Department of Mechanical Engineering
RV College of Engineering®, Bengaluru – 560059

ELEMENTS OF MECHANICAL ENGINEERING

UNIT-IV
MECHANICAL & ELECTRICAL DRIVES

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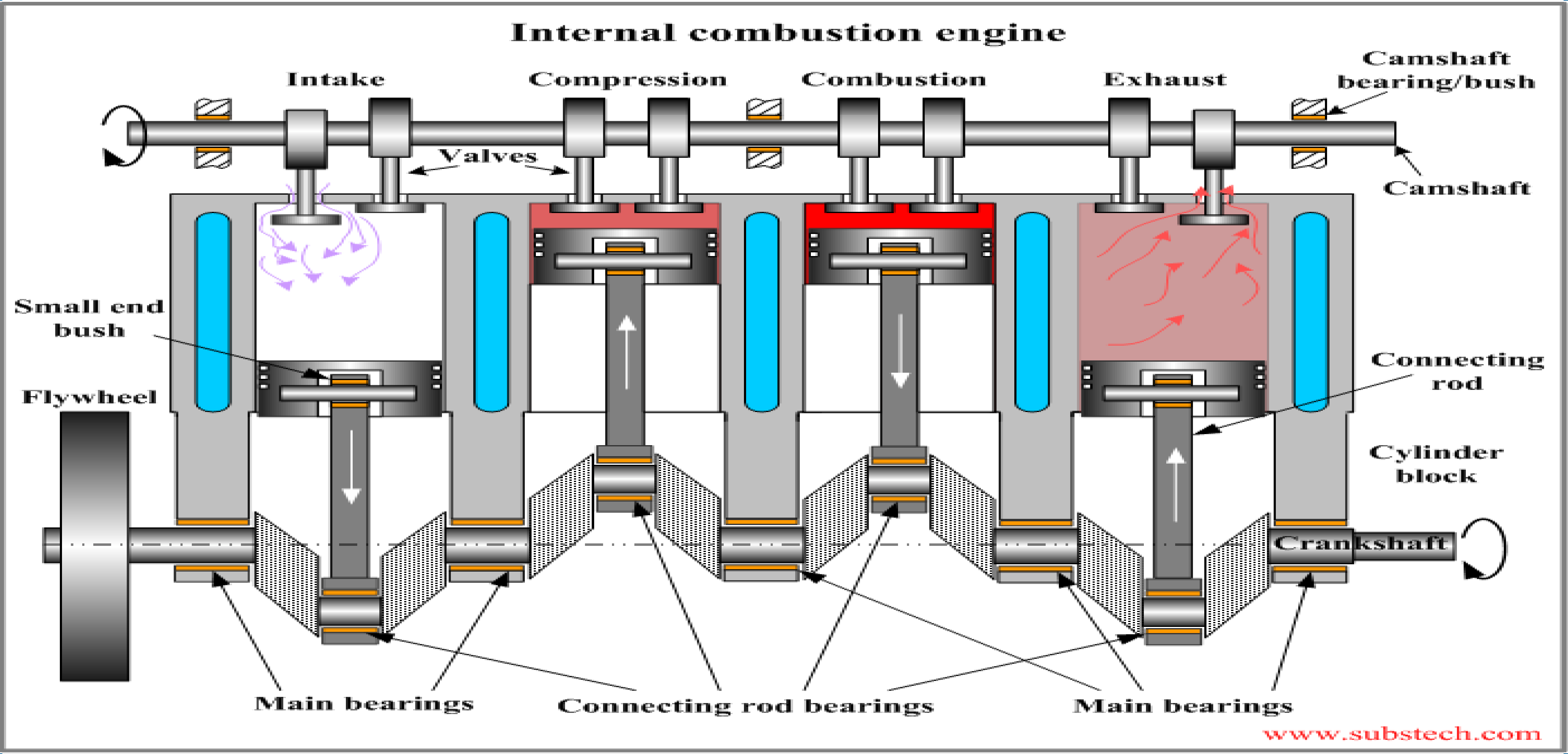
UNIT-IV (6 hours)

- **Mechanical and Electrical Drives**

- **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.


Internal combustion engine
Intake
Compression
Combustion
Exhaust
Camshaft bearing/bush
Valves
Camshaft
Small end bush
Flywheel
Connecting rod
Cylinder block
Crankshaft
Main bearings
Connecting rod bearings
Main bearings
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IC ENGINES

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;

1)External Combustion engines (EC engines)

2)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.

ADVANTAGES OF I.C ENGINES OVER E.C ENGINES

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

CLASSIFICATION 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 S.I. Engine.
- Compression ignition engine, known as C.I engine.

5. Number of Cylinder as

- Single cylinder engine.
- Multi cylinder engine.

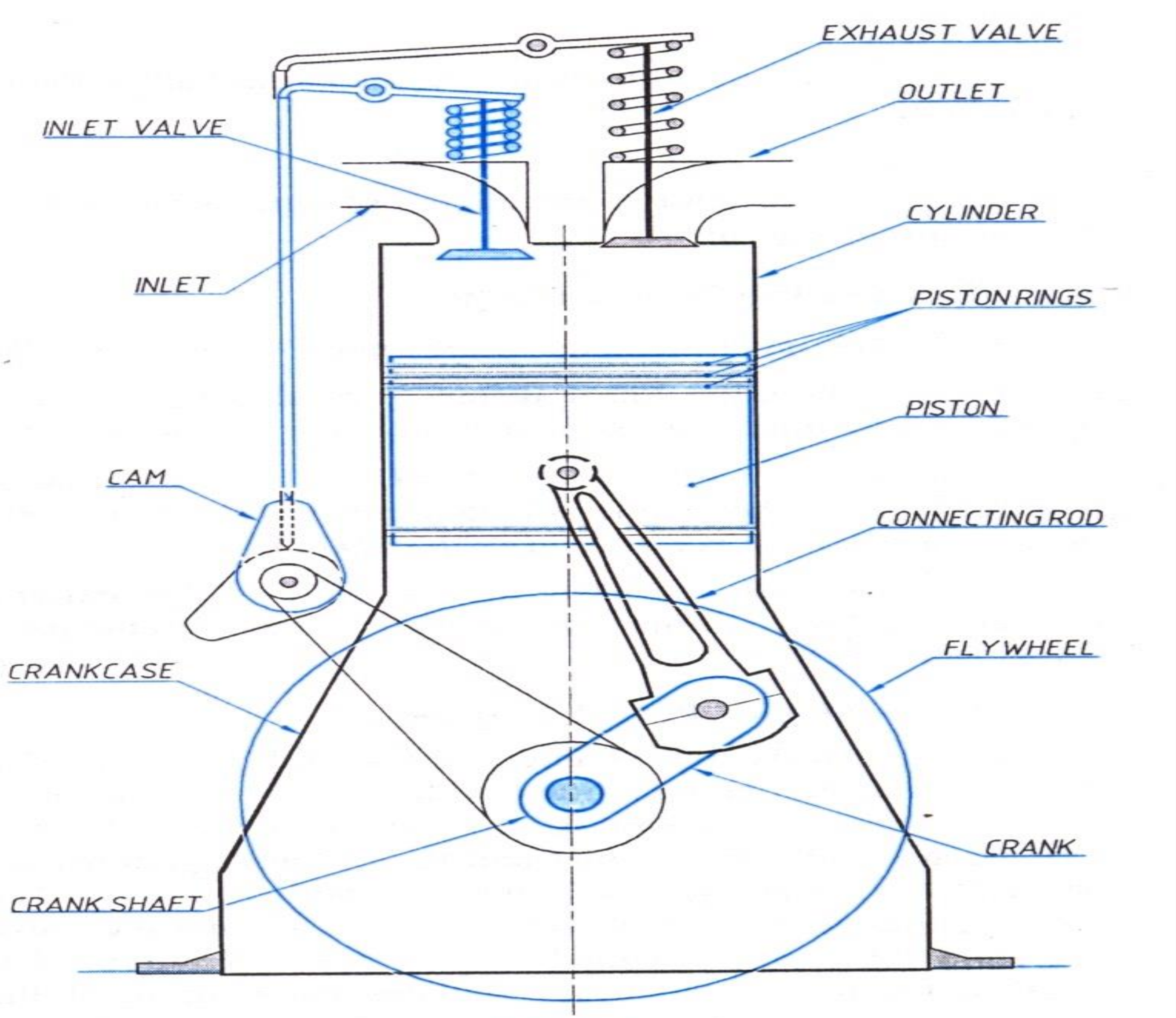
6. Position of the Cylinder

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

7. Method of Cooling

- Air cooled engine.
- Water cooled engine.

PARTS OF I C ENGINE

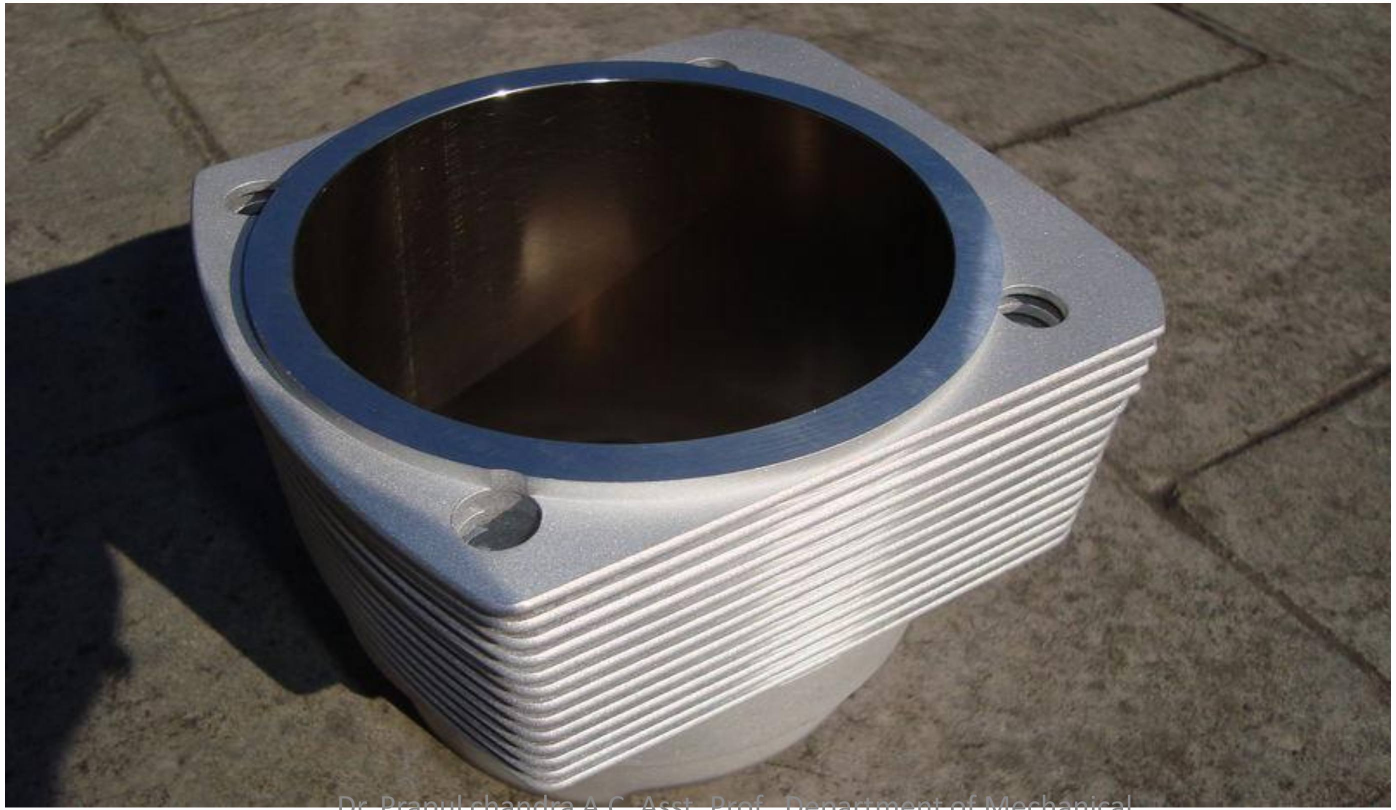


PARTS OF I C ENGINE

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

1.Cylinder:

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



2.Cylinder head:

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

3.Piston:

It is a close fitting hollow cylindrical plunger moving to & fro inside the cylinder.

It is made of aluminium alloys for light weight.

The power developed by the combustion of fuel is transmitted by the piston to the crankshaft through the connecting rod.

4. Piston rings:

These are metallic rings made of cast iron. 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.

5.Connecting rod:

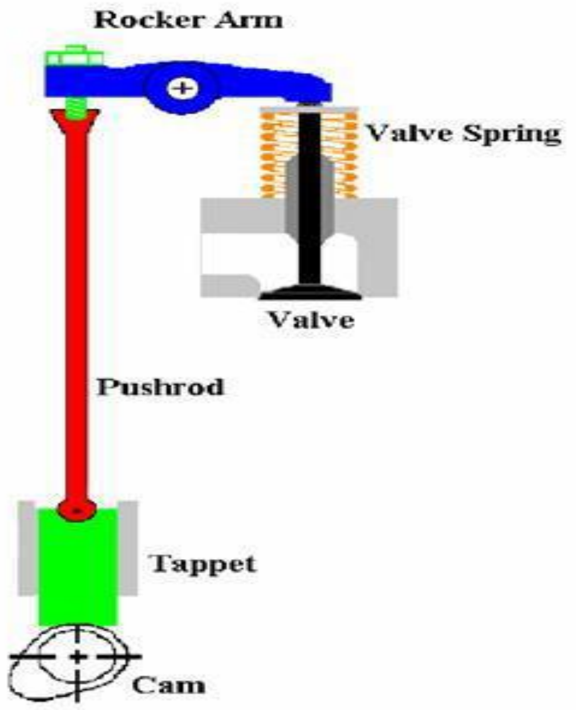
- It is the link that connects the piston and the crankshaft by means of pinjoints.
- It converts the linear motion of the piston in to rotary motion of the crankshaft.
- Connecting rods are made of alloy steels.

6.Crank & Crankshaft:

- Crank is a lever (made of carbon steel) 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.

7.Valves:

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



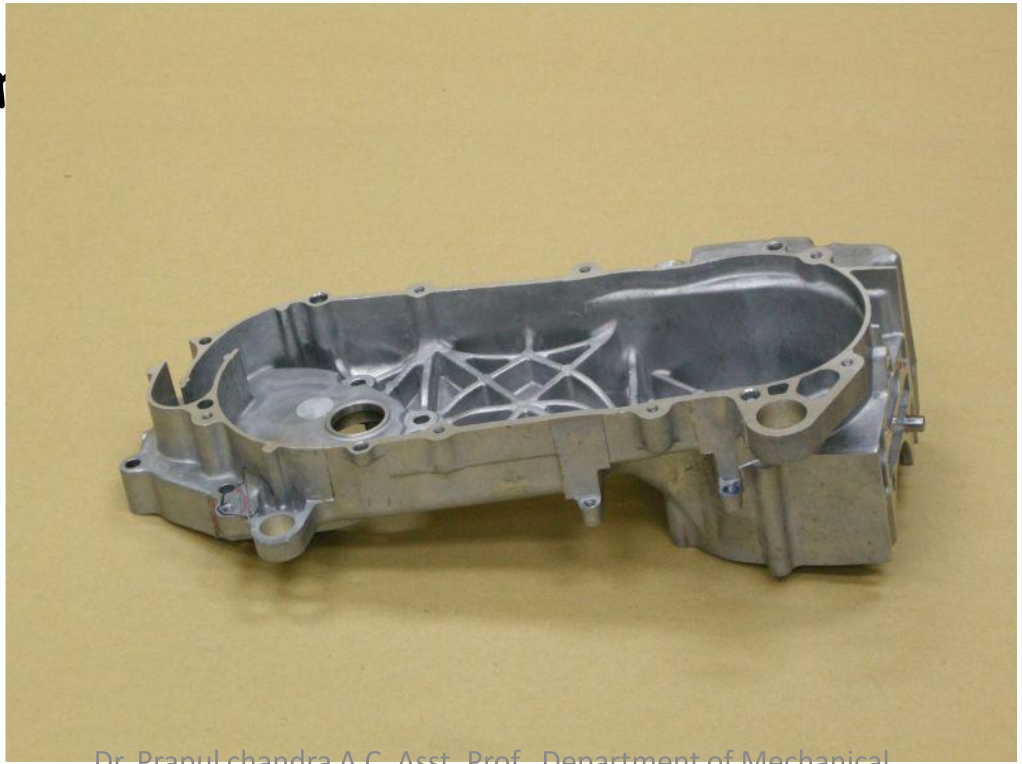
8.Flywheel:

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

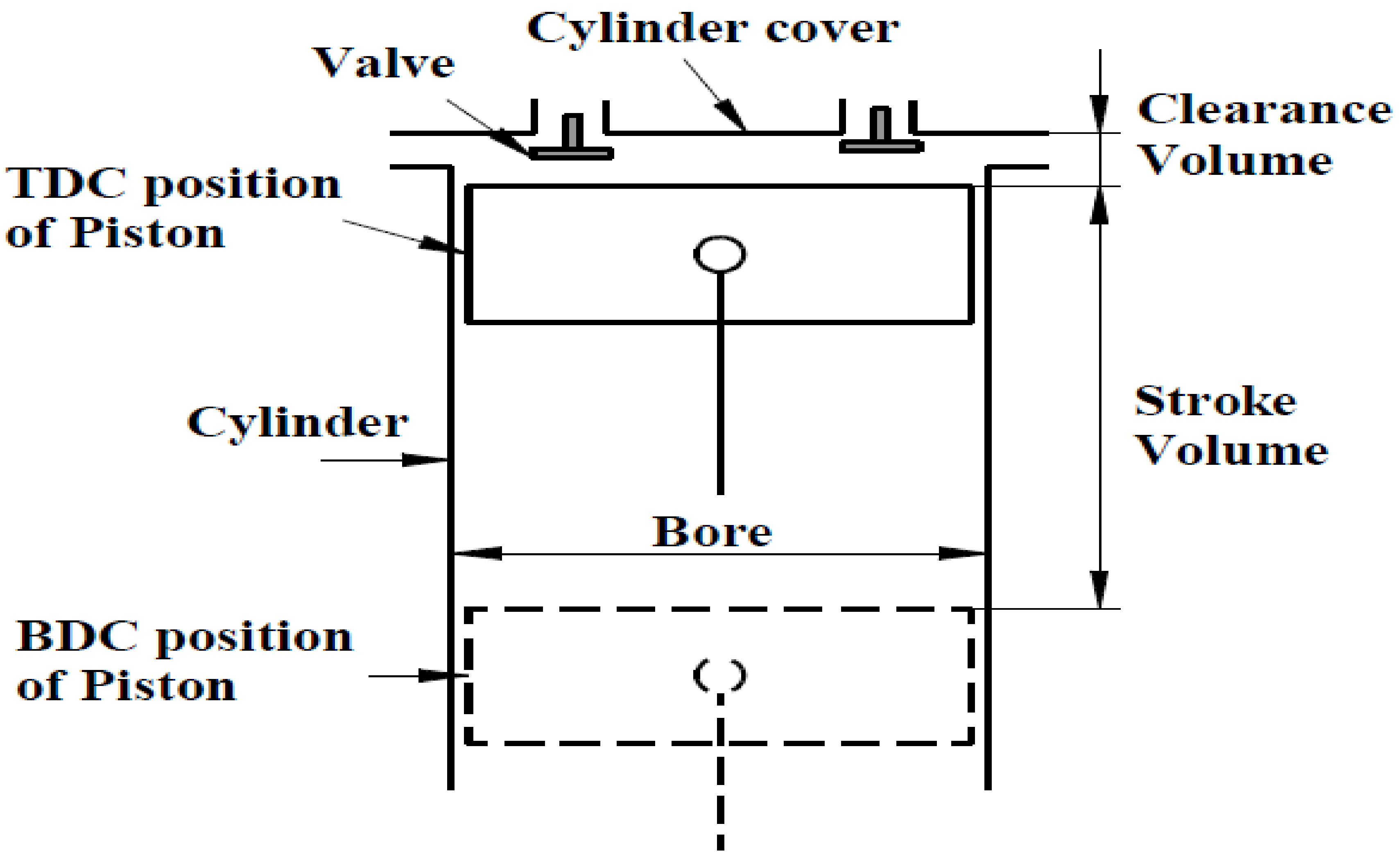
9. Crankcase:

It is the lower part of the engine serving as an enclosure for the crankshaft.

It also serves as a sum

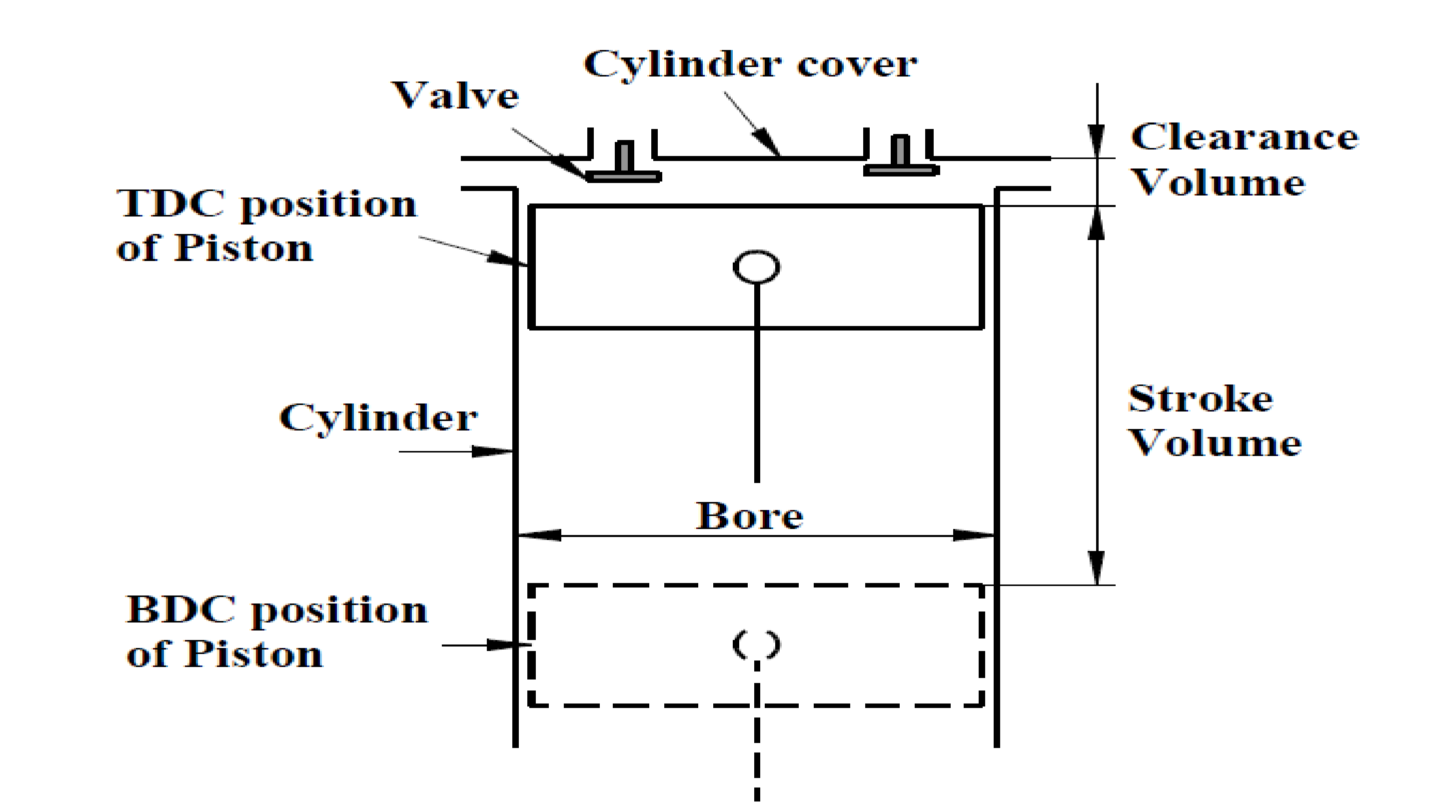


I.C ENGINE TERMINOLOGY



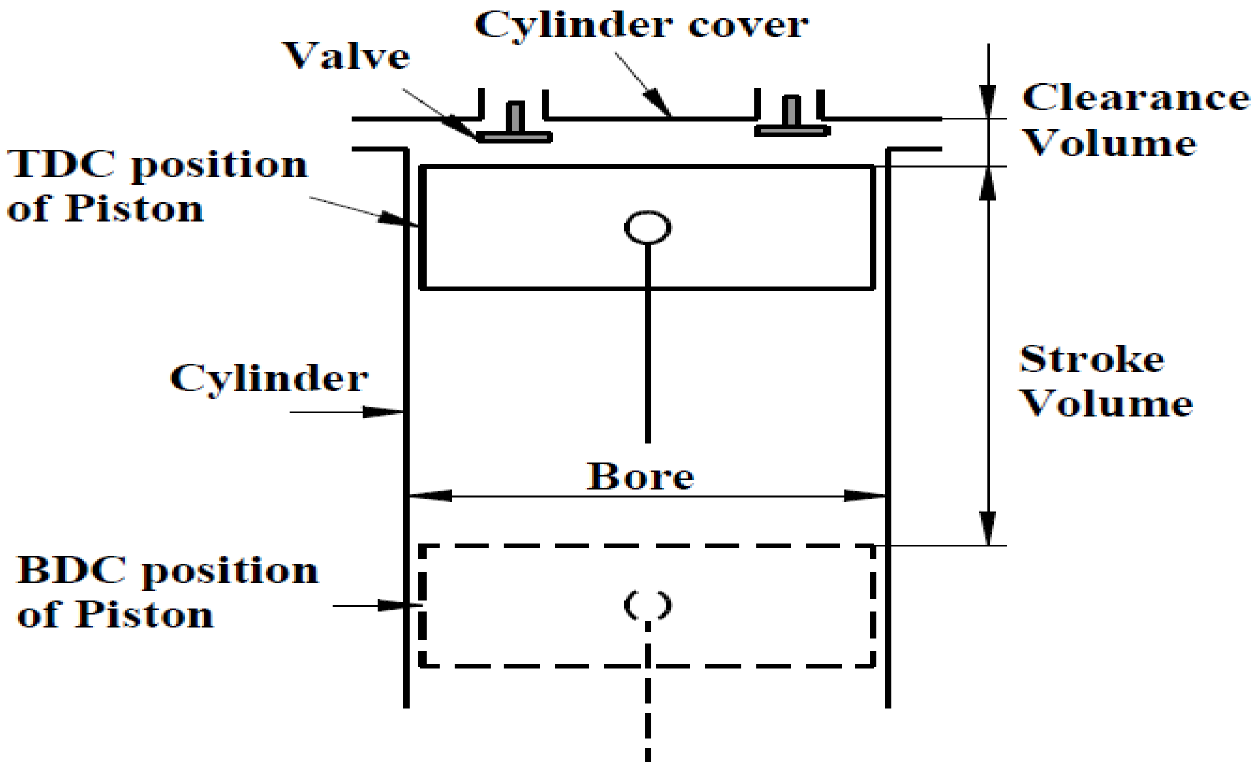
I.C ENGINE TERMINOLOGY

- **Bore**- inside diameter of the cylinder
- **crank radius- Rc** it is the linear distance between the shaft centre and crank pin centre. It is equal to half the stroke le



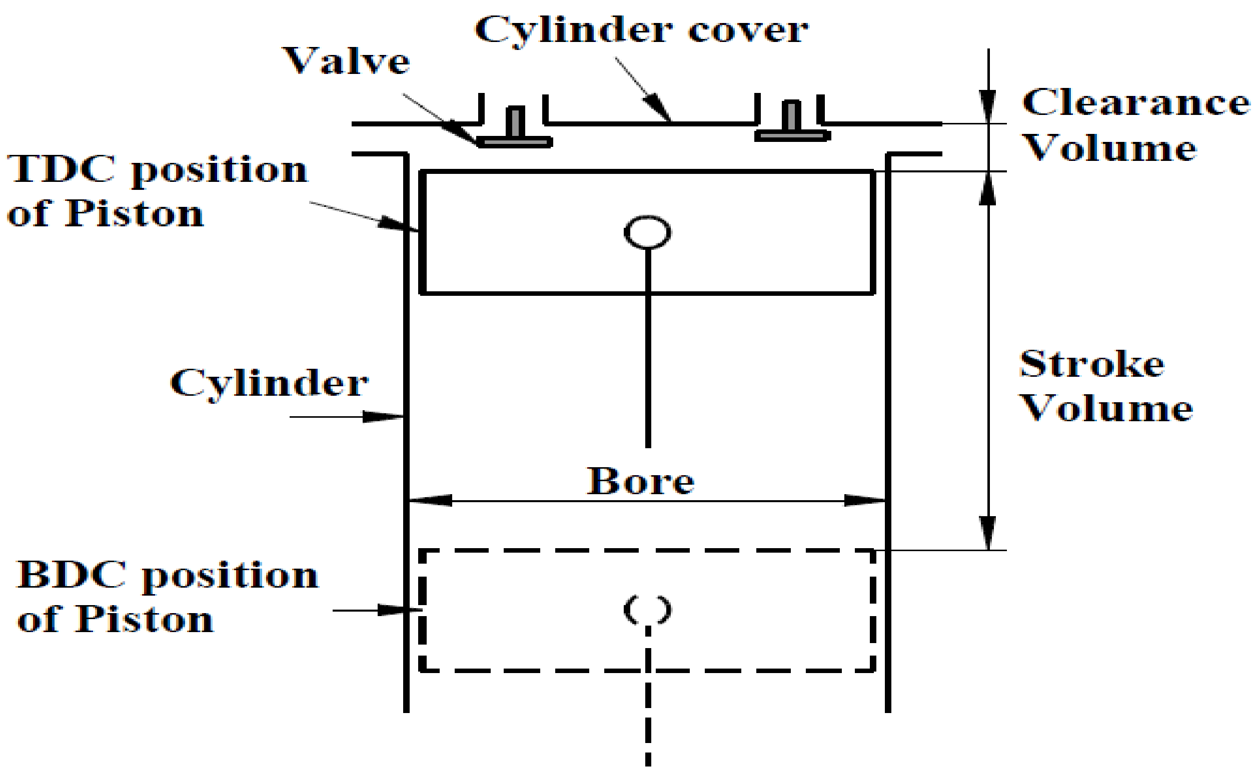
I.C ENGINE TERMINOLOGY

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.



I.C ENGINE TERMINOLOGY

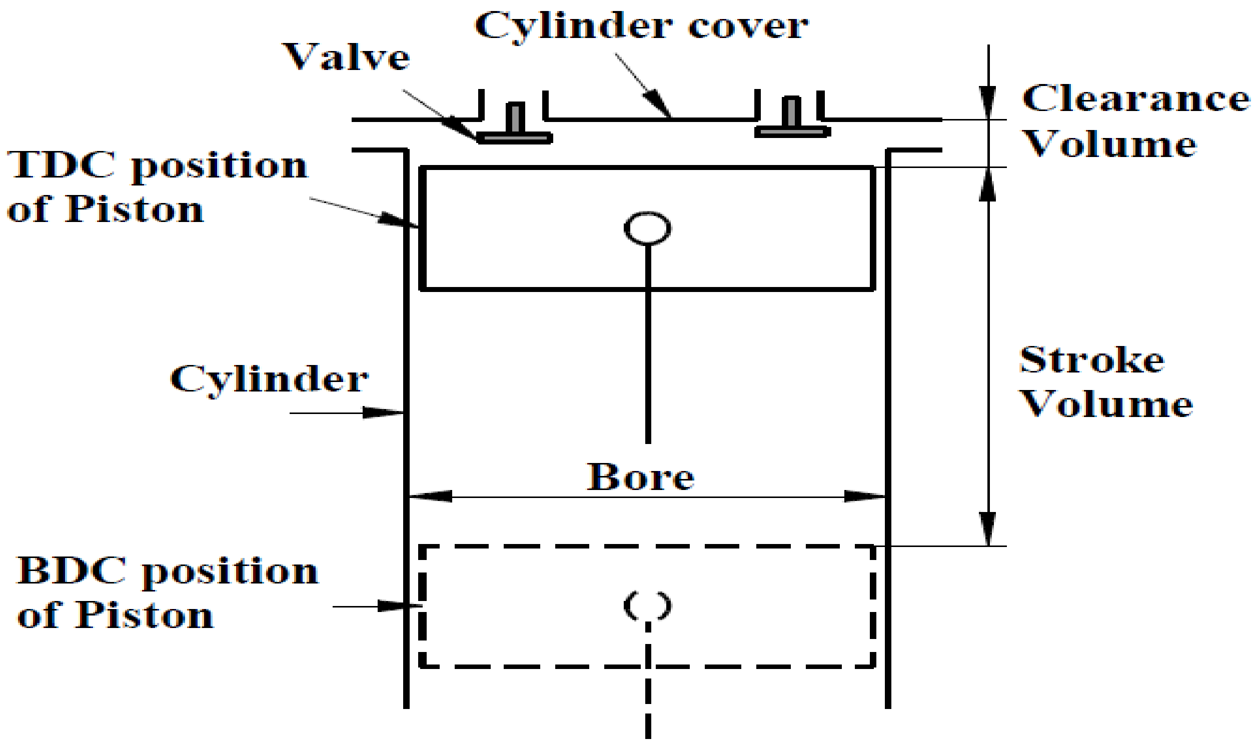
Bottom dead centre / outer Dead centre: It is the extreme position of the piston towards the crank end side of the cylinder. The crank pin moves to the farthest distance from the cylinder.



I.C ENGINE TERMINOLOGY

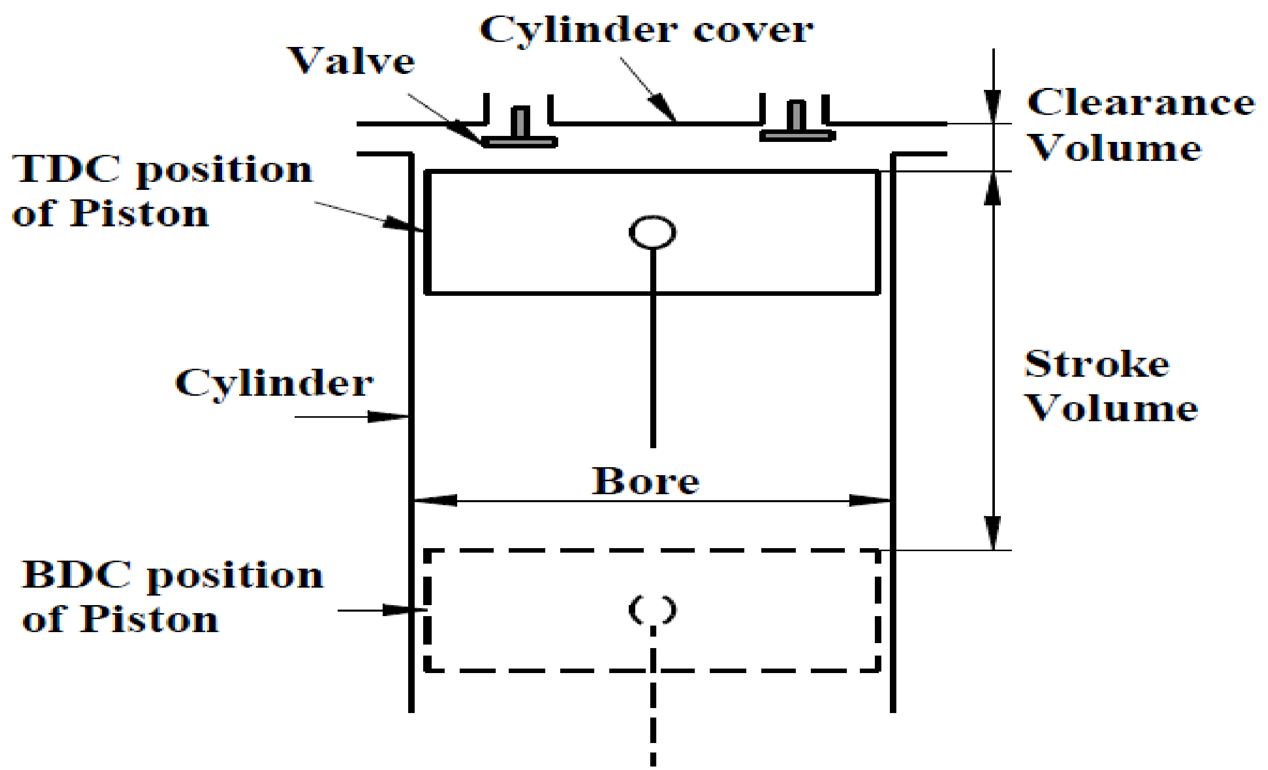
Swept volume : It is the volume through which the piston sweeps during a stroke.

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



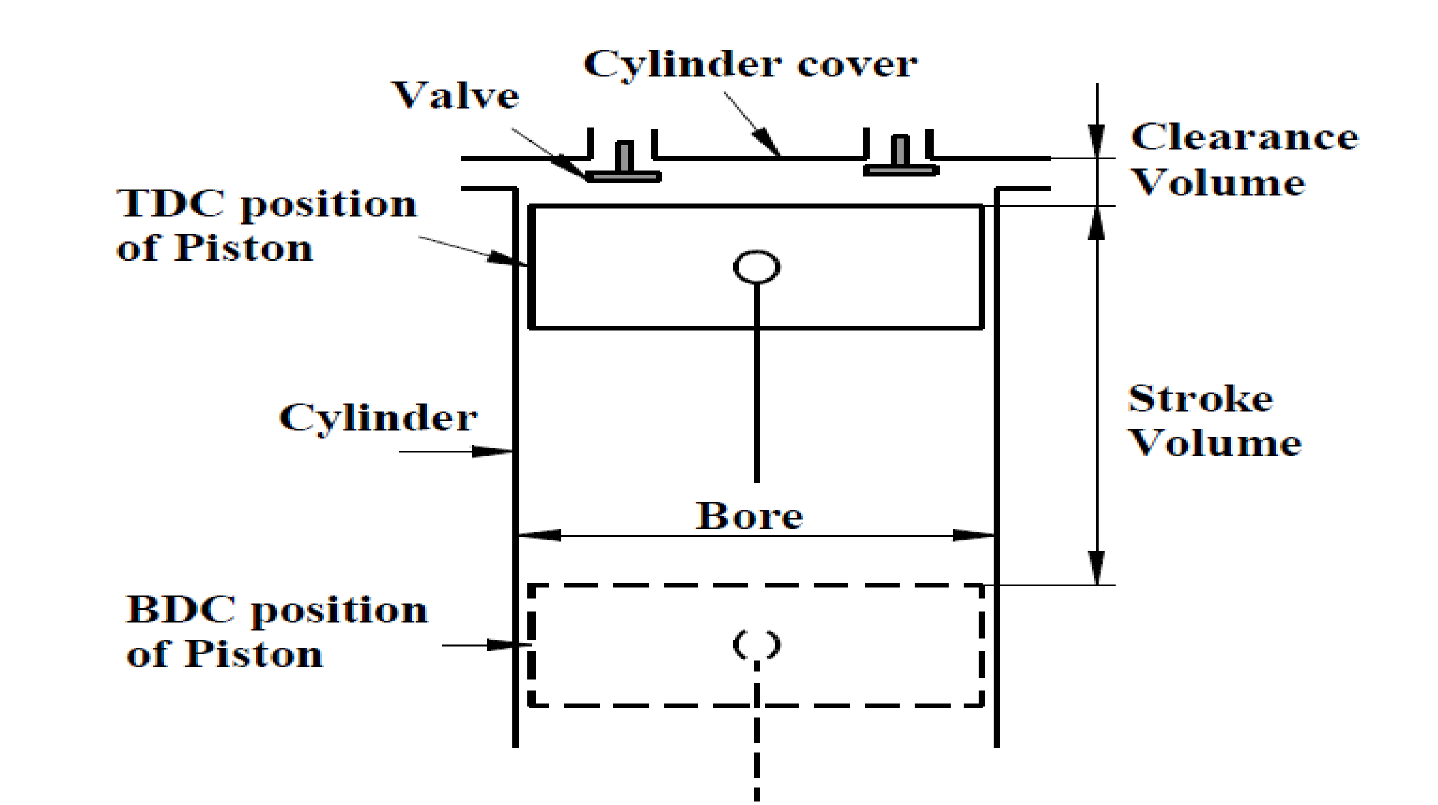
I.C ENGINE TERMINOLOGY

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.



I.C ENGINE TERMINOLOGY

Clearance volume V_c- 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 . The piston never touches the cylinde

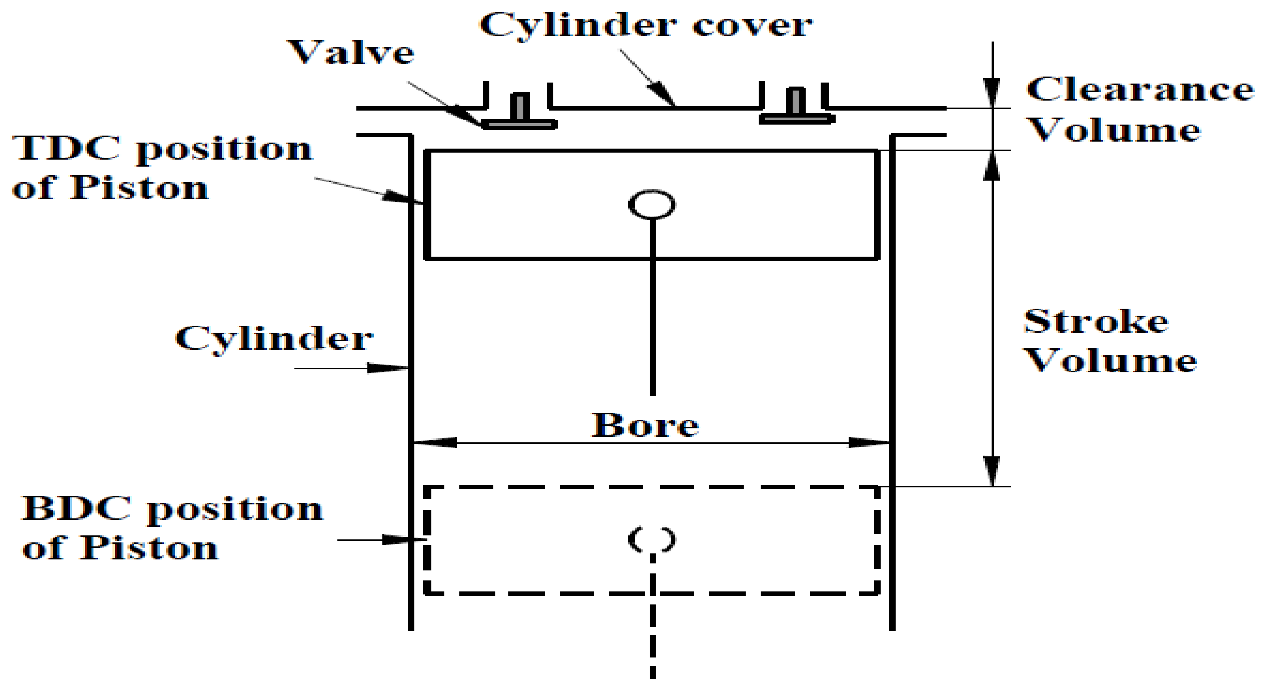


I.C ENGINE TERMINOLOGY

Compression Ratio: It is the ratio of the total cylinder volume to the clearance volume

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

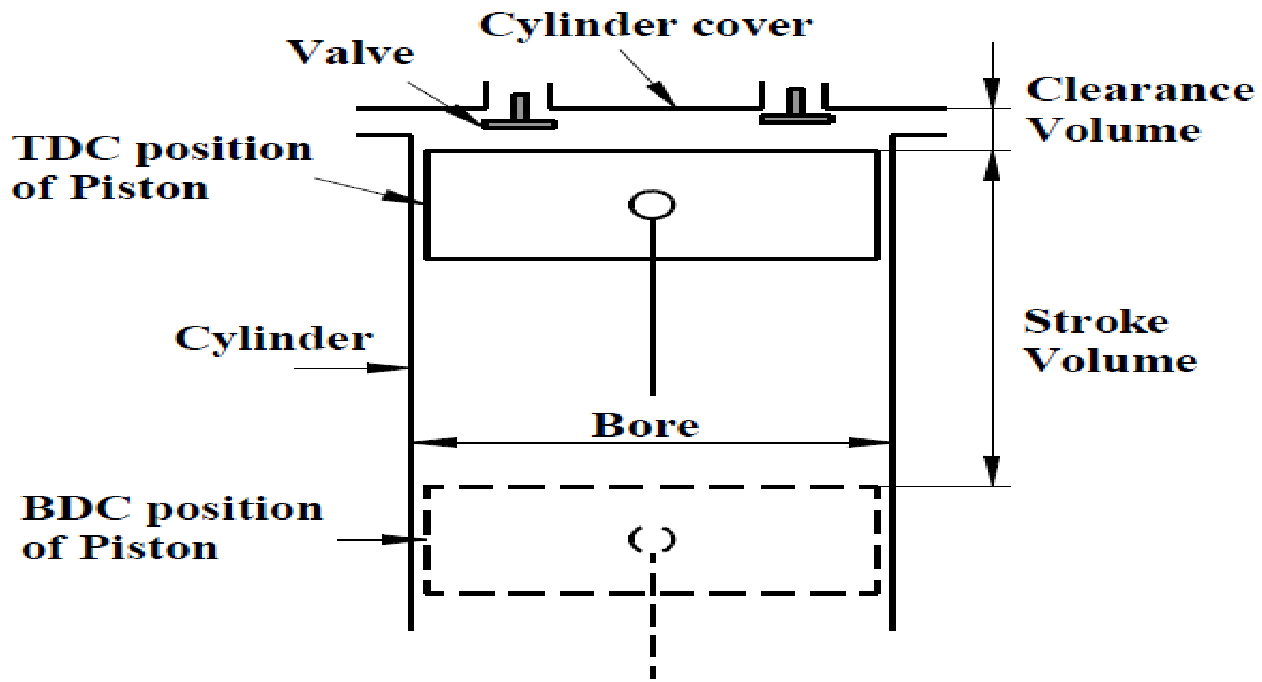
For diesel engine CR varies from 12:1 to 22:1



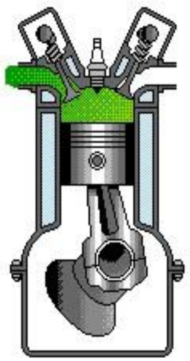
I.C ENGINE TERMINOLOGY

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

Cycle of Operation: It is complete series of events



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 fig.
- The piston performs four strokes (one each in half revolution of crankshaft) to complete the working cycle. (in 2 revolutions of crank shaft)
- The four strokes are:

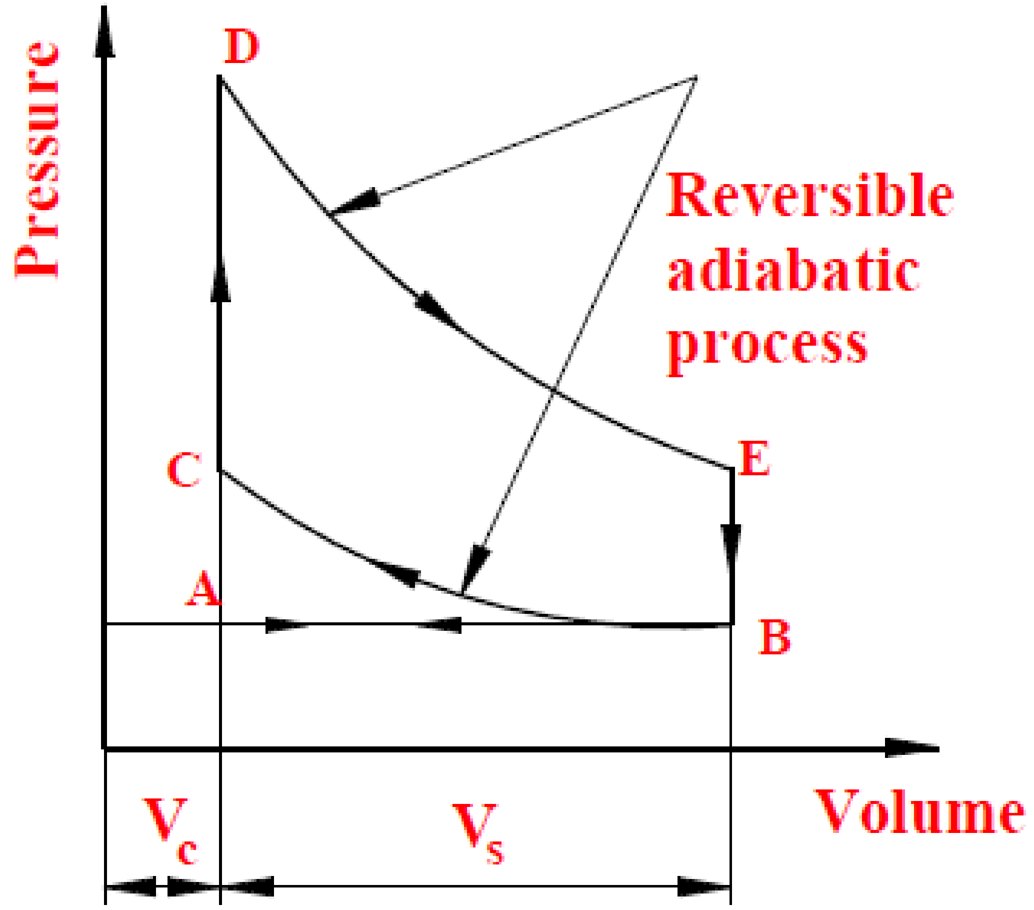
(i) Suction

(ii) Compression

(iii) Working (or) Power stroke

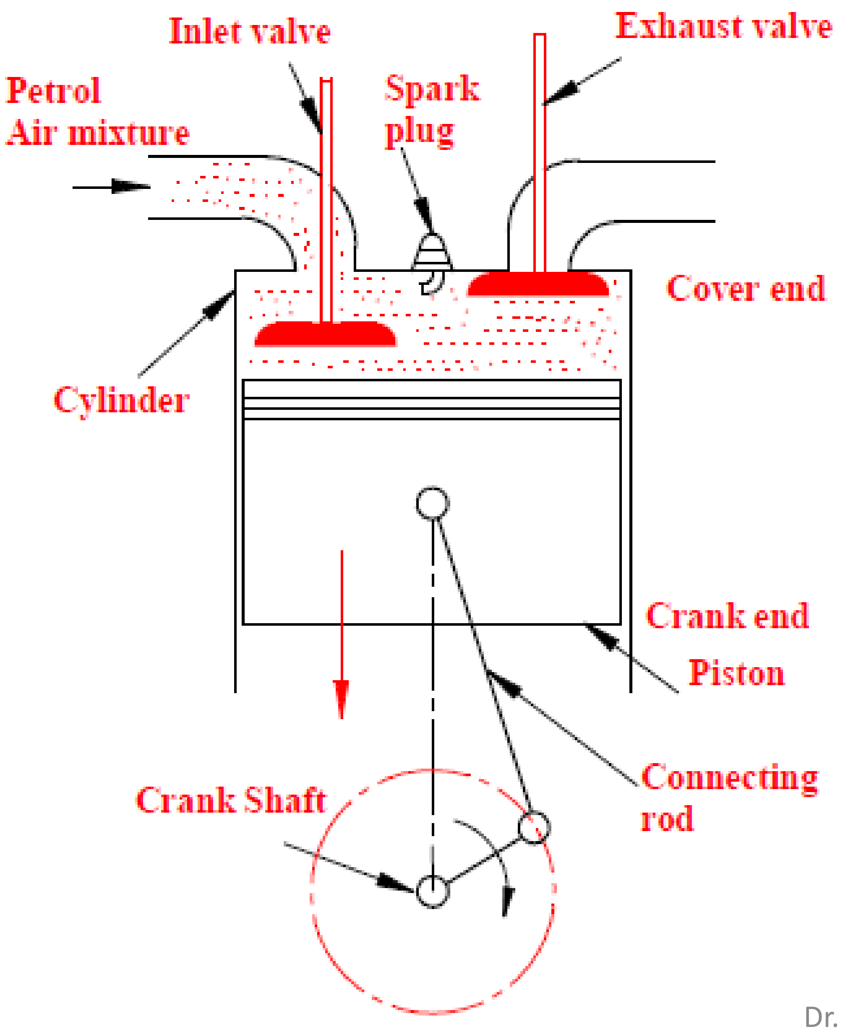
(iv) Exhaust stroke

FOUR STROKE CYCLE PETROL ENGINE



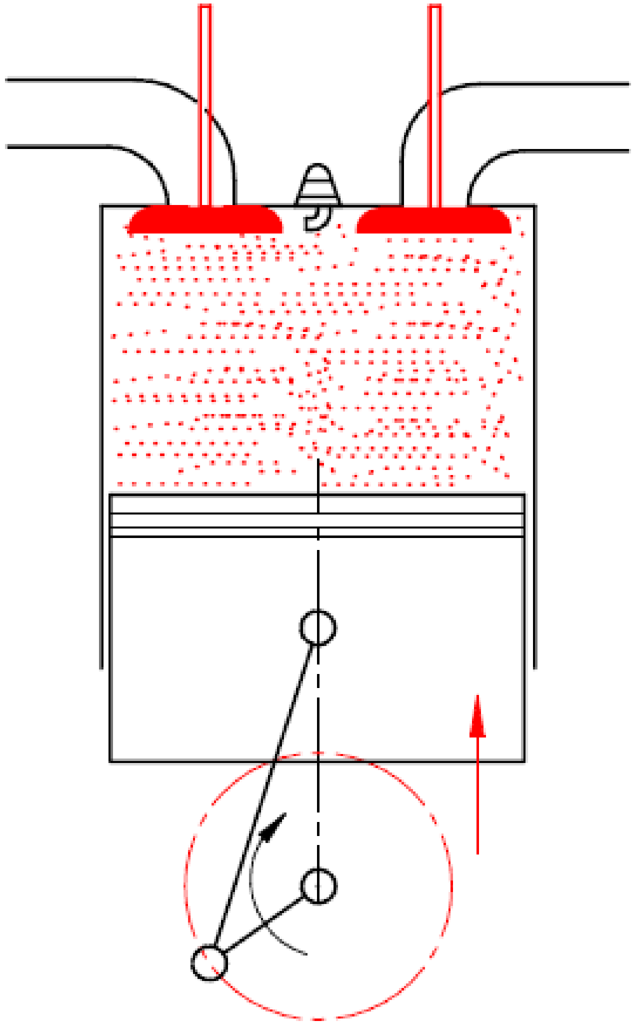
P-V Diagram

SUCTION STROKE



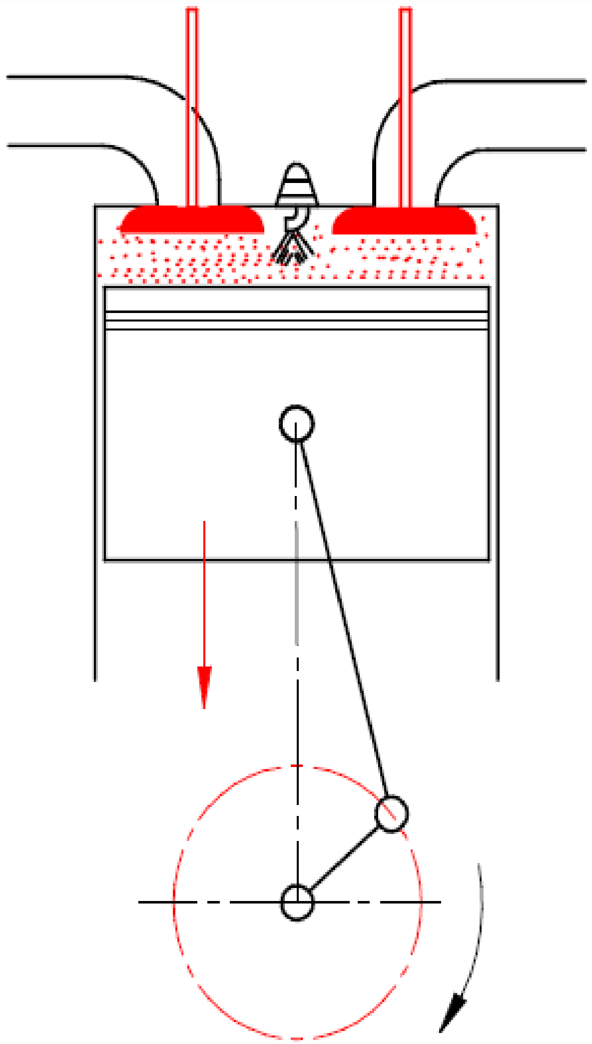
- During suction stroke, the inlet valve is open and exhaust valve is closed.
- The piston moves from cover end to crank end during half revolution of crankshaft.
- The air-petrol mixture is drawn into the cylinder and completely fills the cylinder.
- Suction takes place at atmospheric pressure and is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

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.

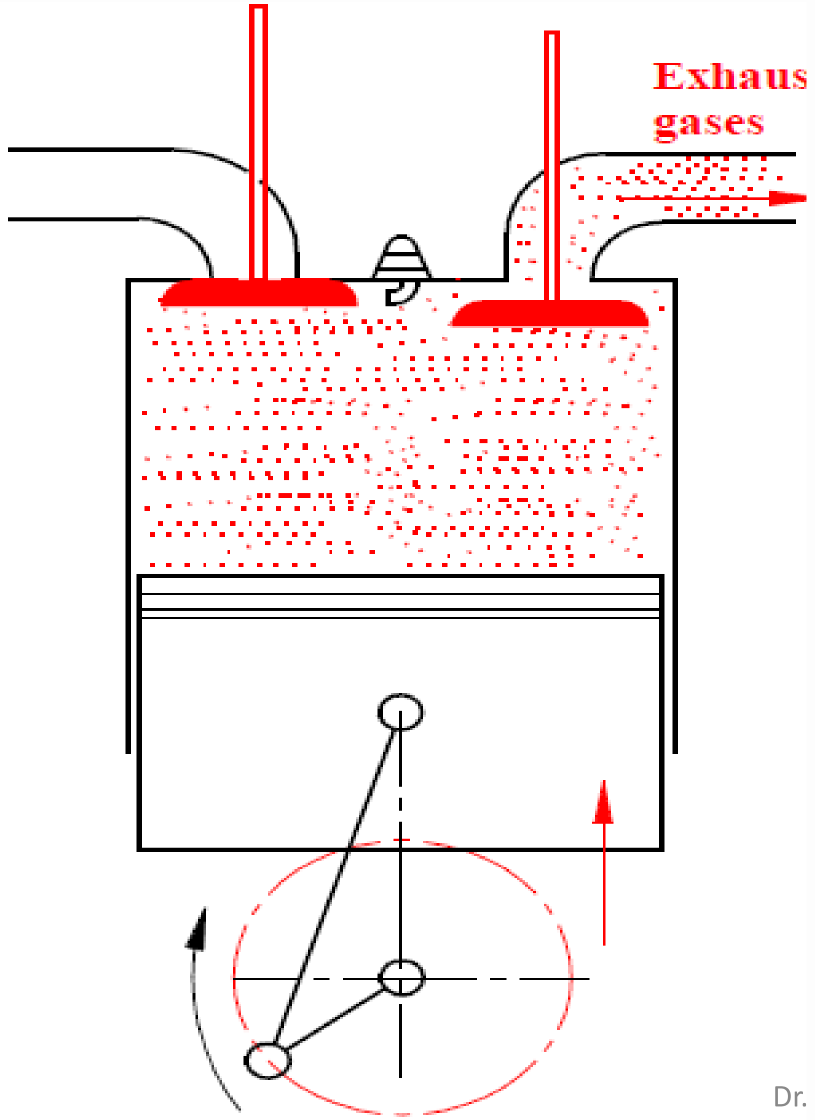
POWER STROKE



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

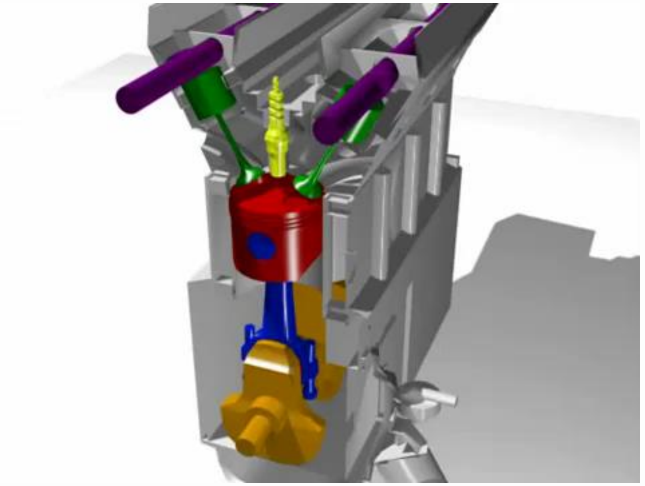
EXHAUST STROKE



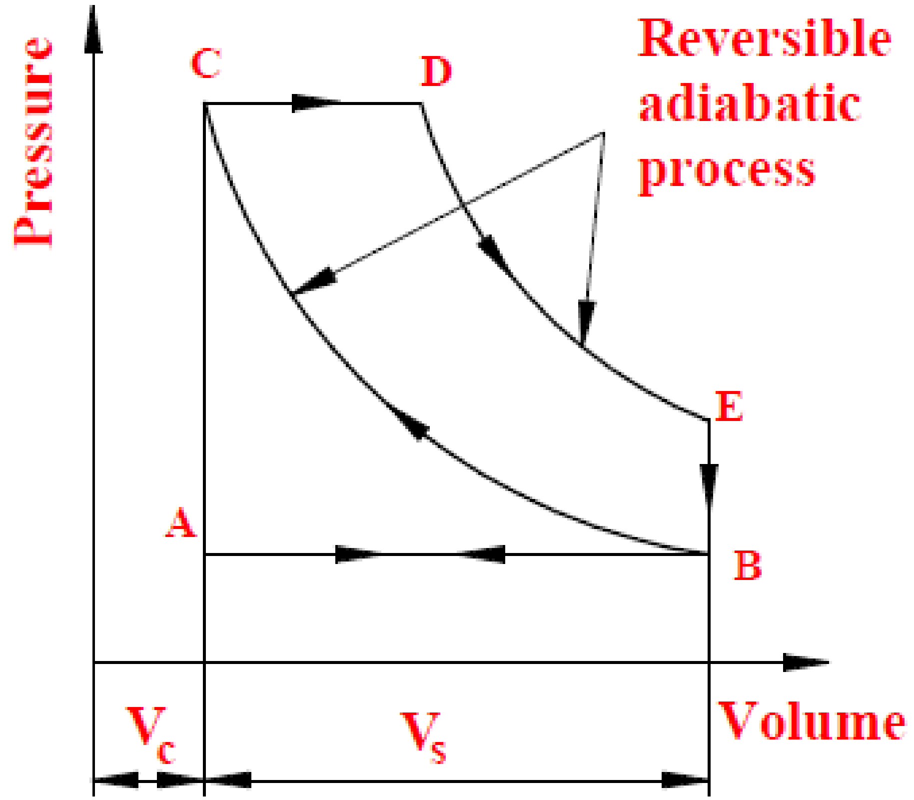
During this stroke, the inlet valve remains closed & the exhaust valve remains open.

- 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, 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.

FOUR STROKE CYCLE DIESEL ENGINE

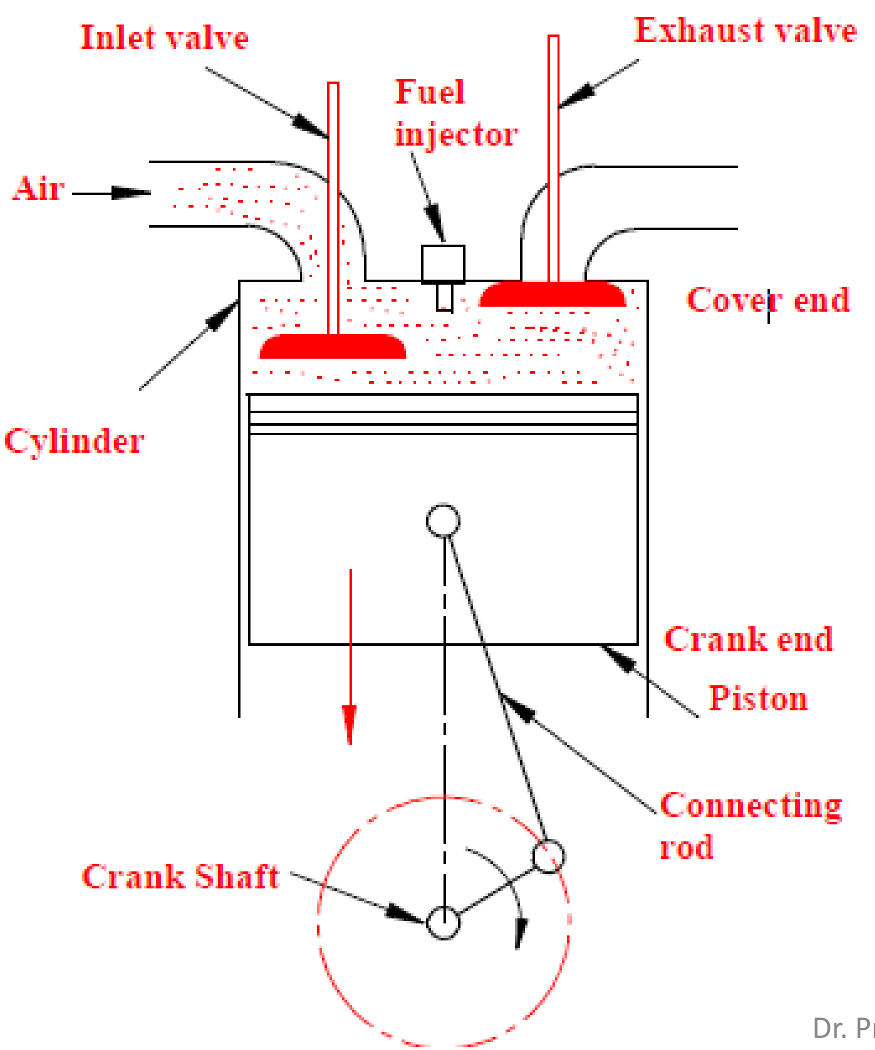


FOUR STROKE CYCLE DIESEL ENGINE



P-V Diagram

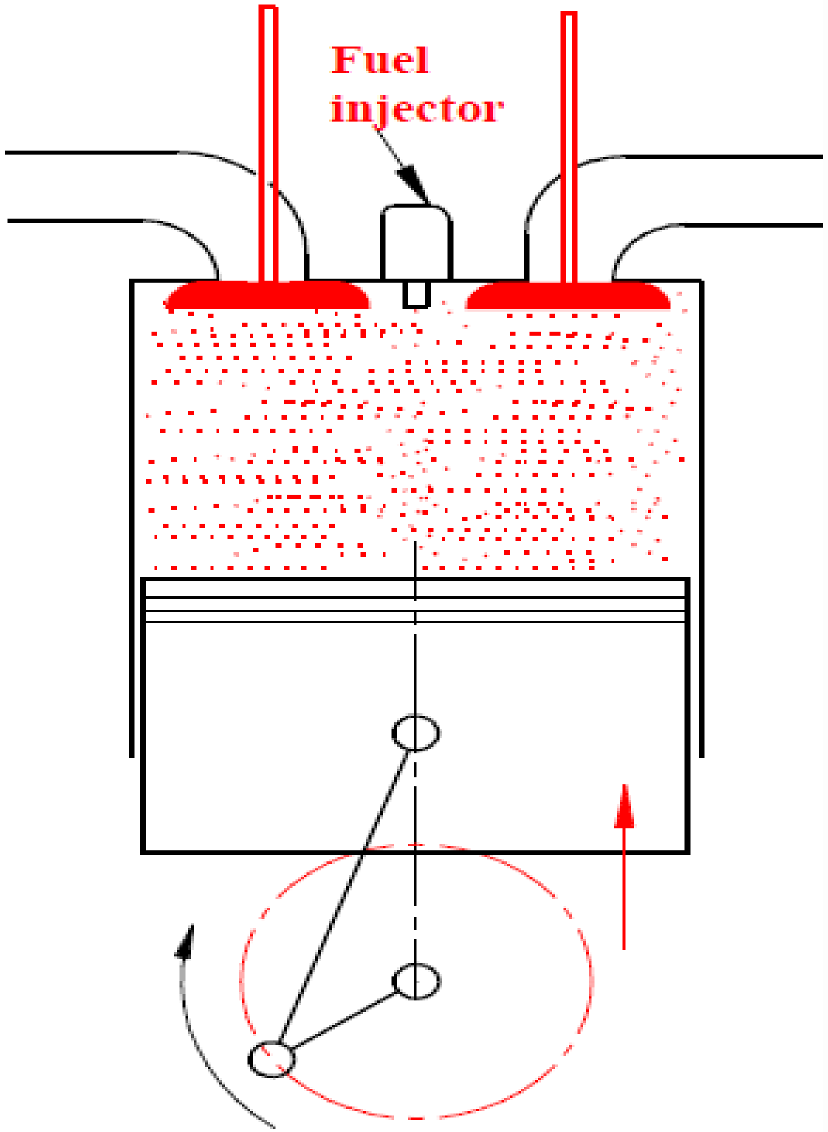
SUCTION STROKE



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

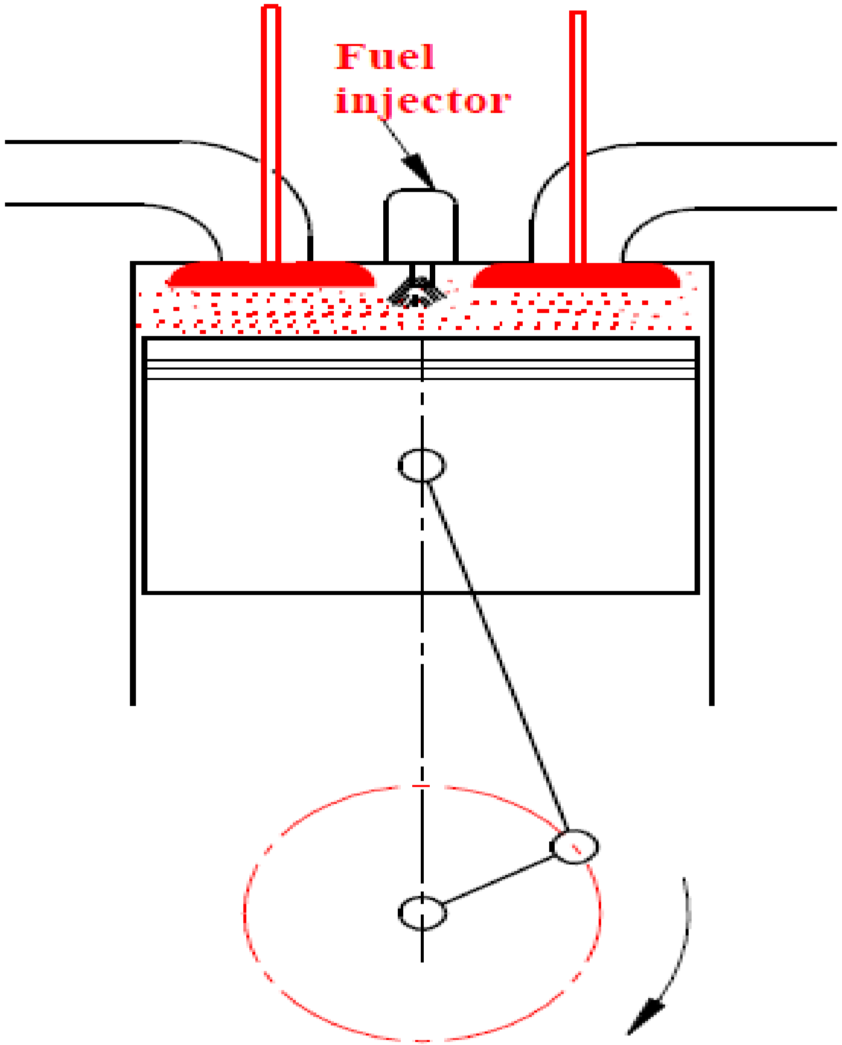
- The piston moves from cover end to crank end during half revolution of crankshaft, and draws ***only air*** into the cylinder.
- The energy required for this stroke is obtained by 'cranking' only at the time of starting & by the flywheel while running.
- Suction takes place at atmospheric pressure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

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

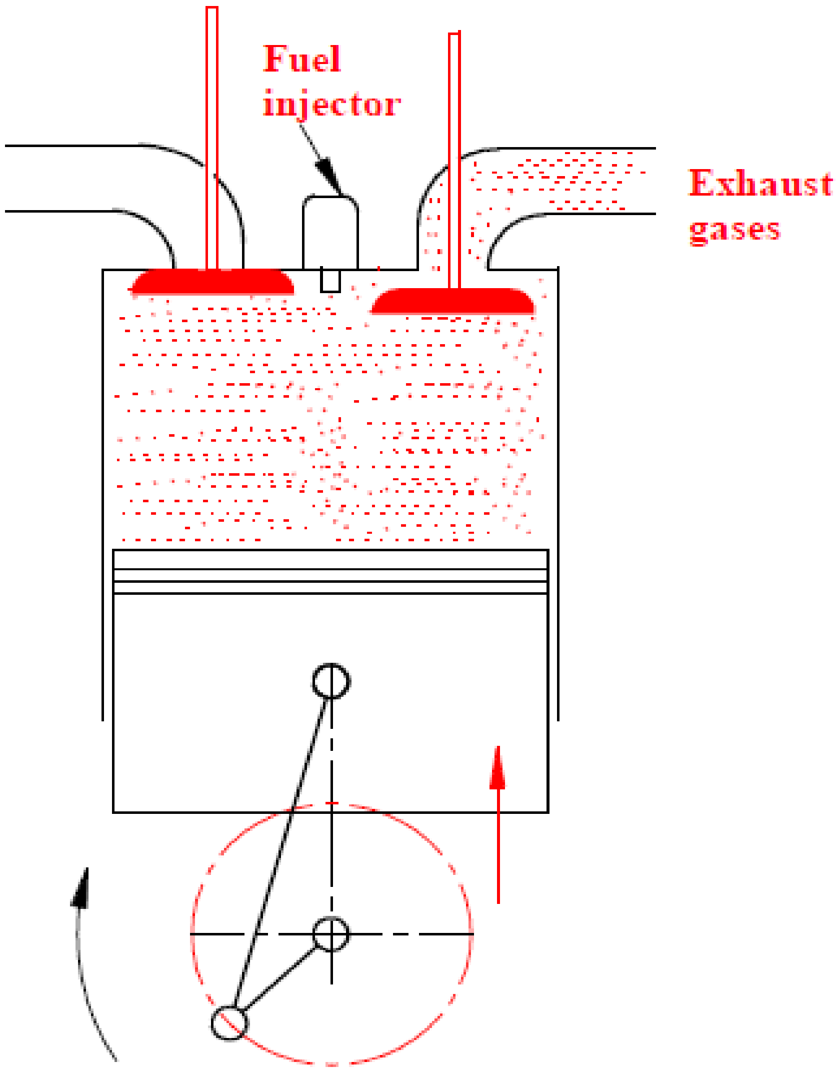
POWER STROKE



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

EXHAUST STROKE



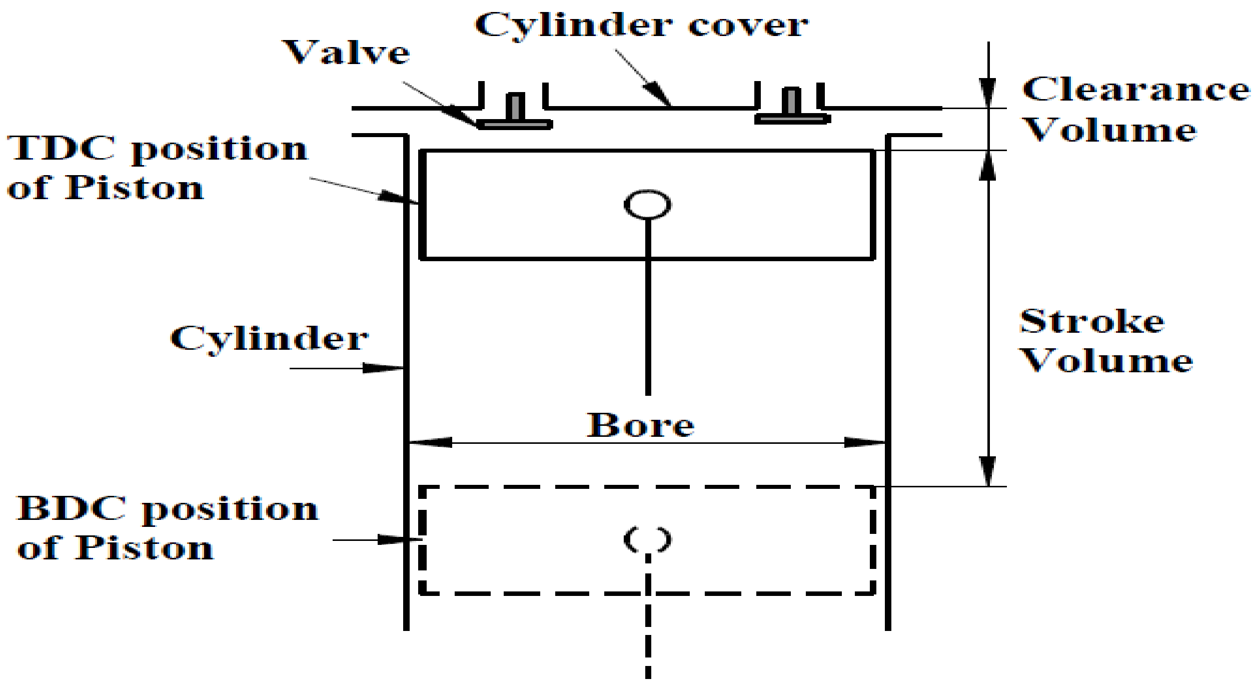
During this stroke, the inlet valve remains closed & the exhaust valve remains open.

- 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, 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.

I.C ENGINE TERMINOLOGY

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

Cycle of Operation: It is complete series of events



COMPARISON BETWEEN PETROL ENGINE & 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

IC ENGINES

Petrol Engine	Diesel Engine
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, Scoters, etc.	Used in heavy duty vehicles like trucks, buses, locomotives, etc.

COMPARISON BETWEEN FOUR STORKE ENGINE & 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 &	For the same power output, the engine is light

Four Stroke cycle Engine	Two Stroke cycle Engine
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.

IC ENGINE CALCULATION

INDICATED POWER (IP) :

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

$$IP= 100P_mLAn / 60 \text{ KW}$$

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.*

BP=2πNT/60 KW

Where: N= Rpm of crank shaft

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

Where: W= Load on brake drum

S=Spring balance reading

R=Radius of the brake drum

Also **FP =(IP - BP) KW**

Where: FP= Loss of power due to friction

EFFICIENCIES OF ENGINE :

(i) Mechanical Efficiency

η_{mech}= BP/IP*100

(ii) Thermal Efficiency

a. Indicated thermal efficiency

$\eta_{\text{indicated-thermal}}$ = IP/m_f*C_v *100

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

C_v= Calorific value of the fuel in KJ/Kg

EFFICIENCIES OF ENGINE :

b. Brake thermal efficiency

$$\eta_{Brake\text{-}thermal} = BP/m_f{*}C_v \;{*}100$$

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**

$$P_m = sa / l \quad N/m^2$$

Where: a=Area of the indicator diagram, cm

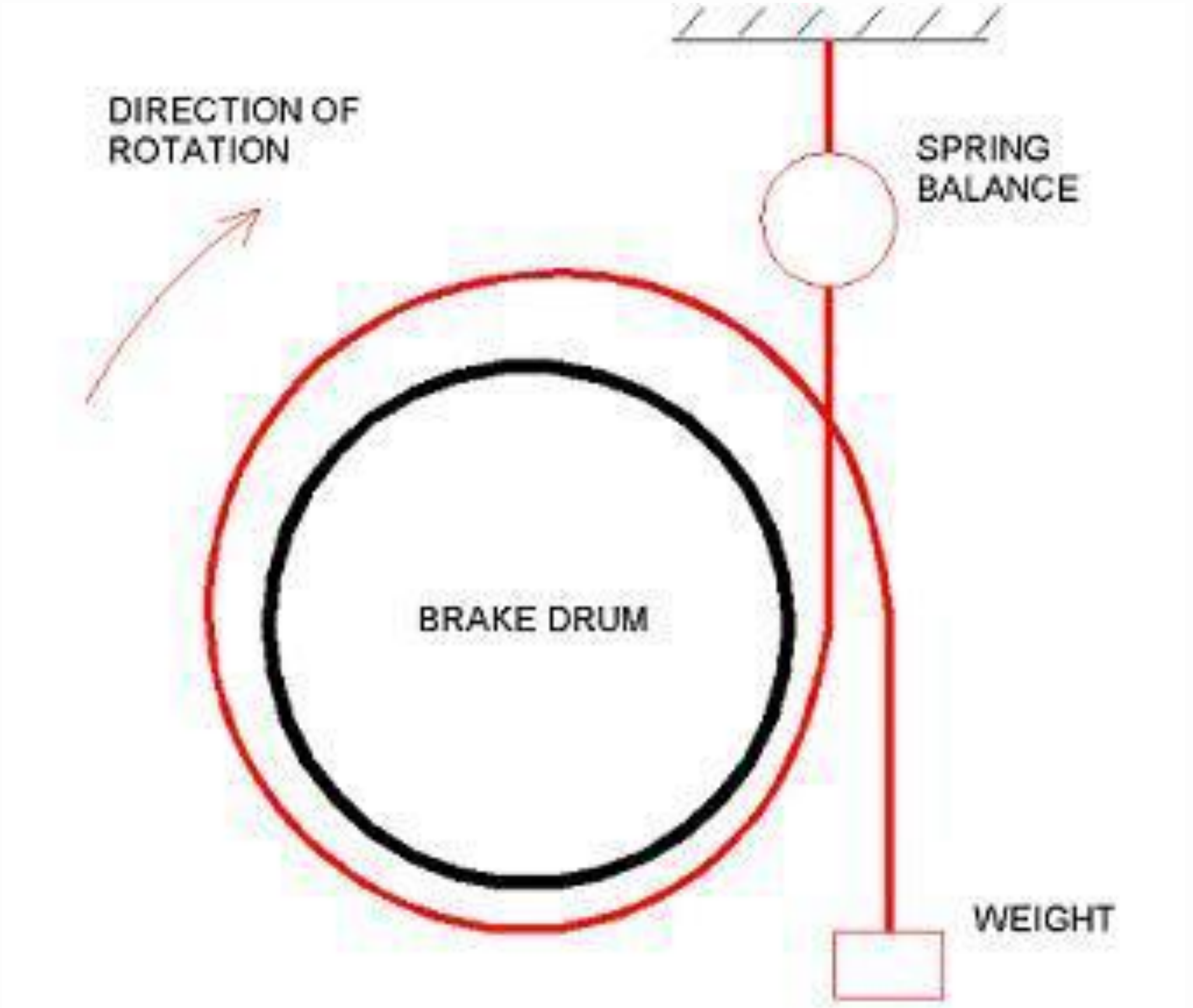
l=Base width of indicator diagram, cm

s= spring constant or spring value, $N/m^2/cm$

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

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

BRAKE DYNAMOMETER



HYBRID ELECTRIC VEHICLE

Hybrid Electric Vehicles

Overview

- What is an HEV?
- HEV objectives
- HEV advantages over conventional engines
- Motor components
- Vehicle propulsion
- Examples
- HEV Challenges
- Review

What is an HEV?

HEV – Hybrid Electric Vehicle

A vehicle that has two or more energy conversion technologies combined with one or more energy storage units.

HEV Objectives

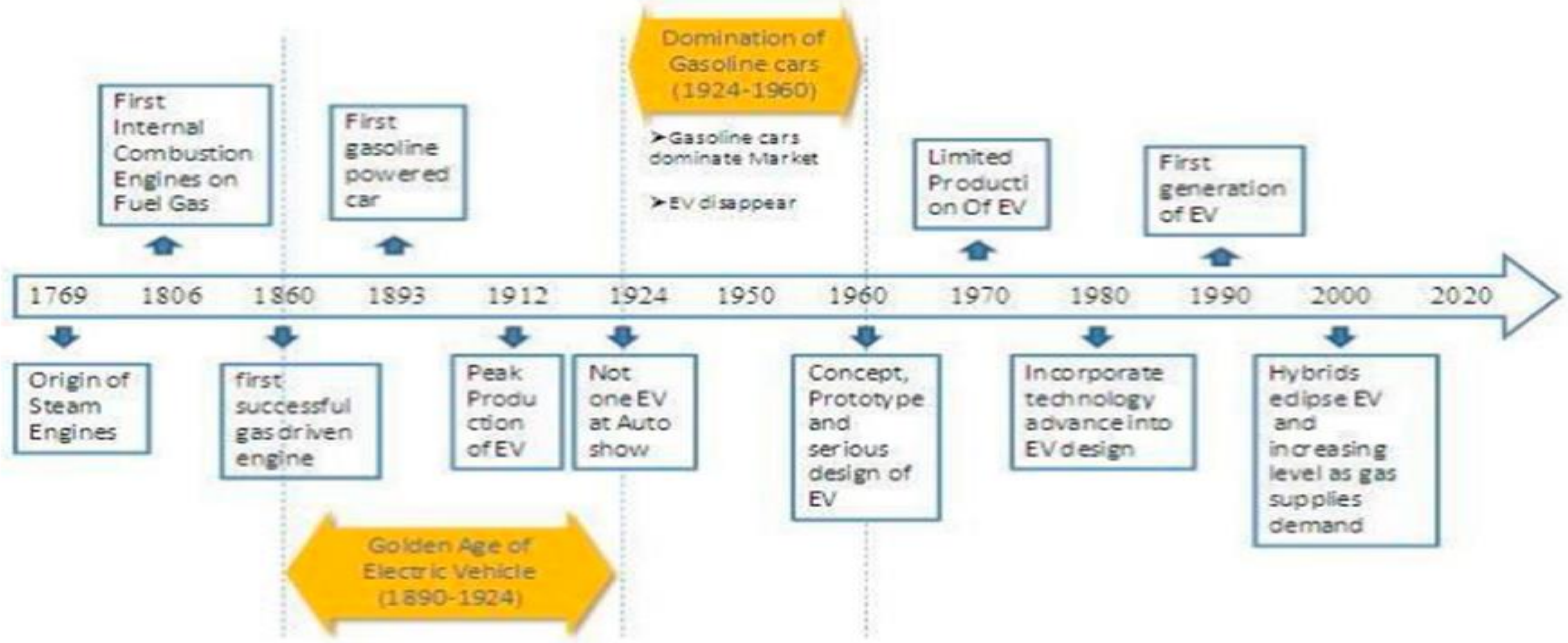
Objectives the HEV wants to obtain:

- Maximize fuel economy
- Minimize emissions
- Minimize propulsion system cost to keep affordable
- Maintain acceptable performance with a reasonable cost
- Reduce the conventional car weight

HEV Advantages Over Conventional Engines

- Regenerative Braking
- Reduction in engine and vehicle weight
- Fuel efficiency is increased
- Emissions are decreased
- Cut emissions of global warming pollutants by 1/3 or 1/2
- Reduce the dependency on fossil fuels
- Some states offer incentives with owning an HEV
- ~2 times more efficient than conventional engines

Hybrid Electric Vehicles



Historical development of automobile and development of interest and activity in the EV from 1890 to present day. Electric Vehicle merged into hybrid electric vehicle.

Well to Wheel Analysis

Well-to-wheels efficiency is **a combination of well-to-vehicle and vehicle-to-wheels efficiencies**

Well-to-wheel is a analysis of all the efficiencies right from fuel extraction to transportation to supply to storing in a fuel tank of a vehicle and tail pipe emissions.

EVs have zero tailpipe emissions, but emissions are produced by the source of electrical power, such as a power plant.

Direct and Well-to-Wheel Analysis

Well-to-wheel analysis **include all emissions** related to fuel production, processing, distribution and combustion

In case of gasoline, emissions are produced while extracting petroleum from the earth, refining it, distributing the fuel to stations, and burning it in vehicles

In case of electricity, most electric power plants produce emissions, and there are **additional emissions** associated with the extraction, processing, and distribution of the primary energy sources they use for electricity production

Batteries - Where it comes from and where it goes

Recycling and final disposal of batteries and its consequences on the environment is also considered even before manufacturing

Traction Motor

- **Traction motor** refers to a type of **electric motor.** A traction motor is used to make **rotation torque** on a machine

- Traction motors are used in **electrically** powered vehicles such as electric vehicles and electric locomotives

- The traction motor of EVs is responsible for **converting electrical energy to mechanical energy**

Selection of Traction Motor

- Matching of desired characteristics
- Good Performance
- Suitable mechanical & electrical features
- Economic & efficient starting
- Effective speed control
- Quick reversal of direction to function as generator

efficient regenerative braking

Characteristics of Traction Motor

Mechanical Characteristics

1. Mechanical

2. Electrical

- Robustness
  - Must be strong enough to withstand continuous vibration and other forces acting during running of train

- Light Weight
  - High power to weight ratio
  - Lesser the weight of motor, higher the operating efficiency

- Overall Size
  - The physical dimension of motor
    - Diameter of driving wheel
    - Width of track gauge
    - Ground clearance
  - Using high speed motor, overall size can be reduced

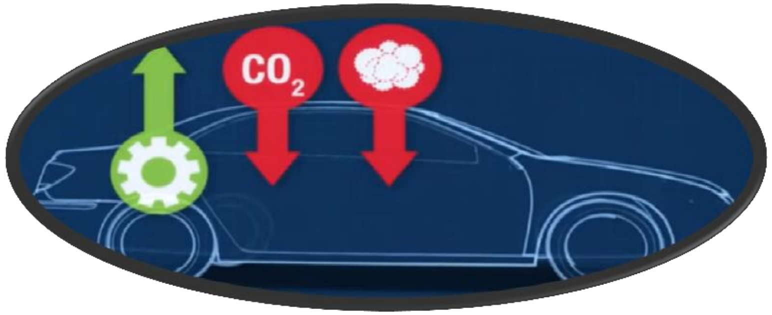
- Totally Enclosed
  - Protects itself against ingress of dirt, dust, mud water etc.

Electrical Characteristics

Selection of Traction Motor

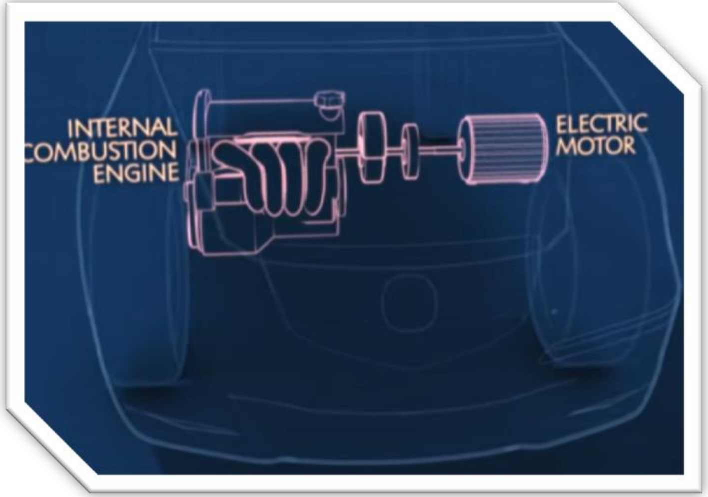
- High starting torque
  - Capable of developing high starting torque as train has to start with heavy load and accelerate to maximum speed
- Easy Electric Braking
  - Easy and simple method of dynamic or regenerative braking
- Parallel Running
  - Can be operated in parallel and mechanically coupled so as to share the load almost constant
- High Efficiency
  - High mechanical & electrical efficiency so as to improve its performance and reduce running cost
- Simple & Easy Speed Control
  - To start & stop frequently, easy, simple & economical speed control is preferred

Features of Hybrid Vehicle System



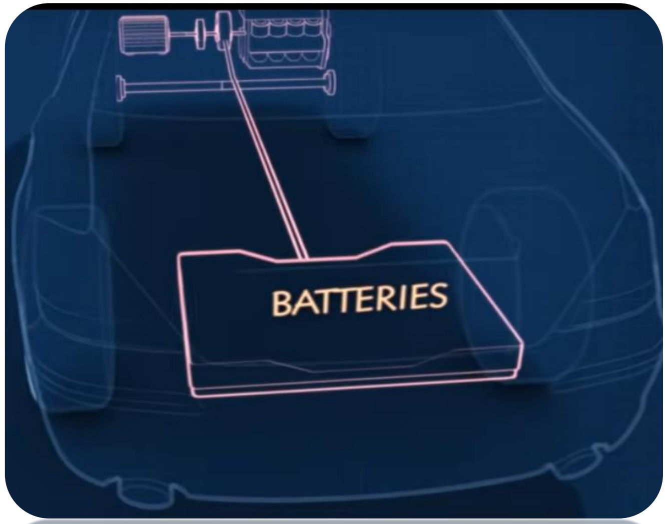
Less pollution, Lower Co2, reduced Green House Gas

Fuel and Electric energy



Internal Combustion engine and electric motor

Dual propulsion systems



Battery pack to drive electric motor

Advantages of Hybrid Drive trains

- Regenerative braking for energy conservation
- More efficient operation
- Smaller capacity ICE

reduces overall size

- Lower emissions & meet emission regulations
- Lower fuel consumption

Advantages of Hybrid Drive trains

HEVs are vehicles propelled by more than one power source such as an engine and electric motor. They are classified by type and level. The advantages of HEVs are improved fuel economy, efficiency, and reduced emissions. The disadvantage of HEVs is cost. The cost aspect may be offset in years to come due to higher gas prices and improved HEV technologies.

Hybrid electric vehicles are powered by an internal combustion engine and an electric motor, which uses energy stored in batteries. A hybrid electric vehicle cannot be plugged in to charge the battery. Instead, the battery is charged through regenerative braking and by the internal combustion engine.

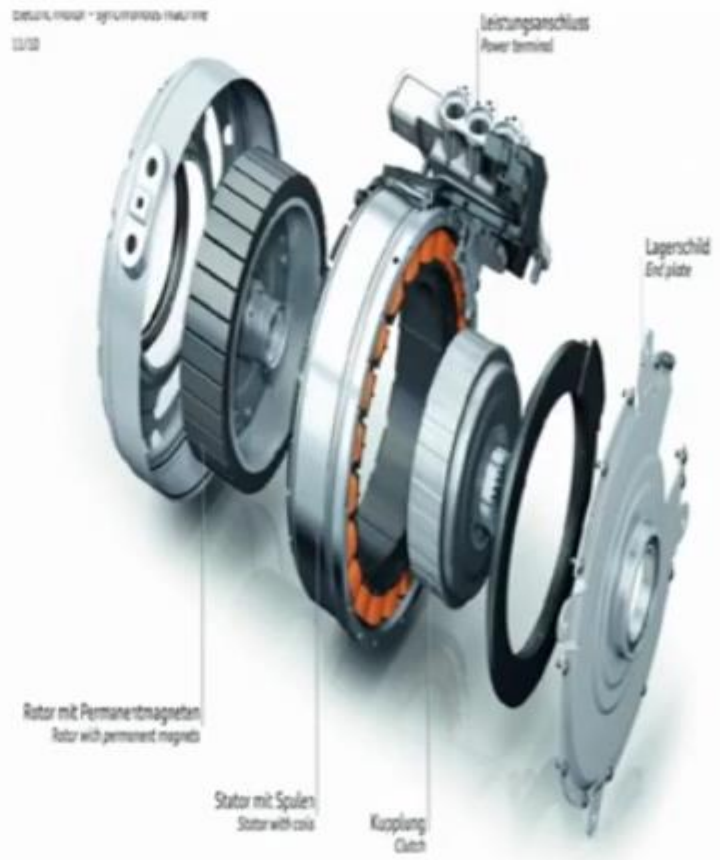
Advantages of Hybrid Drive trains

The extra power provided by the electric motor can potentially allow for a smaller engine. The battery can also power auxiliary loads like sound systems and headlights, and reduce engine idling when stopped. Together, these features result in better fuel economy without sacrificing performance.

COMPONENTS OF A HYBRID VEHICLE

Electric motor

- It transforms the electric energy stored in a battery into mechanical energy i.e. it drives wheels with the help of electricity stored in a battery.



COMPONENTS OF A HYBRID VEHICLE

Electric battery

- Its function is to store electric energy and supply it whenever necessary.

- 384 Volts
- 48 Modules
- 8V/Module
- 4 Cells/Module
- 24kW-Hr
- ≈63 Amp-Hrs

COMPONENTS OF A HYBRID VEHICLE

Inverter

- Electricity stored in an electric battery is in the form of Direct Current (DC) while the majority of the motors used in the present day hybrid vehicles require Alternating Current (AC) to run. So, an Inverter performs the function of converting the DC from the battery to AC for the motor.

COMPONENTS OF A HYBRID VEHICLE

DC/DC converter

- This device converts higher-voltage DC power from the traction battery pack to the lower-voltage DC power needed to run vehicle accessories and recharge the auxiliary battery.

COMPONENTS OF A HYBRID VEHICLE

Electric Generator (Exclusive for series & series-parallel hybrids)

- The function of a generator is to produce electricity when driven by an external power source. Series hybrids use this component where an IC engine drives a generator to produce electricity which then charges the battery.

COMPONENTS OF A HYBRID VEHICLE

Control Module

- It is the most important component of the hybrid vehicle. It controls the entire operation of the vehicle by synchronizing all the power sources employed.

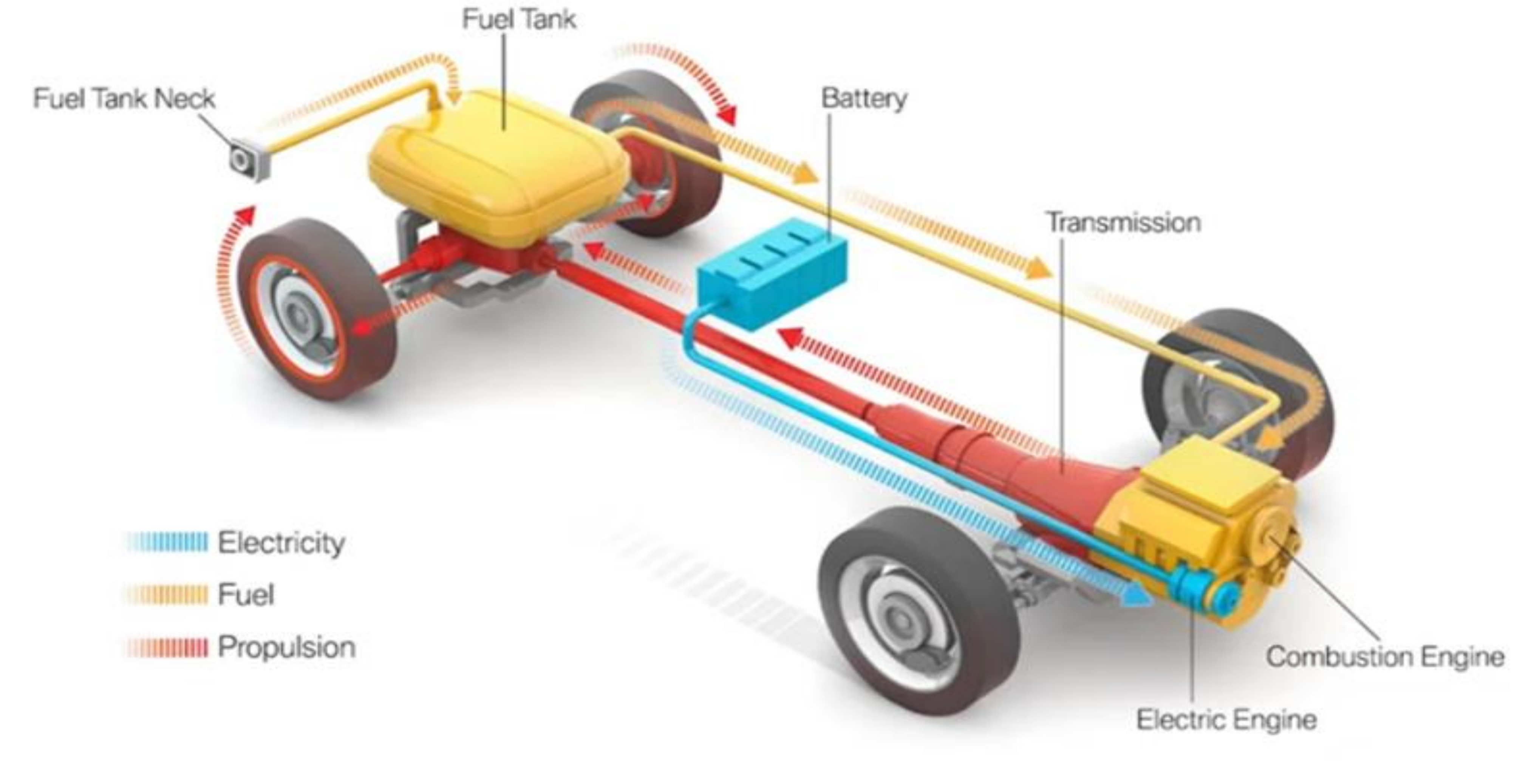
HYBRID ELECTRIC DRIVE TRAINS

The term hybrid vehicle refers to a vehicle with at least two sources of power

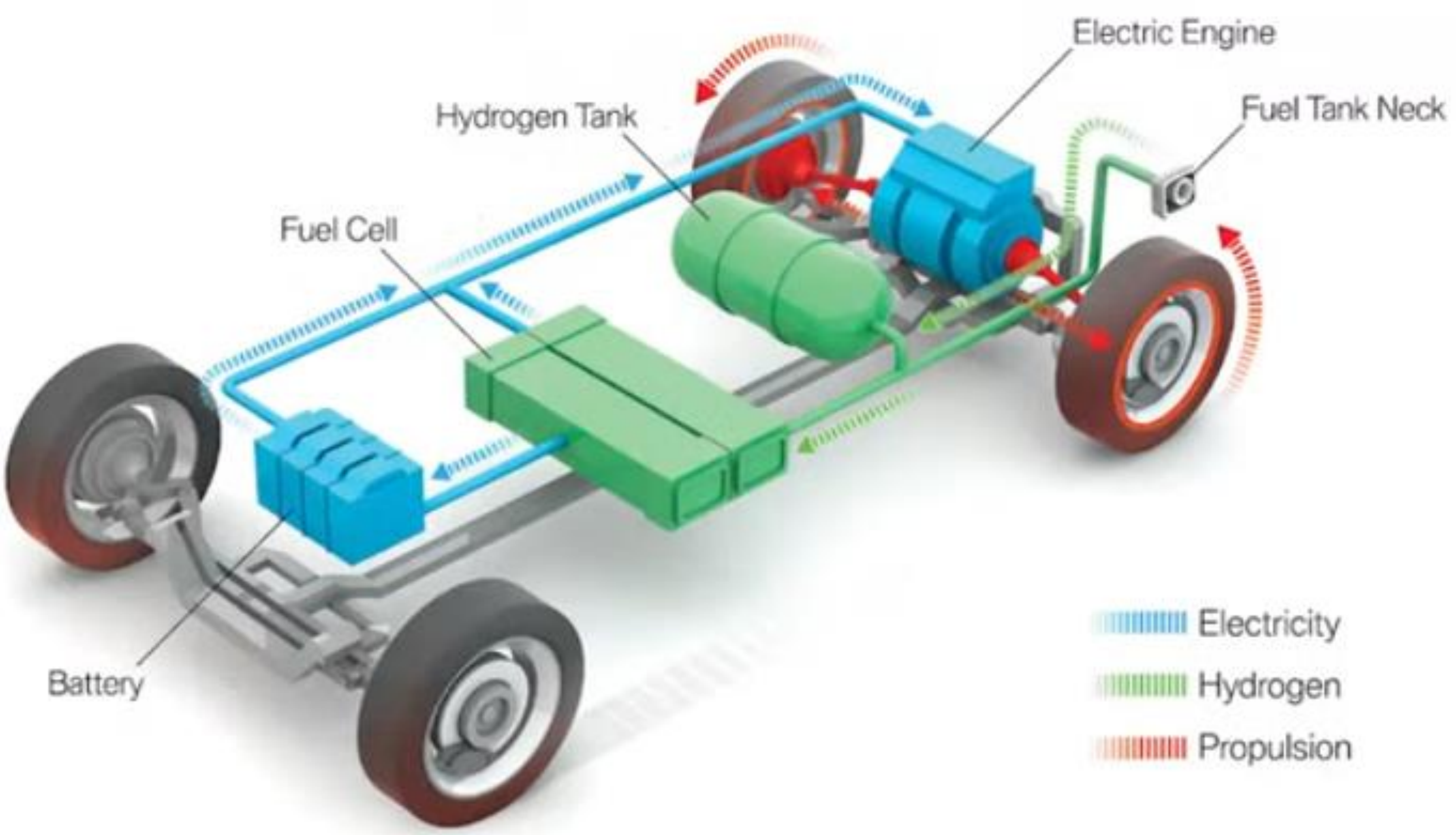
(i) one source of power is provided by an electric motor.

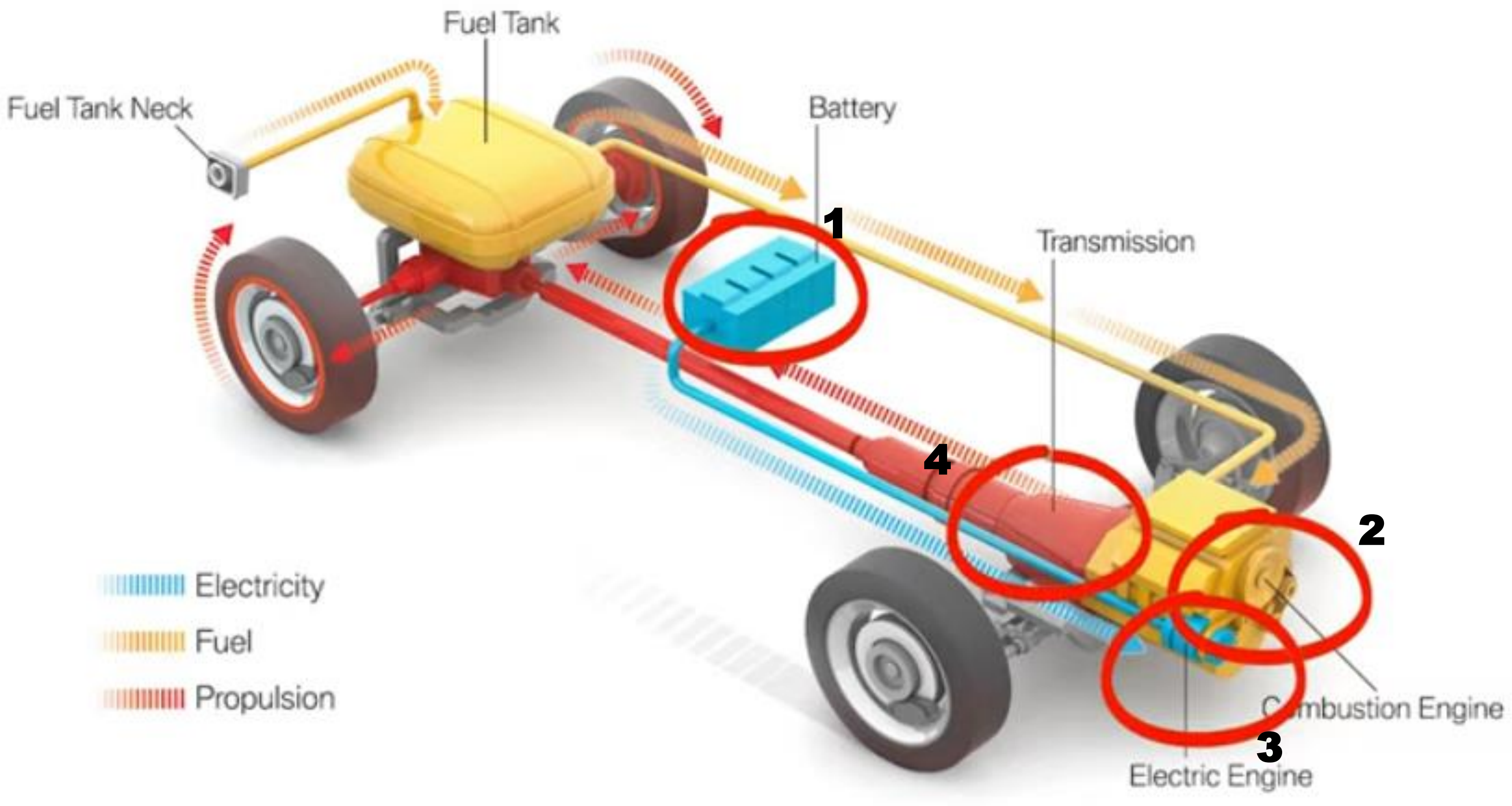
(ii) Second source, typically provided by an IC engine

Internal Combustion Hybrid Vehicle



Hydrogen power cell vehicles





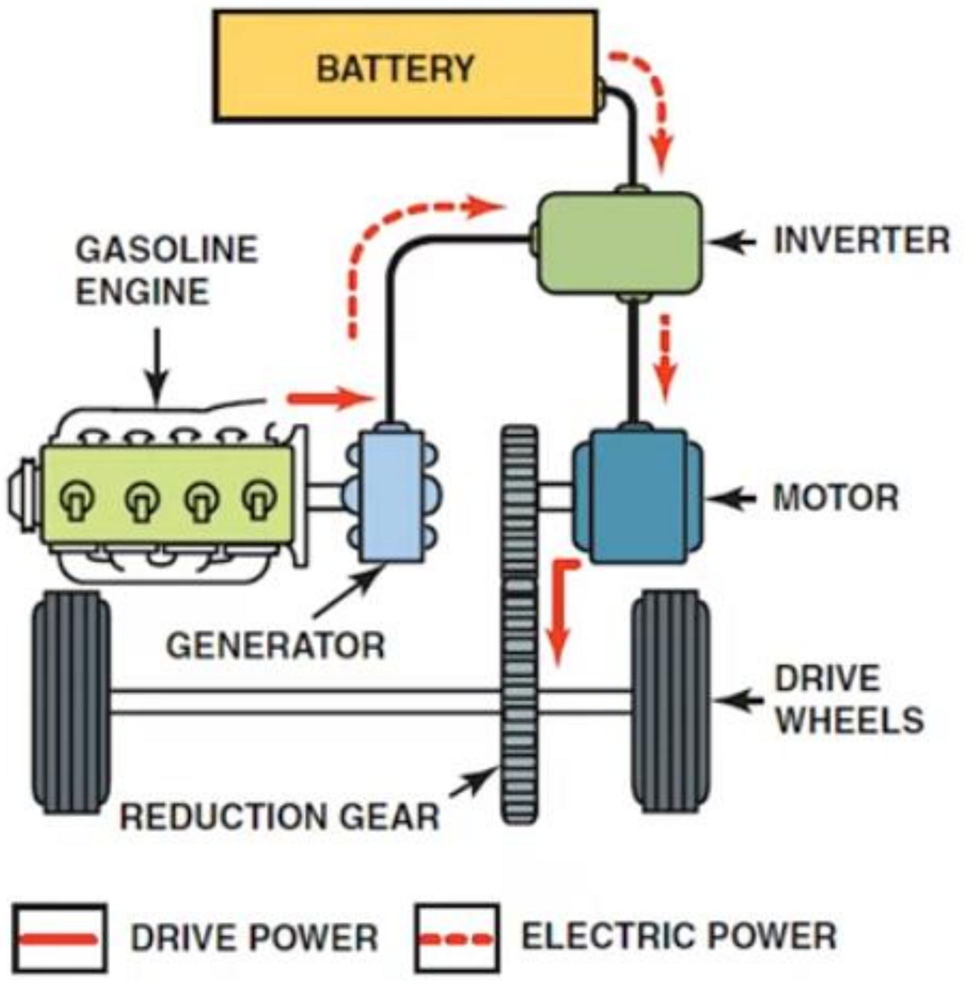
1. **Battery**
2. **IC Engine**
3. **Electric Motor**
4. **Generator**

Depending upon the "Structure of Drivetrain"

Hybrid vehicles are further classified as:

- Series Hybrid/ Micro Hybrid
- Parallel Hybrid
- Series-Parallel Hybrid/ Power split Hybrid

Series Hybrid Vehicle



- **Series hybrid is to couple the ICE with the generator to produce electricity for pure electric propulsion**
- **Mechanical output is first converted into electricity using a generator.**
- **Converted electricity either charges the battery or can bypass the battery to propel the wheels via the motor and mechanical transmission.**
- **Conceptually, it is an ICE assisted Electric Vehicle (EV).**

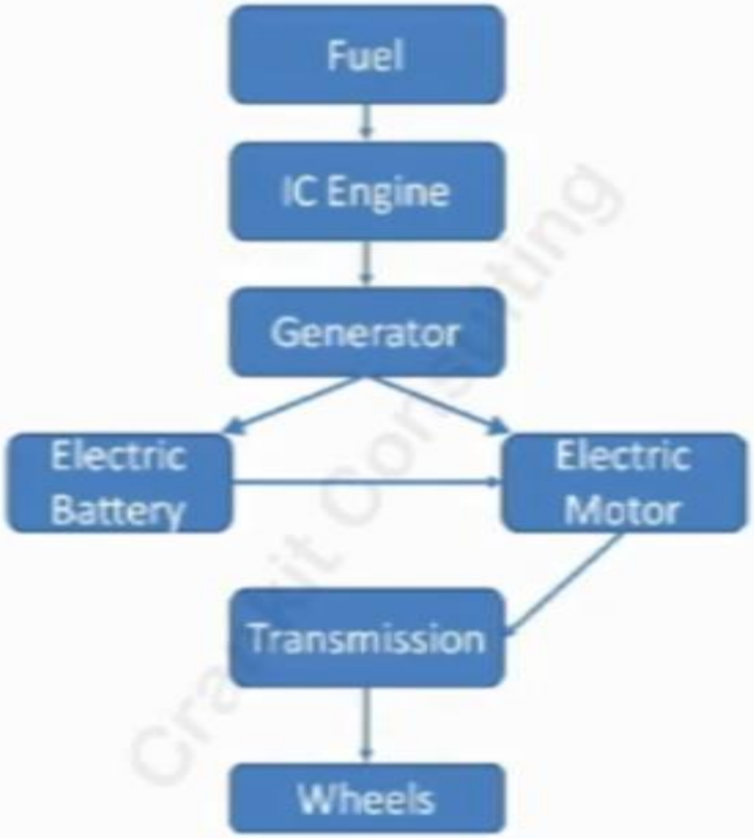
Series Hybrid Vehicle

1. Series Hybrid

In this type of hybrid vehicle, wheels are powered only by an Electric motor which ultimately derives its power from the electric battery. The IC engine installed in the vehicle does not supply power to wheels directly. So, these vehicles need large capacity batteries.

The series hybrid vehicle is more efficient in low-speed driving involving frequent start-stop.

A series hybrid is like a Battery Electric Vehicle (BEV) in design. Here, the combustion engine drives an electric generator instead of directly driving the wheels.



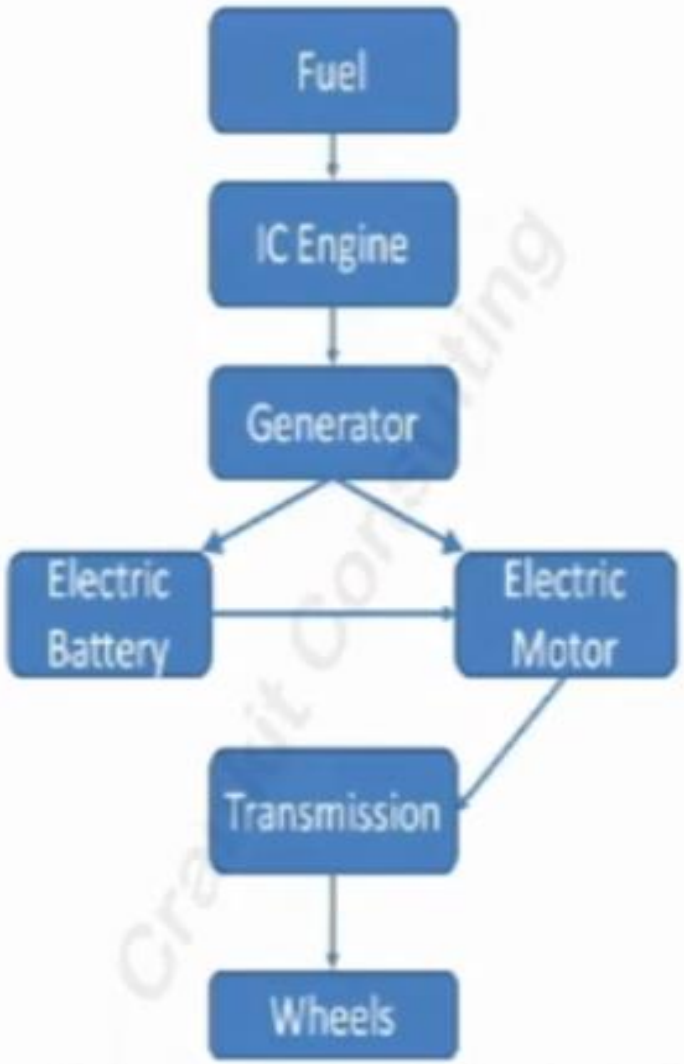
Schematic of a Series hybrid

Series Hybrid Vehicle

1. Series Hybrid

The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the battery and the generator.

Series hybrids may also be referred to as Extended-Range Electric Vehicles (EREVs) or Range-Extended Electric Vehicles (REEVs) since the gas engine only generates electricity to be used by the electric motor and never directly drives the wheels.



Schematic of a Series hybrid

ADVANTAGES

- No Transmission
- No clutch
- No torque converter
- Mechanical decoupling between the ICE and wheels allows IC engine operation at optimal
- Nearly ideal torque-speed characteristics of electric motor make multi-gear transmission unnecessary

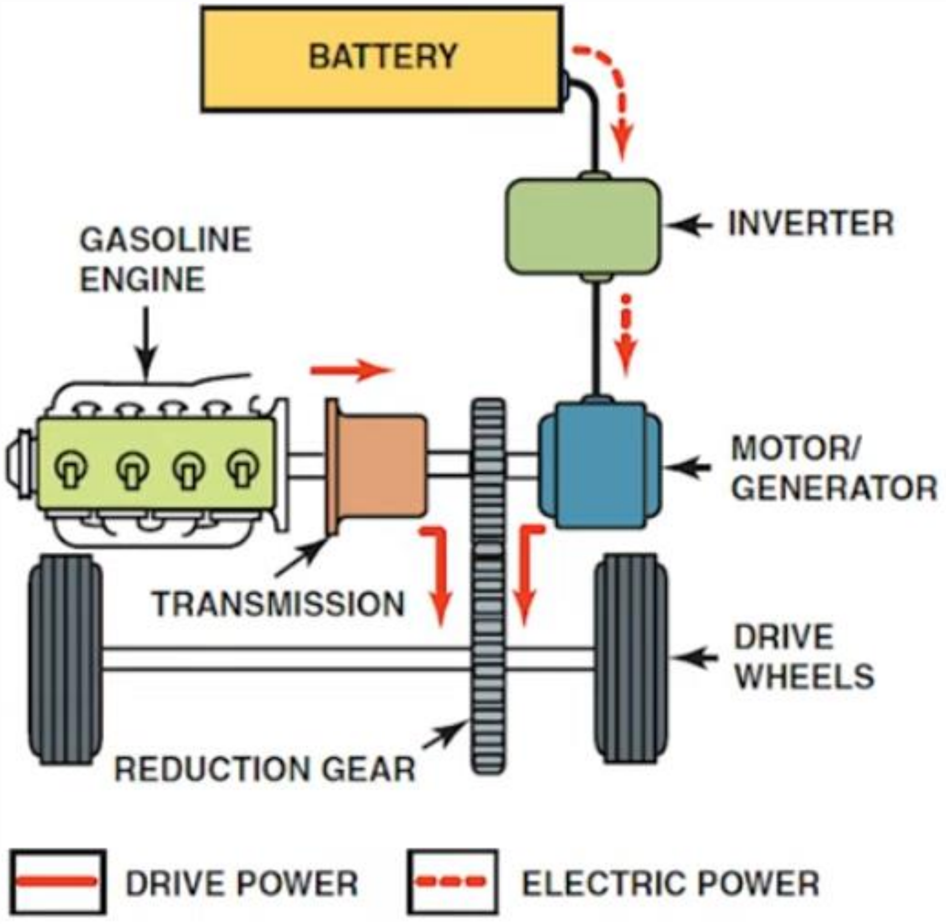
Dis-ADVANTAGES

- Energy is converted twice (mechanical to electrical and then to mechanical) and this reduces the overall efficiency
- Two electric machines are needed and a big motor is required because it is the only torque source of the driven wheels
- Completely dependent on battery power

Application: heavy commercial vehicles, military vehicles and buses.

Reason: large vehicles have space for the bulky engine/generator system

Parallel Hybrid Vehicle



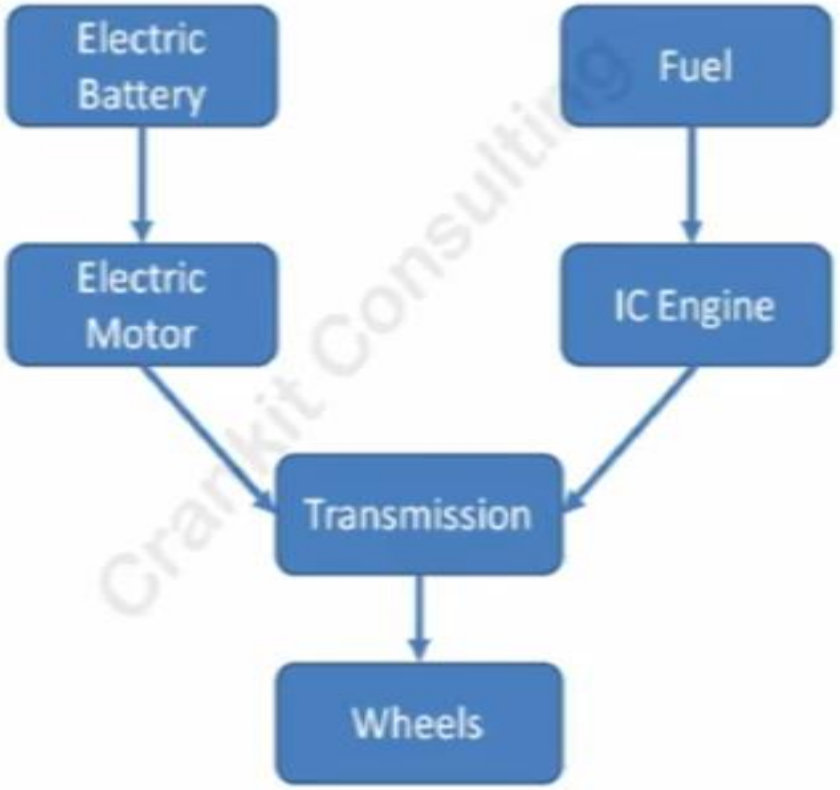
- Allows both ICE and Electric Motor (EM) to deliver power to drive the wheels
- Since both the ICE and EM are coupled to the drive shaft of the wheels via two clutches, the propulsion power may be supplied by ICE alone, by EM only or by both ICE and EM
- EM can be used as a generator to charge the battery by regenerative braking or absorbing power from the ICE when its output is greater than that required to drive the wheels.

Parallel Hybrid Vehicle

2. Parallel Hybrid

In this type of a hybrid vehicle, wheels get power from both the IC engine and an Electric Motor. The drivetrain of these vehicles is so designed that it can receive power from both the IC engine and Battery simultaneously. However, the IC engine serves as the main source of power in the Parallel hybrid vehicle.

As electric battery's role is only to support the engine, these vehicles need a smaller capacity battery. A parallel hybrid is more effective in high-speed driving.

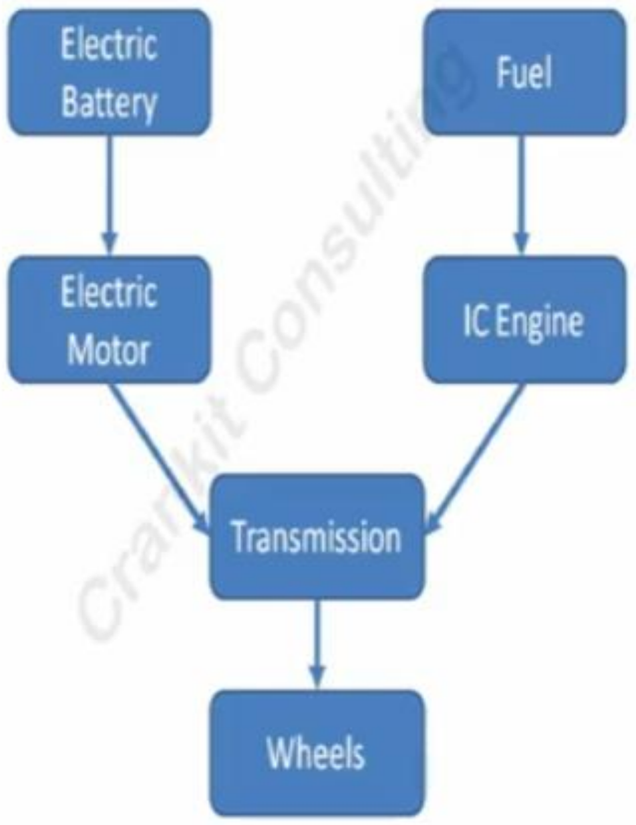


Schematic of a Parallel hybrid

Parallel Hybrid Vehicle

2. Parallel Hybrid

There is no separate generator in a parallel hybrid. Whenever the generator's operation is needed, the motor functions as a generator. In a parallel mild hybrid, the vehicle can never drive in pure electric mode. The electric motor turns on only when a boost is needed.



Schematic of a Parallel hybrid

ADVANTAGES

- Both engine and electric motor directly supply torques to the driven wheels and no energy form conversion occurs
- Compactness due to no both energy sources work in tandem leading to significantly less weight

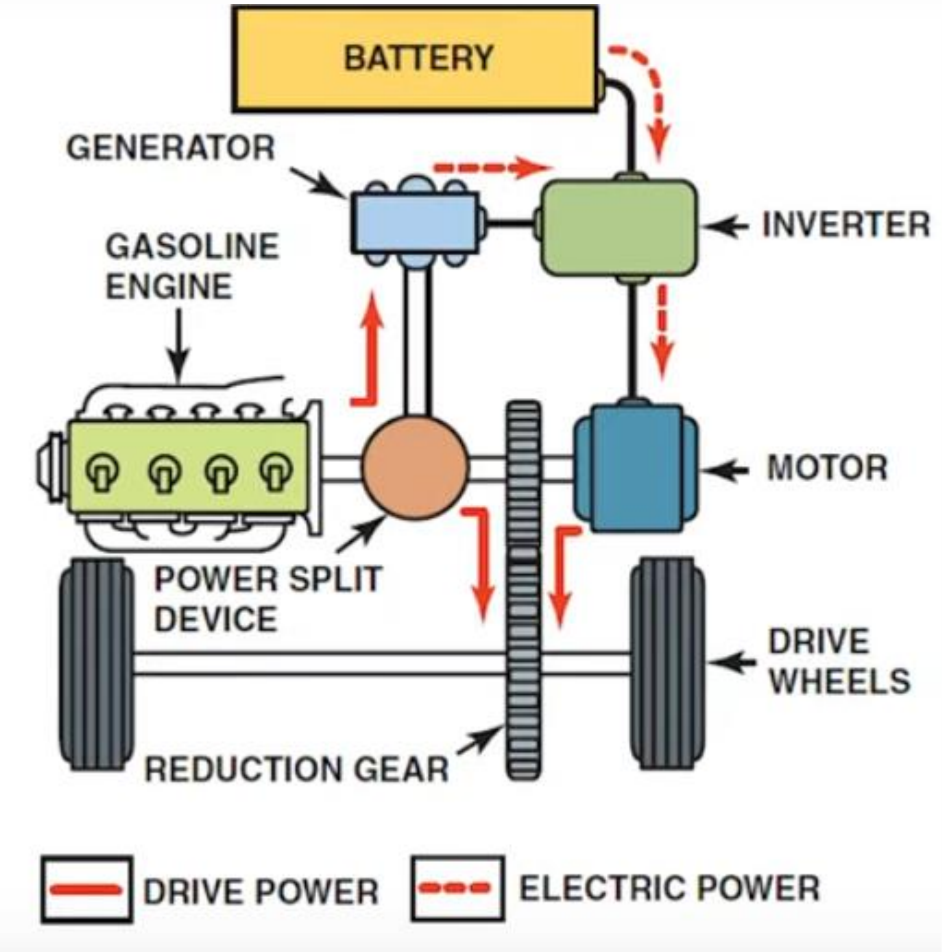
Dis-ADVANTAGES

- Mechanical coupling between the engine and wheels, thus the engine operating points cannot be fixed in a narrow speed region
- Mechanical configuration and the control strategy are complex compared to series hybrid drive train as seamless blending of energy from dual sources resulting in complex software and hardwares

Application: Due to its compact characteristics, small vehicles use parallel configuration.

Most passenger cars employ this configuration.

Series-Parallel Hybrid



- In the series-parallel hybrid (Figure), the configuration incorporates the features of both the series and parallel HEVs
- IC Engine is used to charge the battery as well as drive the wheels resulting in higher efficiency and performance.

However, this configuration needs an additional electric machine and a planetary gear unit making the control complex.

Series-Parallel Hybrid

3. Series-Parallel Hybrid/ Power split Hybrid

This recently developed system is a combination of a series hybrid system and parallel hybrid system. Thus, it takes the best from both the worlds. Depending upon the load on the vehicle, it can act like a parallel hybrid vehicle or a series hybrid vehicle. The control module governs the selection of the most suitable mode.

Based on the "Degree of Hybridization",

Hybrids are Classified into Two Groups:

1. Mild Hybrids/Micro Hybrids:

- These hybrids cannot run on electric battery alone. They always need the support of an IC engine to run as the battery used in these vehicles is of a small capacity.

- Use a battery and electric motor to help power the vehicle and can allow the engine to shut off when the vehicle stops (such as at traffic lights or in stop-and-go traffic), further improving fuel economy. Mild hybrid systems cannot power the vehicle using electricity alone. These vehicles generally cost less than full hybrids but provide less fuel economy benefits than full hybrids.

Based on the "Degree of Hybridization",

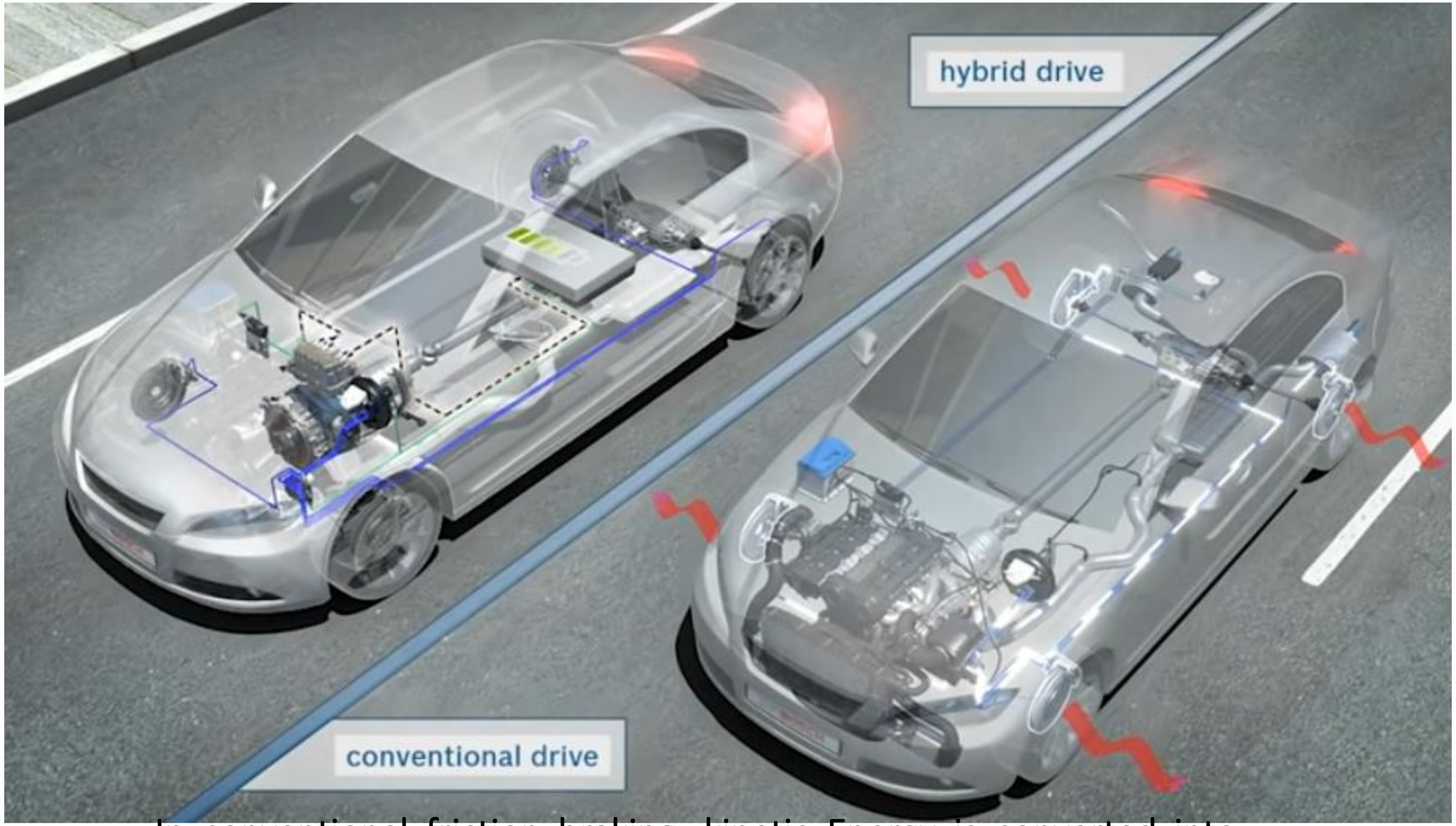
Hybrids are Classified into Two Groups:

2. Full Hybrids:

- This vehicle can run on either the IC engine or the electric battery alone as the battery used in them is of a higher capacity.

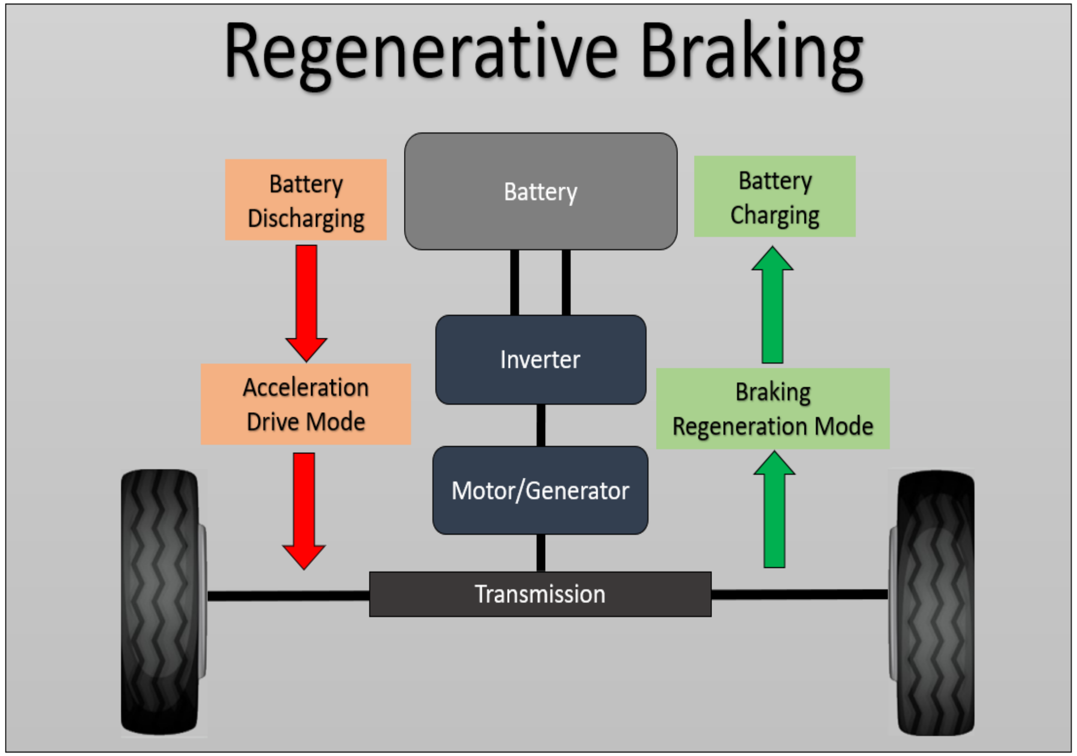
- Have larger batteries and more powerful electric motors, which can power the vehicle for short distances and at low speeds. These vehicles cost more than mild hybrids but provide better fuel economy benefits.

Regenerative Braking



In conventional friction braking, kinetic Energy is converted into heat energy and is released to the environment

Regenerative Braking principle

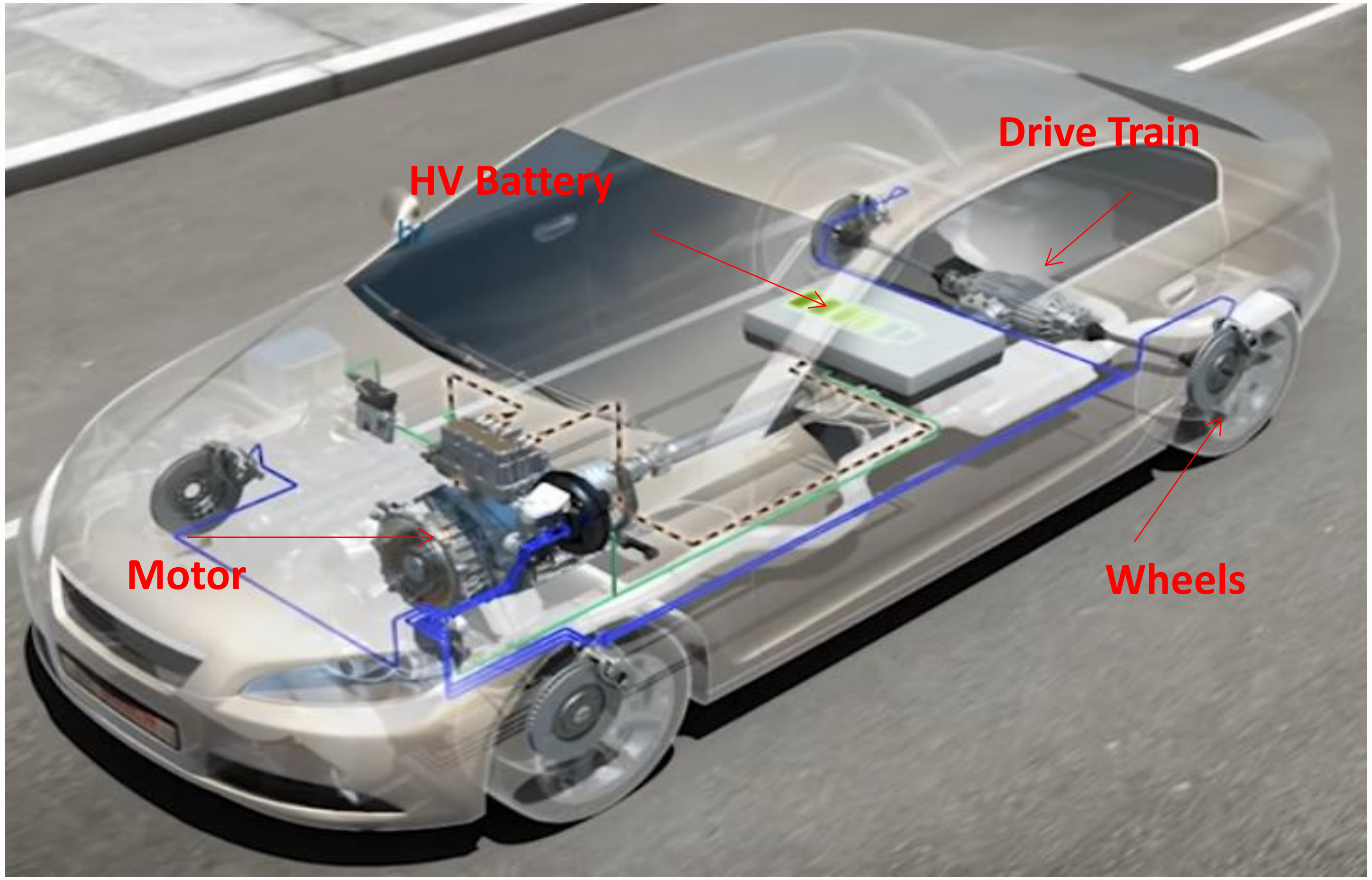


- Regenerative braking is the **recovery of Kinetic Energy (KE)** during braking
- HEV / EV can use the electric motor to **recover a portion of the KE**

Regenerative braking enables

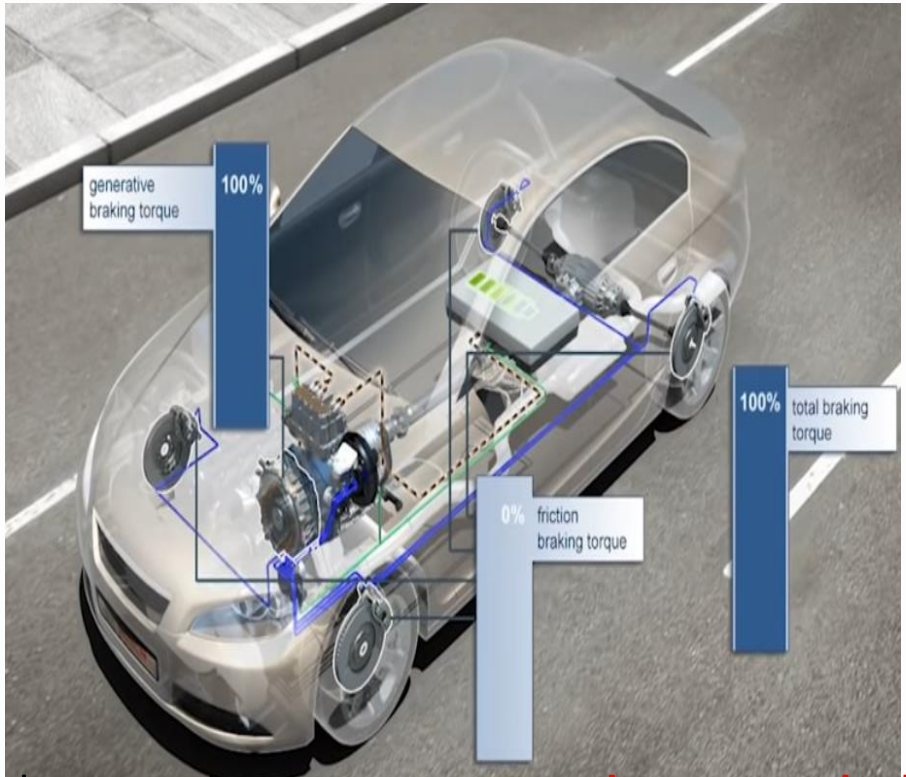
- **Extended range** in electric vehicles
- **Lower fuel consumption** and **Improve CO2 emissions** in hybrid vehicles

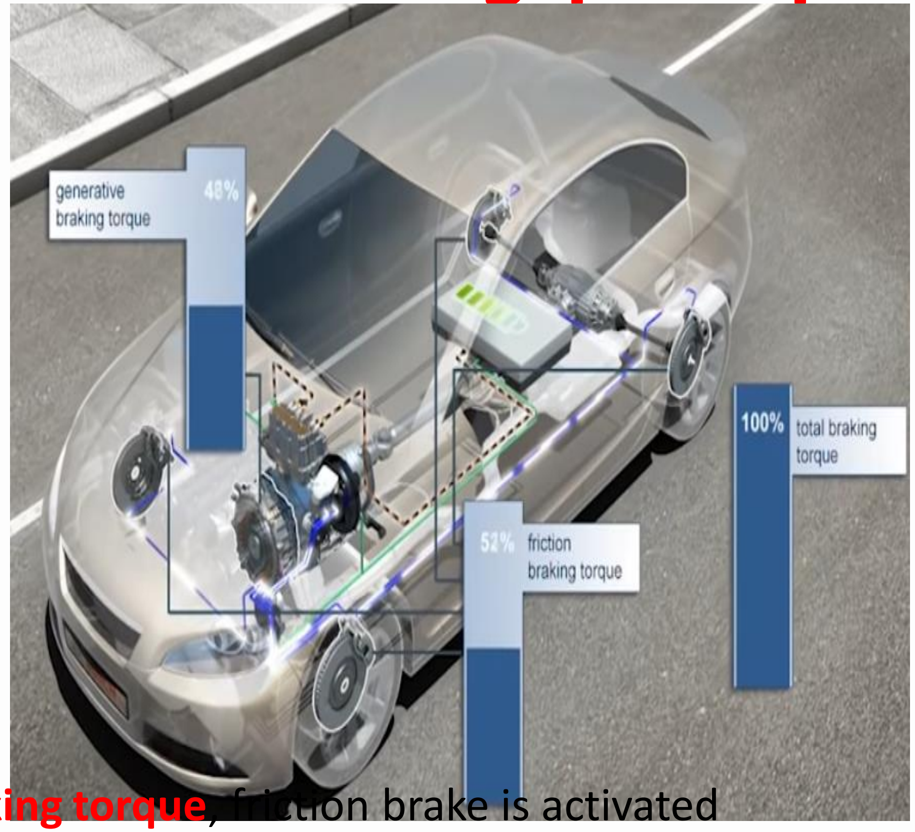
Regenerative Braking principle



- As the driver operates the brake pedal the **electr motor switches to generator mode**
- Wheels transfer the **kinetic energy through the drive train to the generator**
- Through the rotary motion, generator converts a portion of the **KE to electric energy**
- Generator braking torque **resulting in energy generation & decelerates the vehicle**

Regenerative Braking principle





- At low speeds, **generator can no longer supply the braking torque**, friction brake is activated
- **Motor controller** enables the switching to **generator mode**
- The braking torque is continuously adopted by the friction braking to the current generative braking torque – **Process called TORQUE BLENDING**

Regenerative Braking Advantages

Advantages of a Hybrid vehicle:

Switching to a hybrid car has many advantages, a few of which we have highlighted below:

- Environmentally Friendly
- Economical
- Less Fossil Fuel Dependent
- Regenerative Braking System
- Light Build
- Higher Resale Value

Regenerative Braking dis-Advantages

Disadvantages of a Hybrid vehicle:

- Less Power
- Expensive to Purchase
- Poorer Handling
- High Maintenance Cost
- High Voltage Batteries

Examples

Toyota Prius

Honda Insight

HEV Challenges

- Energy storage devices with high power-to-energy ratios
- Frequent shut down and start up of the HEV
- Reduce the size, weight, and cost
- Higher efficiency in the conversion of fuel to useful power
- Advanced configurations for the propulsion system components

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Thank you