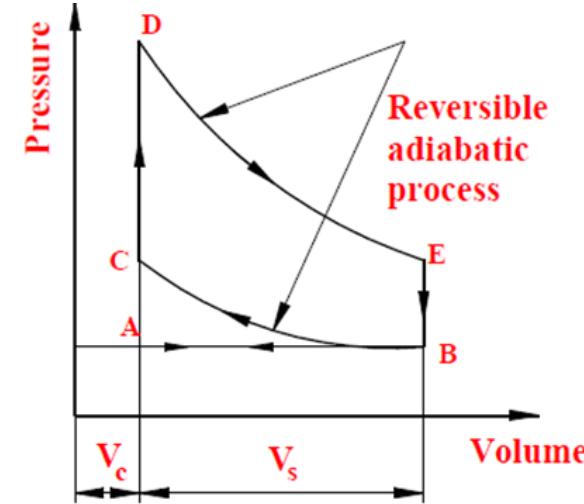
- During this stroke, the **inlet valve** remains closed & the **exhaust valve** remains open
- The piston moves from **crank end** to **cover end** forcing **exhaust gases** out of the cylinder.
- The process is indicated by the **horizontal line BA** in the P-V diagram
- This **completes the cycle**.

- Thus the **cycle is completed in four strokes** of the piston or **two revolutions** of the crankshaft.

- Thereafter, the entire process **repeats itself**.



Diesel Engine
- Exhaust Stroke



P-V Diagram

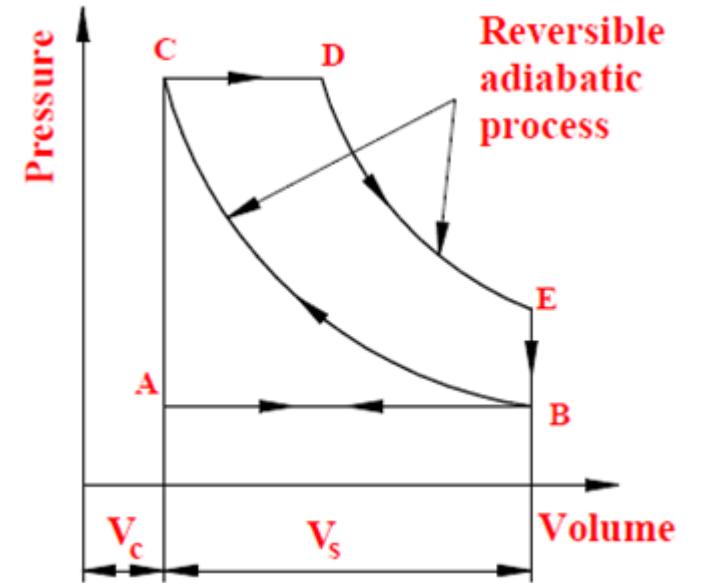
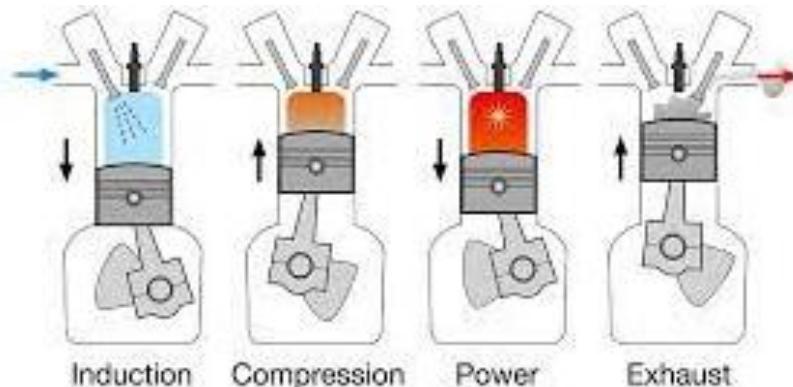
Working Principle of 4-S Direct Injection Engine >>

Four Stroke cycle >> Diesel Engine

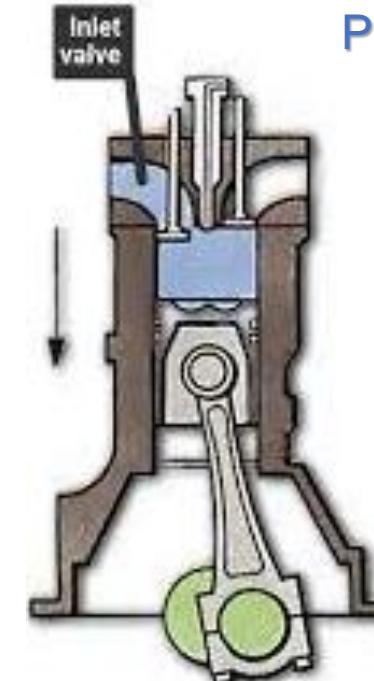
The diesel engine, named after **Rudolf Diesel**, is an internal combustion engine in which ignition of the fuel is caused by the elevated temperature of the air in the cylinder due to mechanical compression, thus, the diesel engine is called **A Compression-Ignition Engine**.

Diesel engines work on the principle of **Diesel cycle**.

- It is also known as Constant Pressure Cycle, shown in figure
- Here also, the **piston performs four strokes** (one each in half revolution of crankshaft) to complete the working cycle (**in 2 revolutions of crank or crank shaft**)
- The **four strokes** are:
 - i) Suction
 - ii) Compression
 - iii) Working (or) Power stroke
 - iv) Exhaust stroke



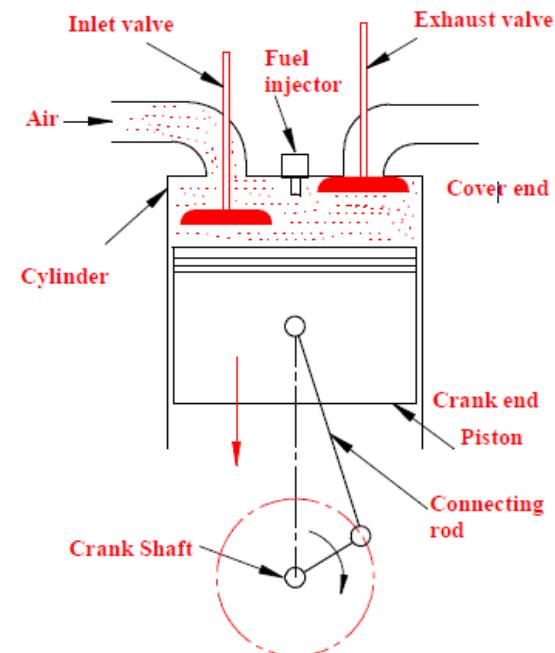
P-V Diagram



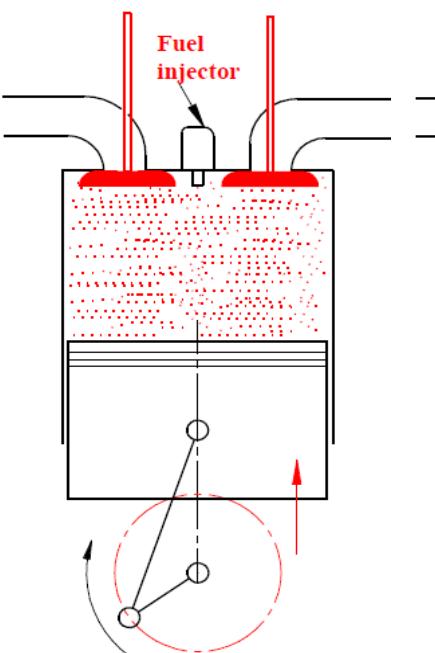
Diesel Engine

Working Principle of 4-S Direct Injection Engine >>

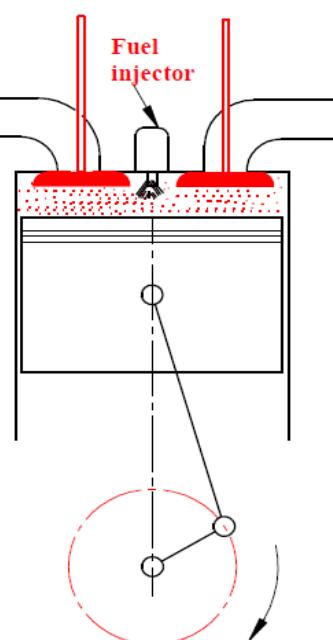
Four Stroke cycle >> Diesel Engine



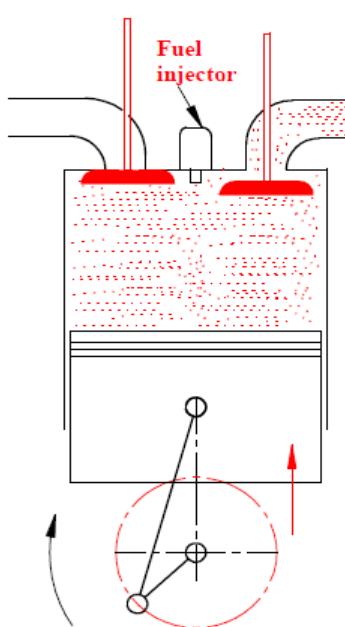
i) Suction
stroke



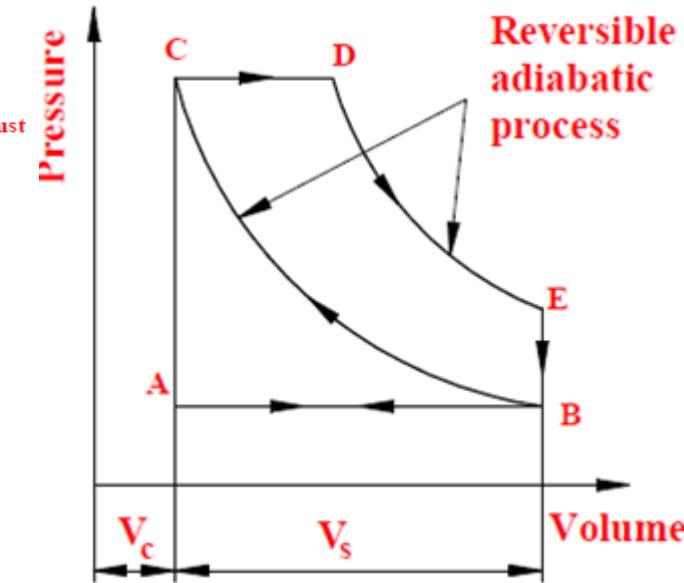
ii) Compression
stroke



iii) Working or
Power stroke



iv) Expansion
stroke



P-V Diagram

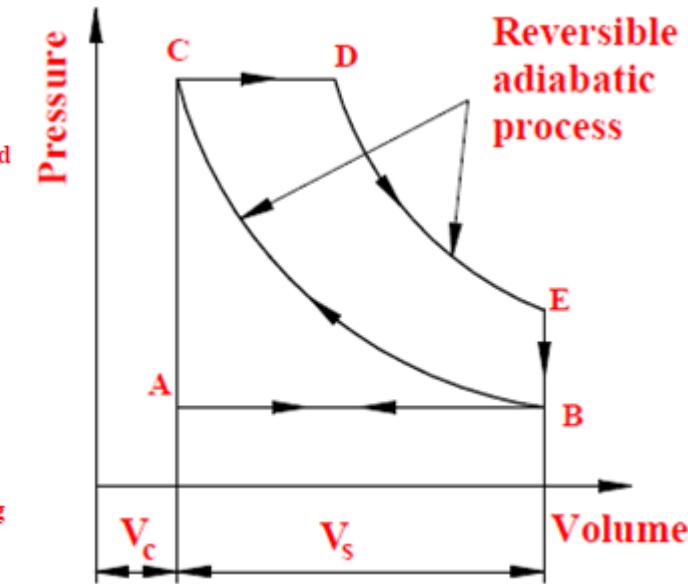
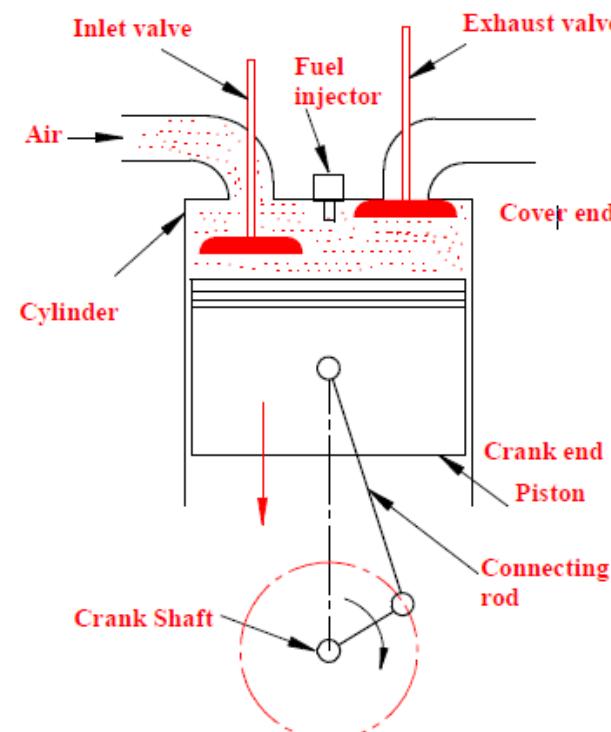
Working Principle of 4-S Direct Injection Engine >>

Four Stroke cycle >> Diesel Engine

i) Suction stroke:

During suction stroke, the inlet valve is open and exhaust valve is closed.

- The piston moves from cover end to crank end during half revolution of crankshaft, and draws **only air** into the cylinder.
- The energy required for this stroke is obtained by 'cranking' only at the time of starting & by the flywheel while running.
- Suction takes place at atmospheric pressure and is indicated by horizontal line AB in the p-v diagram.

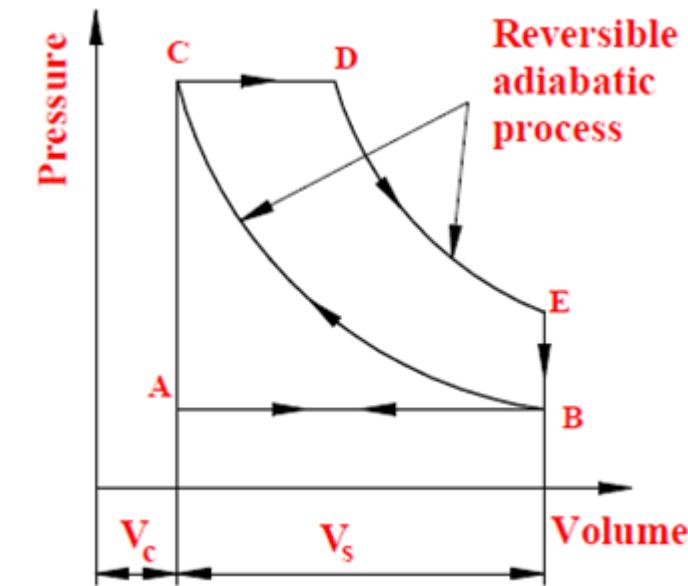
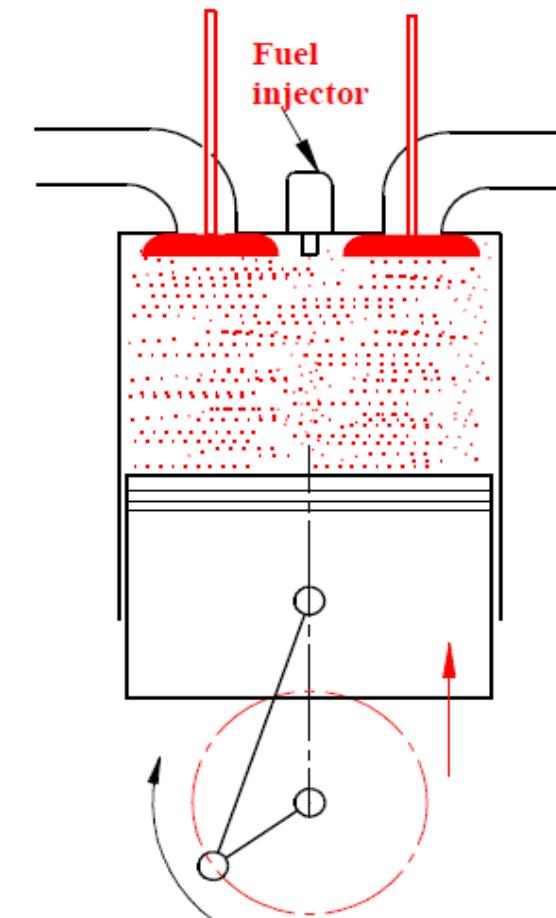


Working Principle of 4-S Direct Injection Engine >>

Four Stroke cycle >> Diesel Engine

ii) Compression stroke:

- During this stroke, both inlet & exhaust valves are closed. The piston moves from crank end to cover end during half revolution of crankshaft.
- The air in the cylinder will be compressed adiabatically as shown by curve BC in the p-v diagram.
- At the end of compression stroke, diesel is injected into the hot compressed air as a fine spray by the fuel injector.
- The fuel will be burnt at constant pressure as shown by line CD.

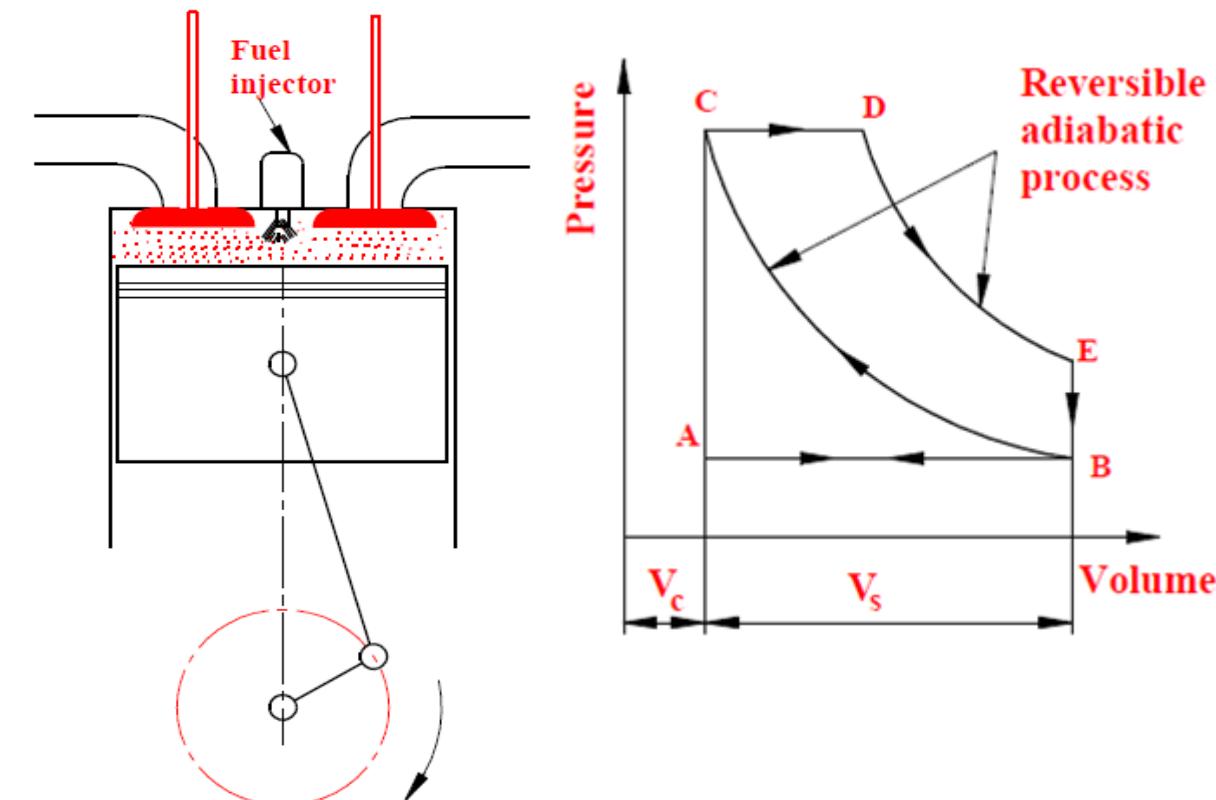


Working Principle of 4-S Direct Injection Engine >>

Four Stroke cycle >> Diesel Engine

iii) Working or Power stroke:

- During this stroke, both inlet & exhaust valves are closed.
- The expansion of gases due to heat of combustion exerts a pressure on the piston forcing it to move towards the crank end.
- The expansion of gases is indicated by adiabatic process DE in the P-V diagram.
- At the end of this stroke, the exhaust valve will open release the burnt gases to the atmosphere thus bringing down the pressure as indicated by vertical line EB in the P-V diagram



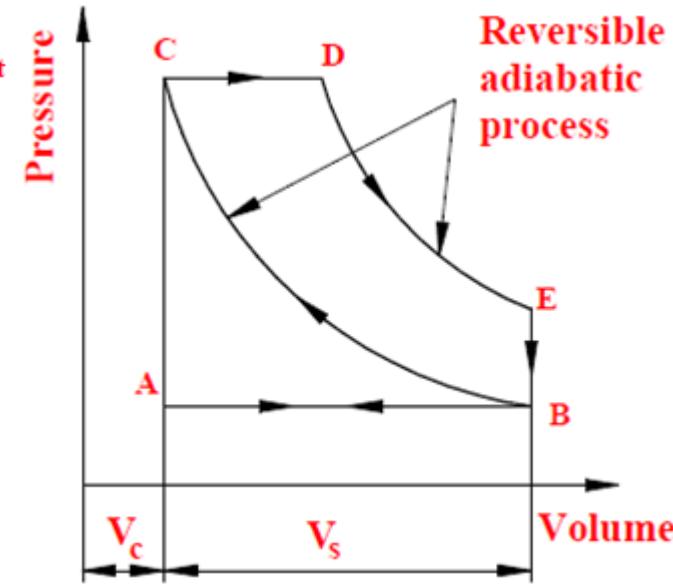
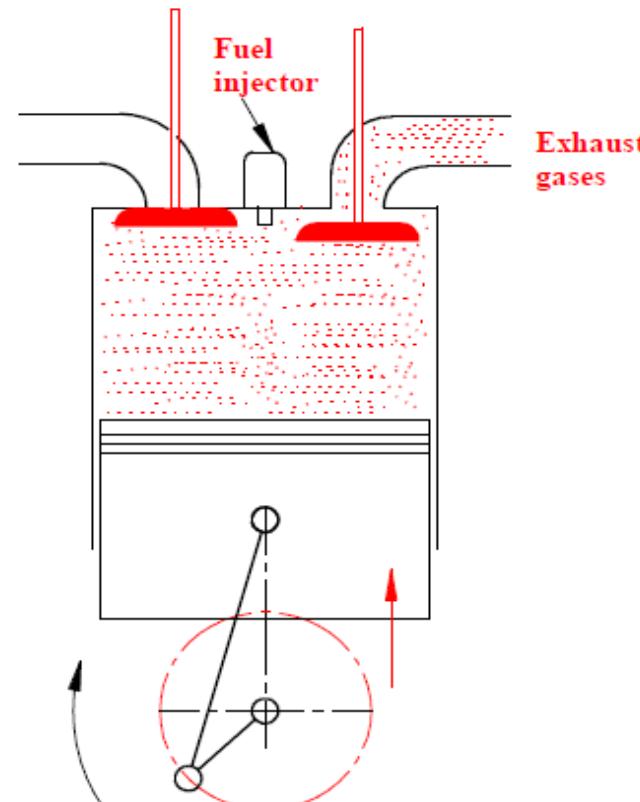
Working Principle of 4-S Direct Injection Engine >>

Four Stroke cycle >> Diesel Engine

iv) Expansion stroke:

During this stroke, the inlet valve remains closed & the exhaust valve remains open.

- The piston moves from crank end to cover end forcing exhaust gases out of the cylinder.
- The process is indicated by the horizontal line BA in the P-V diagram, thus completing the cycle.
- Thus the cycle is completed in four strokes of the piston or two revolutions of the crankshaft.
- Thereafter, the entire process repeats itself.



Fundamentals of Mechanical Engineering

MECHANICAL DRIVES

Assignment – Unit 4a - 02

<<for Practice>>

- 1) Brief about: i) Petrol Engines and ii) Diesel Engines
- 2) State the different strokes of and IC Engine.
- 3) Compare the PV diagrams of petrol engine and diesel engine.
- 4) Explain with the help of neat sketches and PV Diagram, the working of Petrol Engine (Engine works on Otto Cycle).
- 5) Describe with the help of neat sketches and PV Diagram, the working of Diesel Engine (Engine works on Diesel Cycle).

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Mechanical Drives>>

- Working of 4-S direct injection engines contd.....
- Performance Characteristics
- Classification of Gears
- Velocity Ratio of
 - Simple Gear Trains
 - Compound Gear Trains

| Unit -IV | 08 Hrs |
|---|--------|
| Mechanical Drives: Classification of IC Engines, Working of 4-S direct injection engines, Performance characteristics, Classification of gears, velocity ratio for simple and compound gear trains. | |
| Electrical Drives: History, Well to Wheel analysis, Electric vehicles, Configurations, EV/ICEV comparison, Performance, Traction Motor Characteristics, Concept of Hybrid Electric Drive Trains, Classification of hybrid electric vehicles. | |

Differences between Four Stroke Engine and Two Stroke Engine>>

| Four Stroke cycle Engine | Two Stroke cycle Engine |
|---|---|
| ➤ One working cycle for every two revolutions of the crank shaft. | ➤ One working stroke for each revolution of the crankshaft. |
| ➤ Requires heavy flywheel because of high torque fluctuations. | ➤ Requires light flywheel because of more or less uniform torque on crankshaft. |
| ➤ It has inlet & exhaust valves. | ➤ It has inlet, exhaust & transfer ports. |
| ➤ Less fuel consumption & high thermal efficiency. | ➤ More fuel consumption & lower thermal efficiency. |
| ➤ For a given power output, the engine is heavy & bulky. | ➤ For the same power output, the engine is light & compact. |
| ➤ Requires lesser cooling & lubrication. | ➤ Requires greater cooling & lubrication. |
| ➤ Less noise while running as the exhaust valves open gradually. | ➤ More noise due to sudden opening of exhaust port & release of gases. |
| ➤ Engine crankshaft can rotate only in one direction. | ➤ Engine crankshaft can rotate in either direction. |
| ➤ Mechanical efficiency is less because of more moving parts. | ➤ Mechanical efficiency is less because of less moving parts such as valves, cams. |
| ➤ Used in cars, buses, trucks, etc. | ➤ Used in motorcycles, scooters, etc. |

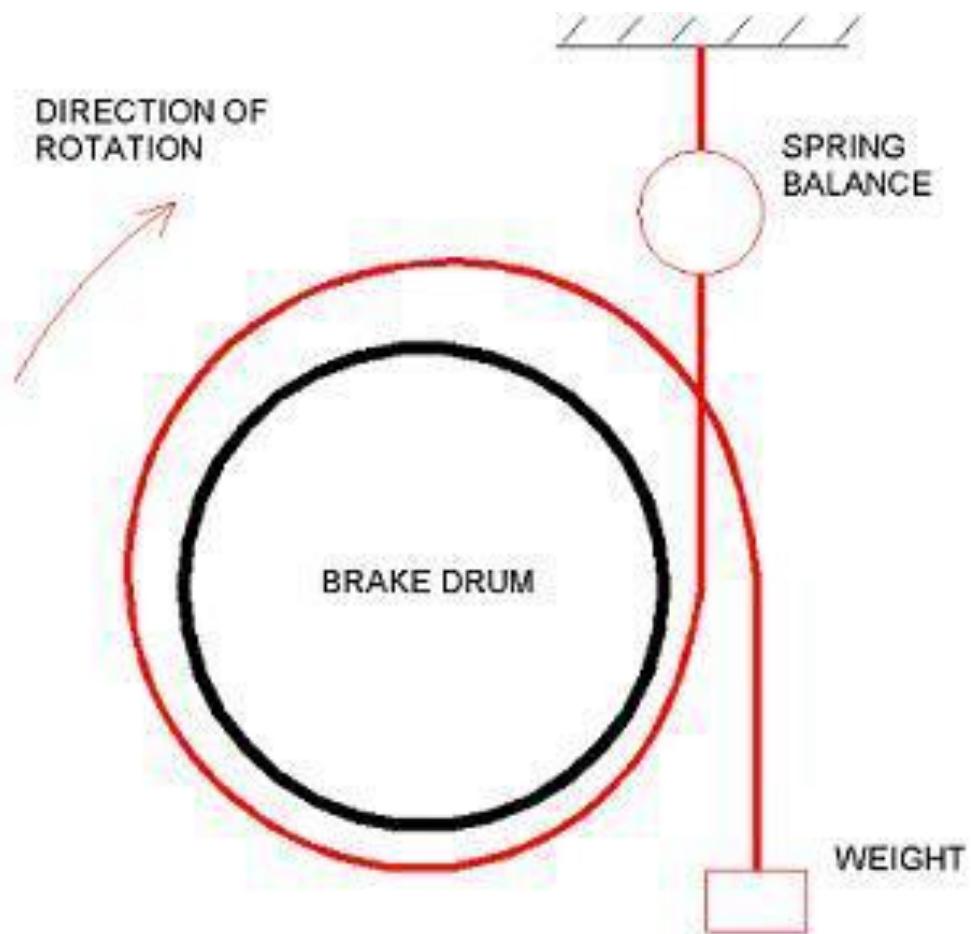
Differences between Petrol Engine and Diesel Engine>>

| Petrol Engine | Diesel Engine |
|---|---|
| ➤ It works on Otto cycle | ➤ It works on diesel cycle |
| ➤ Air & petrol are mixed in the carburettor before they enter into the cylinder | ➤ Air only enters the cylinder & diesel is sprayed into the hot air |
| ➤ Cylinder is fitted with a spark plug. | ➤ Cylinder is fitted with a fuel injector. |
| ➤ Less thermal efficiency and more fuel consumption. | ➤ More thermal efficiency and less fuel consumption. |
| ➤ Low compression ratio ranging from 7:1 to 12:1 | ➤ High compression ratio ranging from 16:1 to 20:1 |
| ➤ Less initial cost & more running cost. | ➤ More initial cost & less running cost. |
| ➤ Light weight & occupies less space. | ➤ Heavy & occupies more space. |
| ➤ Easy to start even in cold weather. | ➤ Difficult to start even in weather |
| ➤ Quantitative governing is used | ➤ Qualitative governing is used. |
| ➤ High engine speeds about 3000 rpm | ➤ Low engine speeds about 1500 rpm. |
| ➤ Used in light vehicles like cars, motor cycles, Scooters, etc. | ➤ Used in heavy duty vehicles like trucks, buses, locomotives, etc. |

Performance Characteristics>>

IC Engine Calculation>>

- Indicated Power (IP)
- Brake Power (BP)
- Efficiencies:
 - ✓ Mechanical Efficiency
 - ✓ Thermal Efficiency
 - Indicated Thermal Efficiency
 - Brake Thermal Efficiency



INDICATED POWER (IP) :

It is the power produced inside the cylinder and calculated by finding the actual mean effective pressure.

$$\text{IP} = 100P_m L A n / 60 \text{ KW}$$

Where: P_m Mean effective Pressure in bar

L= Stroke Length in meters

A= Cross section area of cylinder bore in m : $A = \pi d^2 / 4$

Where : d= bore diameter in meters

n=Number of cycles per min; n=N (For 2 stroke engine)

BRAKE POWER (BP):

It is the net power available calculated at the crank shaft is called Brake Power.

$$\text{BP} = 2\pi N T / 60 \text{ KW}$$

Where, N= Rpm of crank shaft

T= Engine torque (in KN-m) =(W-S) R

W= Load on brake drum

S=Spring balance reading

R=Radius of the brake drum Also,

$$\text{FP} = (\text{IP} - \text{BP}) \text{ KW}$$

Where, FP= Loss of power due to friction

EFFICIENCIES OF ENGINE :

(i) Mechanical Efficiency

$$\eta_{\text{mech}} = \frac{\text{BP}}{\text{IP}} * 100$$

(ii) Thermal Efficiency

a. Indicated thermal efficiency

$$\eta_{\text{indicated-thermal}} = \left(\frac{\text{IP}}{(\text{m}_f \times C_v)} \right) \times 100$$

Where: m_f = Mass of fuel burnt in Kg/Sec

C_v = Calorific value of the fuel in KJ/Kg

b. Brake thermal efficiency

$$\eta_{\text{Brake-thermal}} = \left(\frac{\text{BP}}{(\text{m}_f \times C_v)} \right) \times 100$$

Where: m_f = Mass of fuel burnt in Kg/Sec

C_v = Calorific value of the fuel in KJ/Kg

NOTE:

a. The mean effective pressure is given by

$$P_m = s a / l \text{ N/m}^2$$

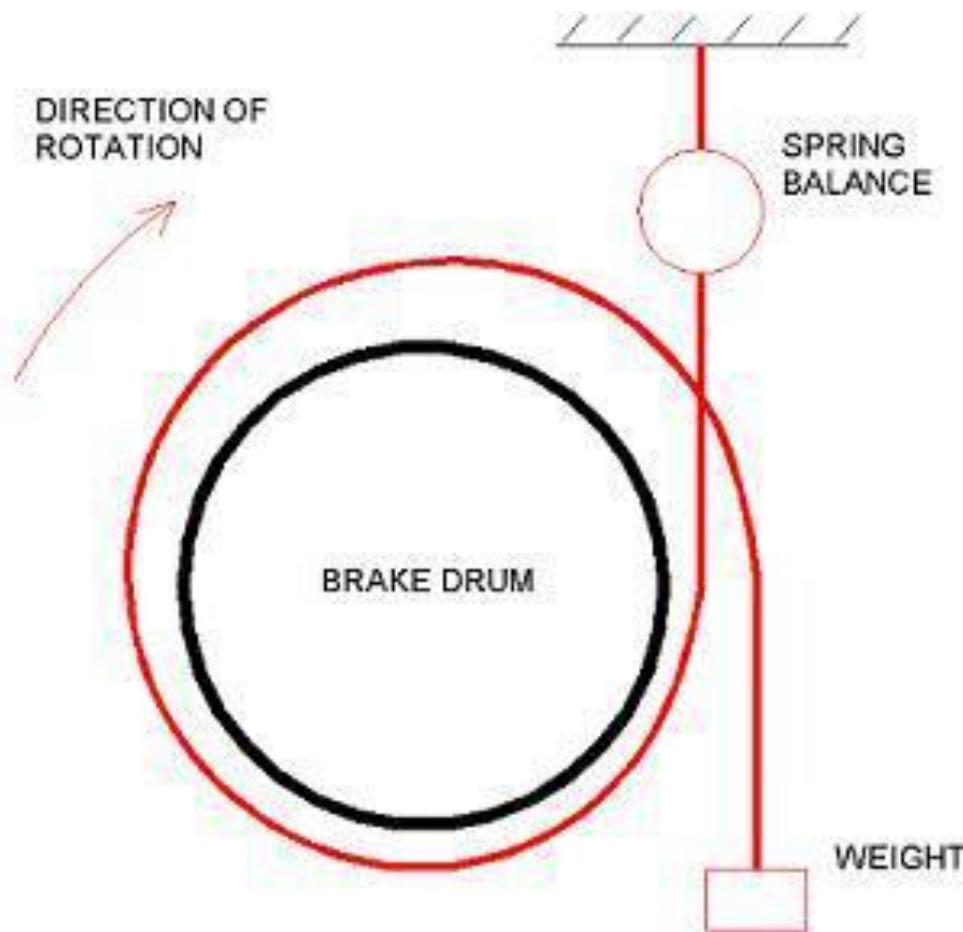
Where: a =Area of the indicator diagram, cm

l =Base width of indicator diagram, cm

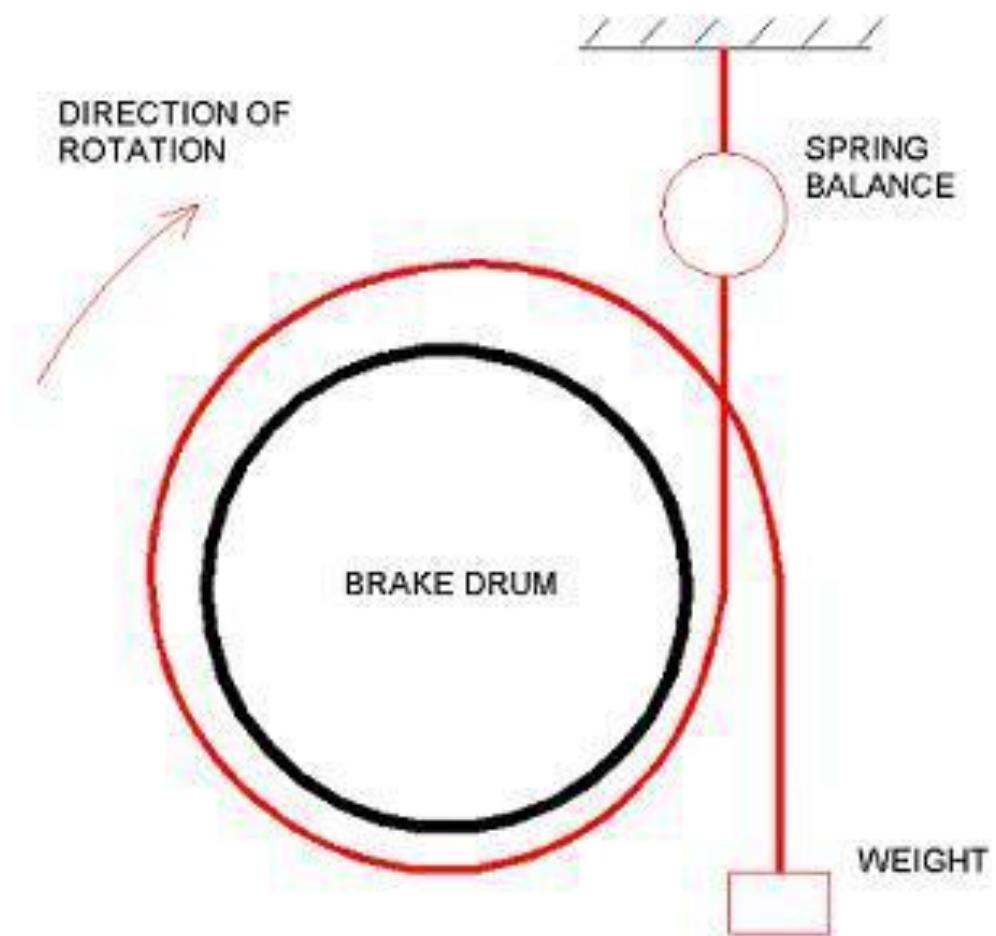
s = spring constant or spring value, $\text{N/m}^2/\text{cm}$

b. If a brake load is in Kg, Torque on brake drum

$$T = (9.81 \times W \times R) / 1000 \text{ KN-m}$$



Brake Dynamometer>>



Toothed Gearing>>

Gears are used to **transmit motion or power** from one shaft to another shaft if the center distance between the shafts is small.

It is a positive & smooth drive.

Classification of Gears>>

Gears are classified as follows:

i) According to relative position of shaft axes:

Parallel axes : Spur gear, helical gear

Intersecting axes : Bevel gears

Non parallel, Non intersecting: Worm gears

ii) According to peripheral velocity (v) of gears:

$V < 3 \text{ m/sec}$: Low velocity gears

$3 < V < 15 \text{ m/sec}$: Medium velocity gears

$V > 15 \text{ m/sec}$: High velocity gears

Toothed Gearing>>

iii) According to type of gearing:

External gearing:

Gears mesh externally , and hence rotate in opposite directions .

Internal gearing:

Gears mesh internally, and hence rotate in same directions.

iv) According to position of the teeth on gear surface:

Straight teeth : Spur gears

Inclined teeth : Helical gears

Skewed (curved) teeth: Spiral gear

Toothed Gearing>>



External Gearing > Spur gear



<Internal Gearing



Herringbone gear



Helical gear

Worm Shaft & worm gear

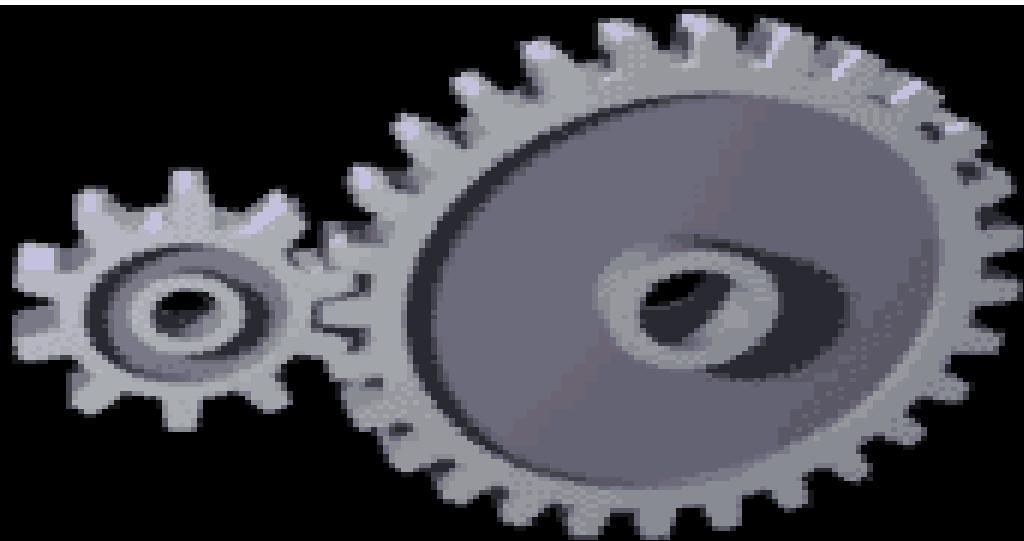


Straight teeth>

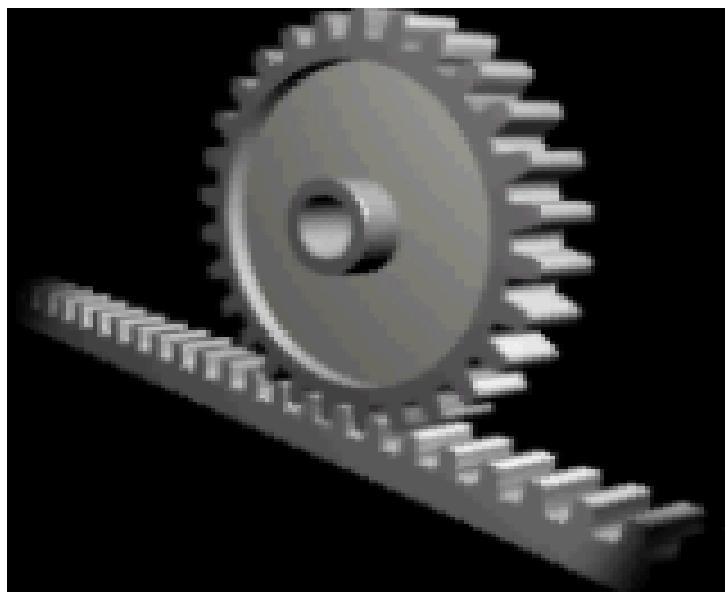


Bevel gears <Skewed or Spiral teeth

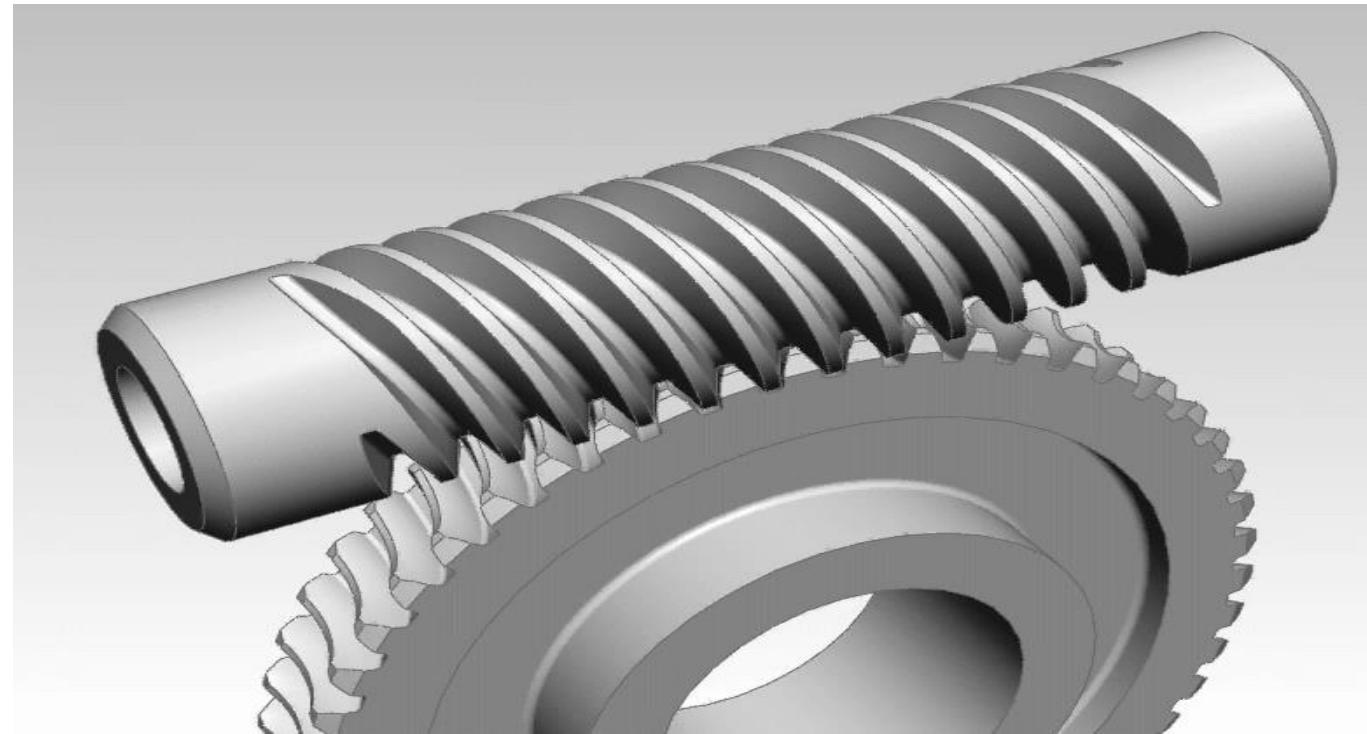
Toothed Gearing>> Animation



Spur Gear



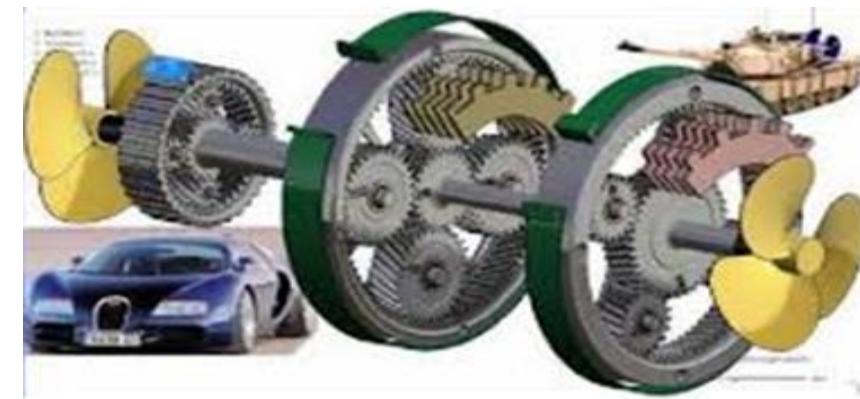
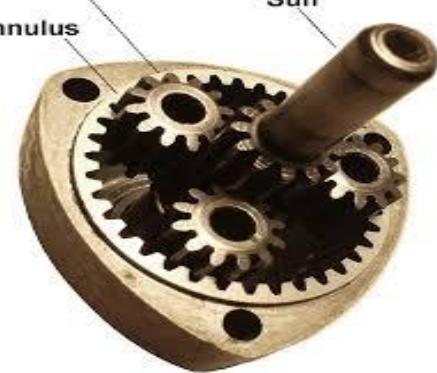
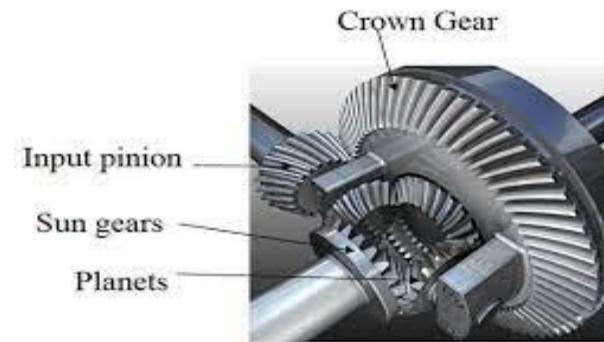
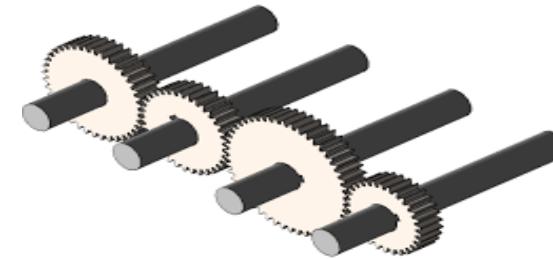
Rack & pinion



Worm Shaft & worm gear

GEAR TRAINS >>

A gear train is an arrangement of two or more successively meshing gears through which power can be transmitted between the driving & driven shafts.



Gear Trains>>

A gear train is an arrangement of two or more successively meshing gears through which power can be transmitted between the driving & driven shafts.

Train Value:

Train value is the ratio of speed of the driven gear to that of the driving gear. It is the reciprocal of the velocity ratio.

Direction of rotation:

When gears mesh externally they rotate in the opposite direction and when they mesh internally, they rotate in the same direction.

Velocity ratio in Gear Drives :

$$\frac{n_1}{n_2} = \frac{d_2}{d_1} = \frac{z_2}{z_1}, \text{ where } n_1 = \text{Speed of driving pulley}, n_2 = \text{Speed of driven pulley}$$

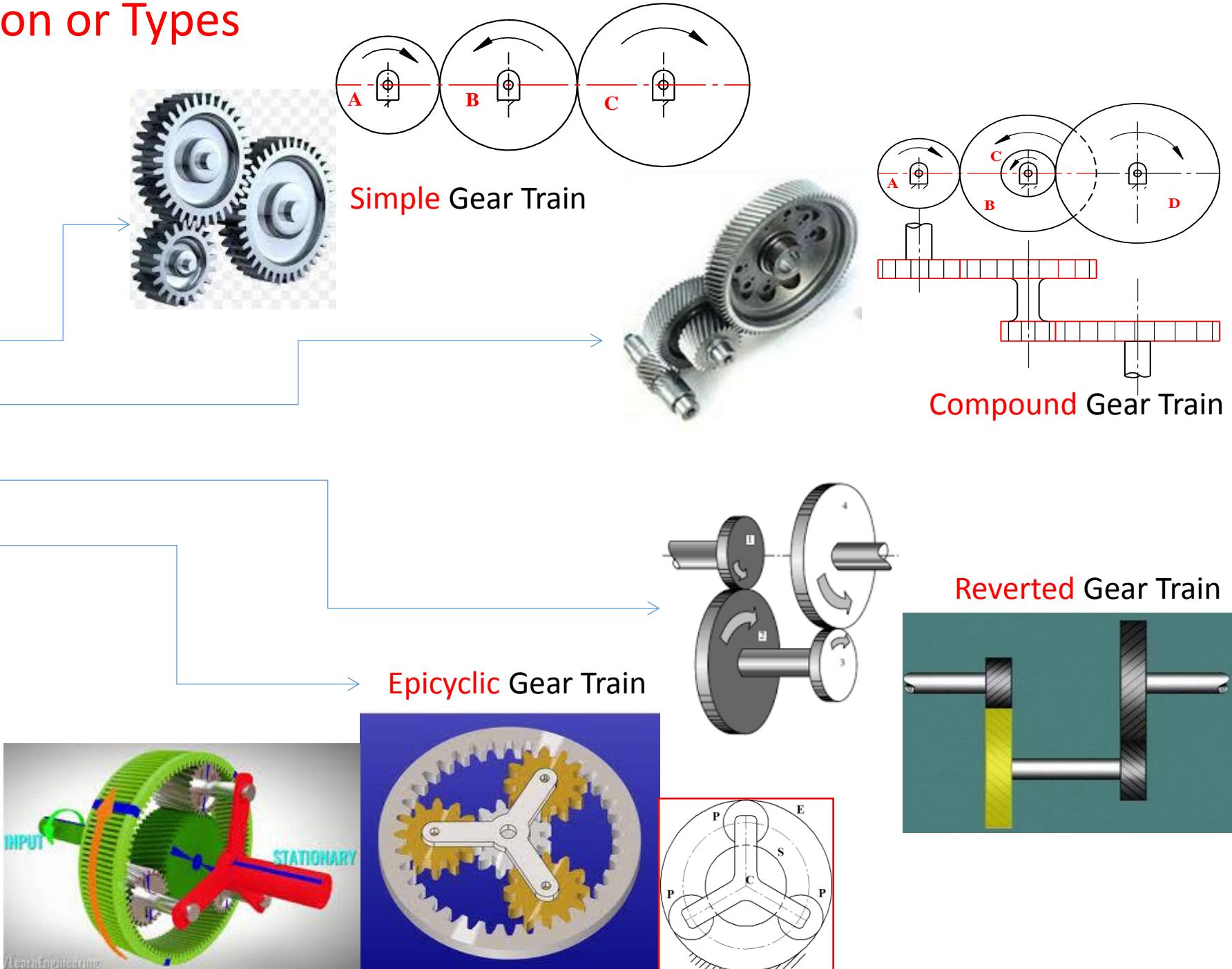
d_1 = Pitch circle diameter (PCD) of driver gear, d_2 = PCD of driven gear

z_1 = No of teeth on driver gear, z_2 = No of teeth on driven gear

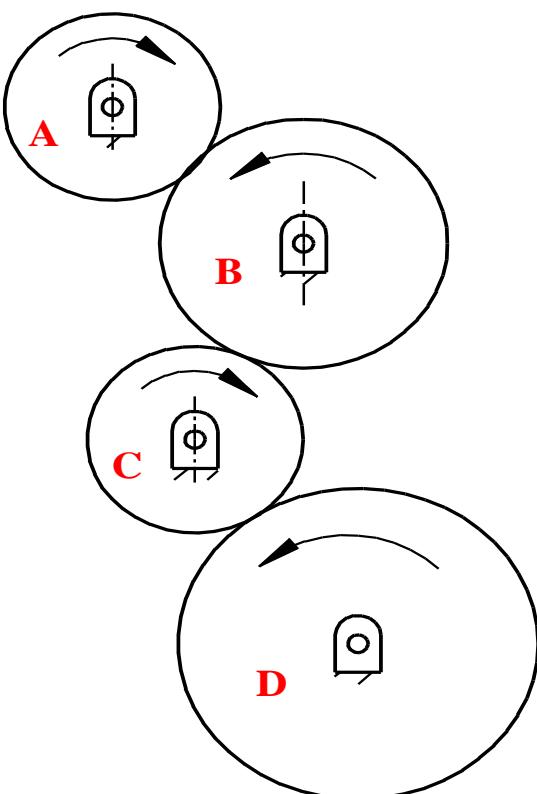
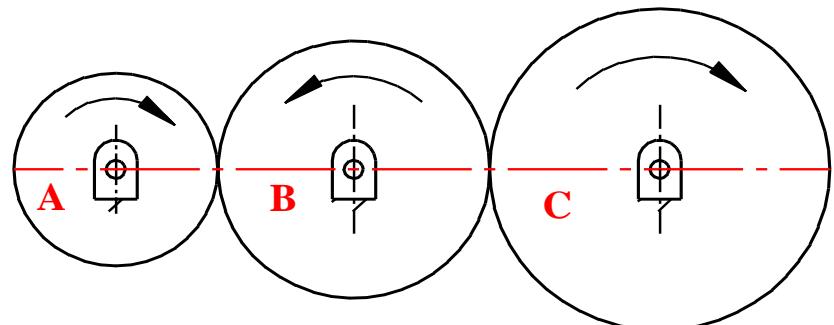
Gear Trains>> Classification or Types

A gear train may be broadly classified into the following.

- Simple Gear Train
- Compound Gear Train
- Reverted Gear Train
- Epicyclic Gear Train



Simple Gear Train:

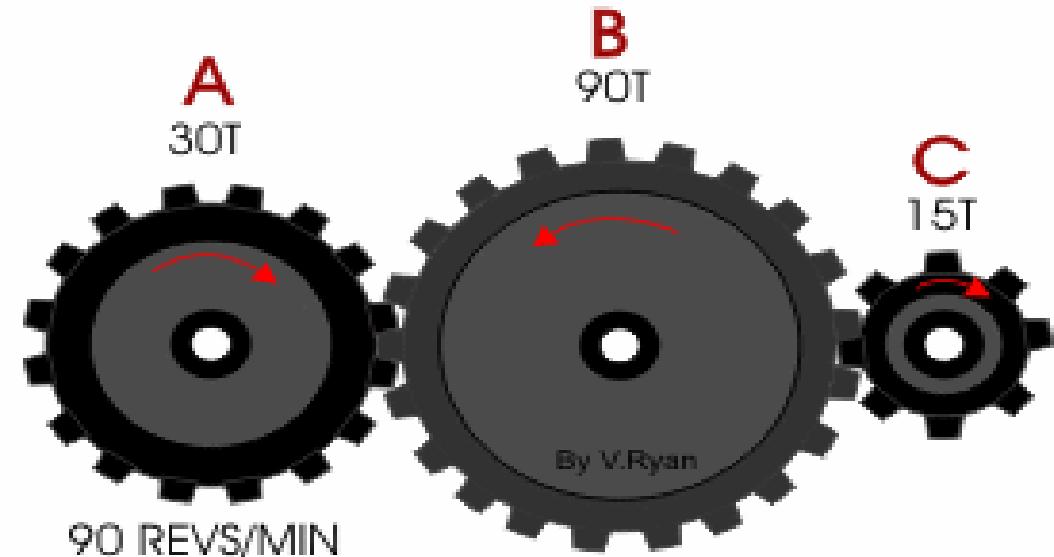
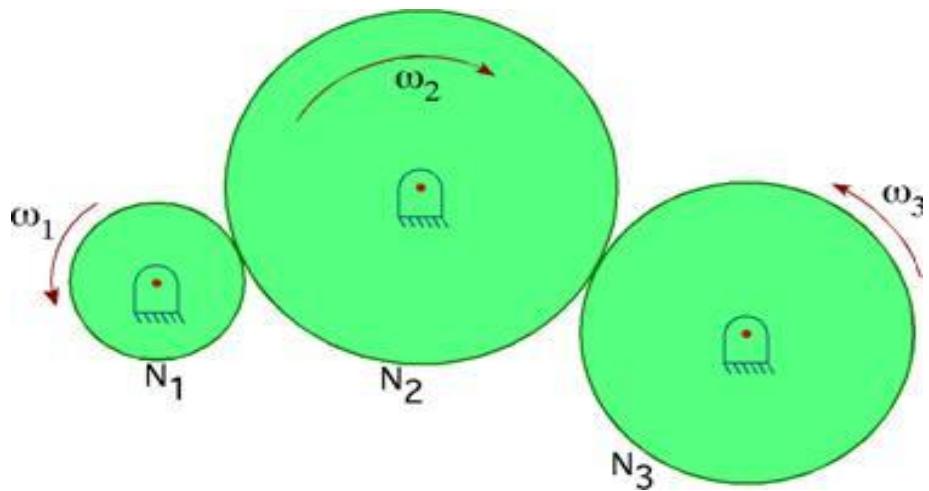


$$\text{Velocity ratio } \left(\frac{N_A}{N_C} \right) = \left(\frac{z_C}{z_A} \right)$$

$$\text{Velocity ratio } \left(\frac{N_A}{N_D} \right) = \left(\frac{z_D}{z_A} \right)$$

- A **simple gear train** is one in which **each shaft carries only one gear**.
- From the fig, gear A is the driving gear and gear D is the driven gear. B & C are the **intermediate gears** or **Idler gears**.
- The idler gears do not affect the velocity ratio but simply bridge the gap between the driver & the driven gears.
- Also if **odd** number of intermediate gears are used, the driver & the driven gears rotate in the **same direction**.
- If **even** number of intermediate gears are used, the driver & the driven gears rotate in the **opposite directions**.

Simple Gear Train:

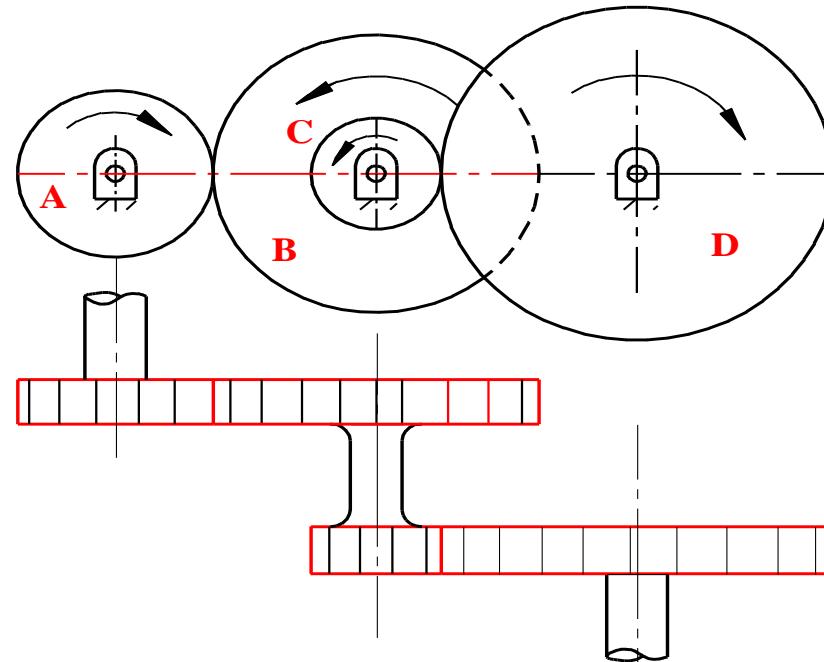


From the fig, $\left(\frac{N_A}{N_B}\right) = \left(\frac{z_B}{z_A}\right)$ and also $\left(\frac{N_B}{N_C}\right) = \left(\frac{z_C}{z_B}\right)$

$$\therefore \left(\frac{N_A}{N_B}\right) \times \left(\frac{N_B}{N_C}\right) = \left(\frac{z_B}{z_A}\right) \times \left(\frac{z_C}{z_B}\right) \Rightarrow \left(\frac{N_A}{N_C}\right) = \left(\frac{z_C}{z_A}\right)$$

The speed of gear C, $N_C = \left(\frac{z_A}{z_C}\right) \times N_A \Rightarrow N_C = \left(\frac{30}{15}\right) \times 90 = 180 \text{ rpm.}$

Compound Gear Train:



- In a **compound gear train** the **intermediate shaft carries two or more gears** which are keyed to it.
- Compound gears are used when a high velocity ratio is required in a limited space.
- The intermediate gears will have an effect on the overall velocity ratio.

$$\text{From the fig, } \left(\frac{N_A}{N_B} \right) = \left(\frac{z_B}{z_A} \right) \text{ and also } \left(\frac{N_C}{N_D} \right) = \left(\frac{z_D}{z_C} \right)$$

$$\therefore \left(\frac{N_A}{N_B} \right) \times \left(\frac{N_C}{N_D} \right) = \left(\frac{z_B}{z_A} \right) \times \left(\frac{z_D}{z_C} \right)$$

As gears B & C are on same shaft, $N_B = N_C$

$$\Rightarrow \left(\frac{N_A}{N_D} \right) = \left(\frac{z_B \times z_D}{z_A \times z_C} \right)$$

$$\text{i.e. } \frac{\text{Speed of first driver}}{\text{Speed of the last driven}} = \frac{\text{Product of no of teeth on driven gears}}{\text{Product of no of teeth on driving gears}}$$

Fundamentals of Mechanical Engineering

MECHANICAL DRIVES

Assignment – Unit 4a - 03

<<for Practice>>

- 1) Differentiate between 4S engines and 2S engines.
- 2) Compare petrol engine and diesel engine focusing on significant features.
- 3) State the engine performance characteristics
- 4) Define the following:
 - i) Indicated Power, ii) Brake Power, iii) Mechanical Efficiency,
 - iv) Indicated Thermal Efficiency and v) Brake Thermal Efficiency
- 5) What is a Brake Dynamometer? Explain with neat sketch.
- 6) Define the terms: i) Gears, ii) Gear Train, iii) Velocity ratio, iv) Train value and v) Idler gears
- 7) Classify the Gears and Gear trains.
- 8) Explain with neat sketches simple gear train and compound gear train. Indicate their velocity ratios.

Note:

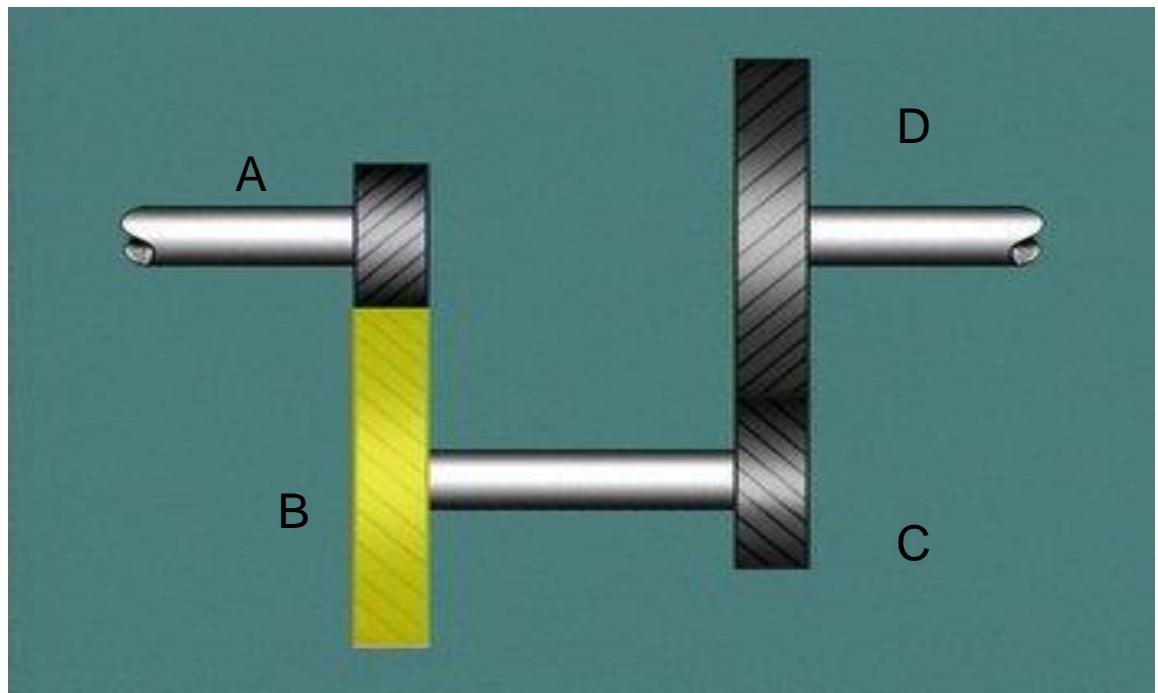
- i) Use new A4 size sheets, provide 1" left and top margin for each sheet.
- ii) Write Roll No., Name (at right top), Topic and Assignment No. (at top Middle) in the 1st sheet.
- iii) Use red pen to write the questions and blue or black pen for answer
- iv) Draw neat sketches using instruments (avoid free hand sketching)

Mechanical Drives>>

- Velocity Ratio of – Reverted Gear Trains (a special case of compound gear train)
- Simple Numerical Problems

| Unit -IV | 08 Hrs |
|--|--------|
| <p>Mechanical Drives: Classification of IC Engines, Working of 4-S direct injection engines, Performance characteristics, Classification of gears, velocity ratio for simple and compound gear trains.</p> <p>Electrical Drives: History, Well to Wheel analysis, Electric vehicles, Configurations, EV/ICEV comparison, Performance, Traction Motor Characteristics, Concept of Hybrid Electric Drive Trains, Classification of hybrid electric vehicles.</p> | |

Reverted Gear Train:



- A reverted gear train is a compound gear train in which the first & the last gears are on the same axis.
- Hence, in a reverted gear train, the center distances for the two gear pairs must be same.
- Reverted gear trains are used in automotive transmissions, lathe back gears, and in clocks.

$$\text{As } \left(\frac{d_A + d_B}{2} \right) = \left(\frac{d_C + d_D}{2} \right),$$

But $d = mz$, and the module 'm' is same for all gears,

$$\therefore z_A + z_B = z_C + z_D$$

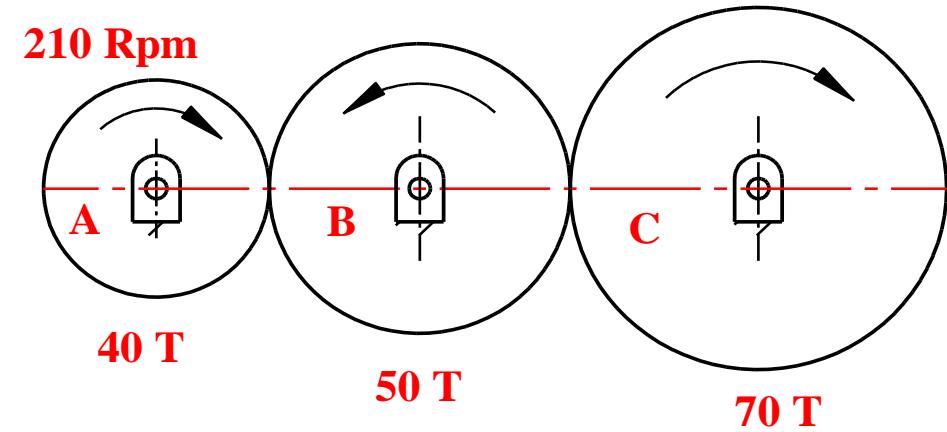
Epicyclic Gear Train:



- An epicyclic gear train is one in which the axis of one or more gears moves relative to the frame.
- Large speed reductions are obtained with an epicyclic train.
- They are compact in size and
- Used in automobile differential.

#1 A simple train of wheels consists of successively engaging three wheels having number of teeth 40, 50 & 70 respectively. Find its velocity ratio. If the driving wheel having 40 teeth runs at 210 rpm clockwise, find the speed of the driven wheel and its direction of rotation.

Solution:



$$\text{From the fig, } \left(\frac{N_B}{N_A} \right) = \left(\frac{z_A}{z_B} \right) \quad \text{and also } \left(\frac{N_C}{N_B} \right) = \left(\frac{z_B}{z_C} \right)$$

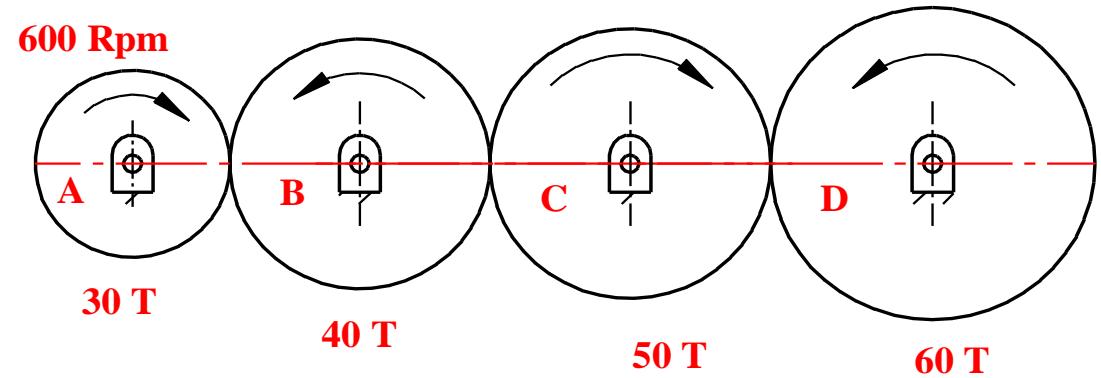
$$\therefore \left(\frac{N_B}{N_A} \right) \times \left(\frac{N_C}{N_B} \right) = \left(\frac{z_A}{z_B} \right) \times \left(\frac{z_B}{z_C} \right) \Rightarrow \left(\frac{N_C}{N_A} \right) = \left(\frac{z_A}{z_C} \right)$$

$$\text{The speed of gear C, } N_C = \left(\frac{z_A}{z_C} \right) \times N_A \Rightarrow N_C = \left(\frac{40}{70} \right) \times 210 = 120 \text{ rpm.}$$

As there are odd number of idler gears, the driven gear rotates at 120 rpm clockwise.
(i.e. same as that of driving gear)

#2 In a simple gear train consists of four wheels having number of teeth 30, 40, 50 & 60 teeth respectively. Determine the speed and the direction of rotation of the last gear if the first makes 600 rpm, clockwise.

Solution:



$$\text{From the fig, } \left(\frac{N_D}{N_A} \right) = \left(\frac{z_A}{z_B} \right) \times \left(\frac{z_B}{z_C} \right) \times \left(\frac{z_C}{z_D} \right)$$

$$\Rightarrow \left(\frac{N_D}{N_A} \right) = \left(\frac{z_A}{z_D} \right)$$

$$\text{The speed of gear D, } N_D = \left(\frac{z_A}{z_D} \right) \times N_A \Rightarrow N_D = \left(\frac{30}{60} \right) \times 600 = 300 \text{ rpm.}$$

As there are even number of idler gears, the driven gear rotates at 300 rpm counter clockwise.
(i.e. opposite to that of driving gear)

#3 A compound gear train consists of 4 gears, A, B, C & D and they have 20, 30, 40 & 60 teeth respectively. A is keyed to the driving shaft, and D is keyed to the driven shaft, B & C are compound gears. B meshes with A & C meshes with D. If A rotates at 180 rpm, find the rpm of D.

Solution:

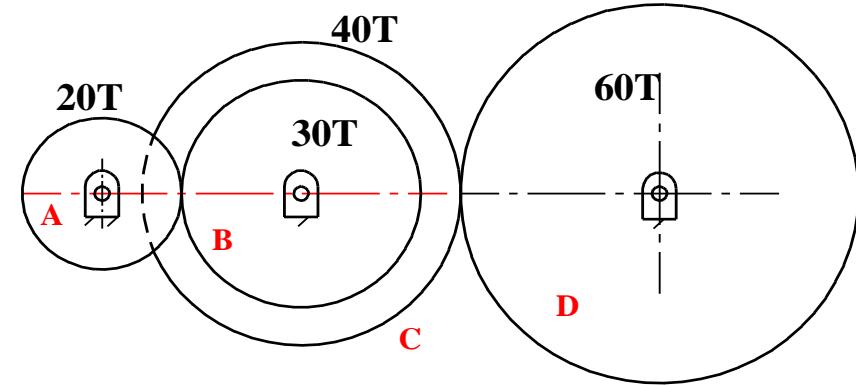
From the fig, $\left(\frac{N_B}{N_A}\right) = \left(\frac{z_A}{z_B}\right)$ and also $\left(\frac{N_D}{N_C}\right) = \left(\frac{z_C}{z_D}\right)$

$$\therefore \left(\frac{N_B}{N_A}\right) \times \left(\frac{N_D}{N_C}\right) = \left(\frac{z_A}{z_B}\right) \times \left(\frac{z_C}{z_D}\right)$$

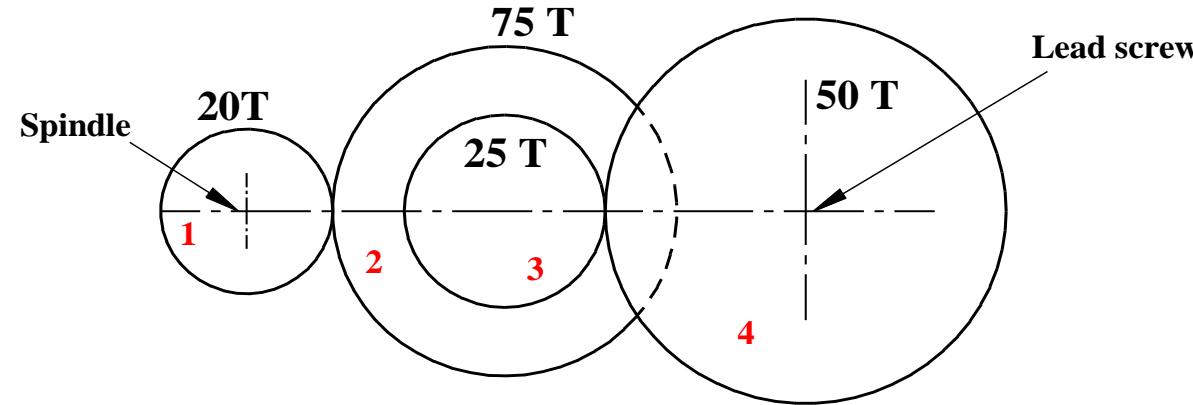
As gears B & C are on same shaft, $N_B = N_C$

$$\Rightarrow \left(\frac{N_D}{N_A}\right) = \left(\frac{z_A \times z_C}{z_B \times z_D}\right)$$

$$\therefore N_D = \left(\frac{20 \times 40}{30 \times 60}\right) \times 180 = 80 \text{ RPM}$$



#4 Figure shows a train of gears from the spindle of a lathe to the lead screw used for cutting a screw thread of a certain pitch. If the spindle speed is 150 rpm, what is the lead screw speed? Gears 2 & 3 form a compound gear.



Solution:

From the fig, velocity ratio

$$\left(\frac{\text{Speed of the driven shaft}}{\text{Speed of the driving shaft}} \right) = \left(\frac{\text{Product of the no of teeth on driver}}{\text{Product of the no of teeth on driven}} \right)$$

$$\Rightarrow \left(\frac{N_4}{N_1} \right) = \left(\frac{Z_1 \times Z_3}{Z_2 \times Z_4} \right) \text{ As } N_1 = 150 \text{ rpm,}$$

$$\therefore N_4 = \left(\frac{20 \times 25}{75 \times 50} \right) \times 150 = 20 \text{ RPM}$$

#5 Figure shows a reverted gear train used in a lathe headstock. If the motor runs at 1200 rpm, find the speed of the spindle.

Solution:

As the center distance between the shafts is same,

$$\left(\frac{d_1 + d_2}{2}\right) = \left(\frac{d_3 + d_4}{2}\right) \Rightarrow (d_1 + d_2) = (d_3 + d_4)$$

The circular pitch $= \left(\frac{\pi d}{z}\right) = \pi m$ $\Rightarrow d = mz$ where 'm' is known as module.

For two gears in mesh, circular pitch and hence the module is same.

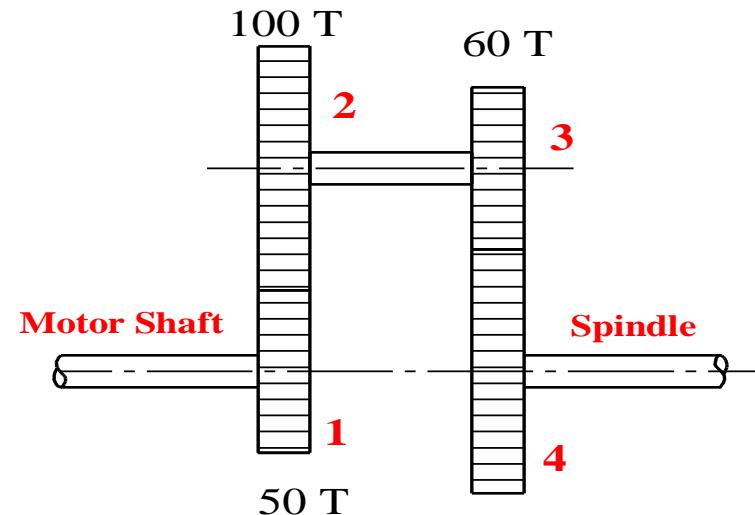
$$\text{As } z_1 + z_2 = z_3 + z_4$$

$$50 + 100 = 60 + z_4$$

No of teeth on gear 4=90 teeth.

$$\therefore \text{Speed of the spindle } N_4 = \left(\frac{z_1 \times z_3}{z_2 \times z_4} \right) \times N_1$$

$$\Rightarrow N_4 = \left(\frac{50 \times 60}{100 \times 90} \right) \times 1200 = 400 \text{ rpm}$$



Fundamentals of Mechanical Engineering

MECHANICAL DRIVES

Assignment – Unit 4a - 04

<<for Practice>>

- 1) Explain with neat sketch reverted gear train.
- 2) Brief about epicyclic gear train. Draw the sketch to illustrate the gear train.
- 3) Solve more numerical problems on simple gear train.
- 4) Solve more numerical problems on compound gear train.

Note:

- i) Use new A4 size sheets, provide 1" left and top margin for each sheet.
- ii) Write Roll No., Name (at right top), Topic and Assignment No. (at top Middle) in the 1st sheet.
- iii) Use red pen to write the questions and blue or black pen for answer
- iv) Draw neat sketches using instruments (avoid free hand sketching)

Course Outcomes (COs):

Course Outcomes: After completing the course, the students will be able to:-

| | |
|-------------|---|
| CO 1 | Understand the knowledge of various properties of Engineering materials and their Joining processes |
| CO 2 | Elucidate the principles and operation of vision system in product inspection. |
| CO 3 | Illustrate the Energy sources, mechanical drives and electrical drives in industrial applications |
| CO 4 | Understand about Mechatronics, Automation and Robotics in Industrial Applications |

References:

| Reference Books | |
|------------------------|---|
| 1. | Elements of Mechanical Engineering, K. R. Gopalakrishna, Subhas Publications, 18 th Edition. ISBN 5551234002884 |
| 2. | Material Science & Engineering- William D Callister, 2 / 10 th Edition, ISBN 978-1-119-45520-2. |
| 3. | Welding Technology (PB), Khanna O P, Dhanpat Rai publication, 4 th Edition, ISBN 9383182555. |
| 4. | Electric and Hybrid Vehicles, Design Fundamentals – Iqbal Husain, CRC Press, 2 nd Edition, 2010. ISBN – 13-978-1439811757. |
| 5. | Modern Electric, Hybrid Electric & Fuel Cell Vehicles, Fundamentals, Theory and Design - Mehrdad Ehsani, CRC Press, 1 st Edition, 2005. ISBN – 13- 978-0849331541. |
| 6. | Mechatronics – Electronic control systems in Mechanical and Electrical Engineering, William Bolton, Pearson, 6 th Edition, ISBN: 978-1-292-07668-3, 2015. |



Assessment and Evaluation Pattern:

| CONTINUOUS INTERNAL EVALUATION | | | |
|---|--------------|--------------|------------|
| ASSESSMENT AND EVALUATION PATTERN | | | |
| Theory & quizzes questions are to be framed using Bloom's Taxonomy Levels - Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating | | | |
| WEIGHTAGE | CIE (50%) | SEE (50%) | |
| A. QUIZZES: Each quiz is evaluated for 10 marks | | | |
| Quiz-I for 10 Marks | | 20 | ***** |
| Quiz-II for 10 Marks | | | |
| B. TESTS: Each test will be conducted for 50 Marks adding upto 100 marks. Final test marks will be reduced to 40 | | | |
| Test – I for 50 Marks | | 40 | ***** |
| Test – II for 50 Marks | | | |
| C. EXPERIENTIAL LEARNING: | | | |
| Fabrication of prototype of energy generator – 10 marks | | | |
| Fabrication of Mechatronics/Electrical/Mechanical drive prototype components– 20 marks | | 40 | ***** |
| Prototype models of Robot – 10 marks | | | |
| TOTAL MARKS FOR THE COURSE (A+B+C) | | 100 | 100 |



Prepare & Practice
*****All The Best*****