Introduction to I.C. Engines and Electric Vehicles

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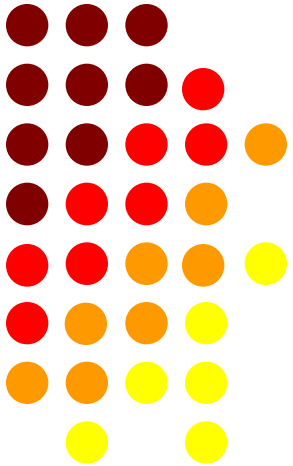
UNIT-2



SYLLABUS

- IC Engine: Basic definition of Engine and Components, Construction and Working of Two stroke and four stroke SI & CI engine, merits and demerits, scavenging process; difference between Two stroke and four stroke IC engines and between SI & CI engines

- Electric Vehicles and Hybrid Vehicles: Components of an EV, EV batteries, chargers, drives, transmission and power devices, Advantages and disadvantages of EVs, Hybrid Electric Vehicles, HEV drive train components, Advantages of HV.

Lecture No.9

Engine ?

- **It is a device which converts one form of energy into another form of useful energy.**

- Based on combustion engines are classified into

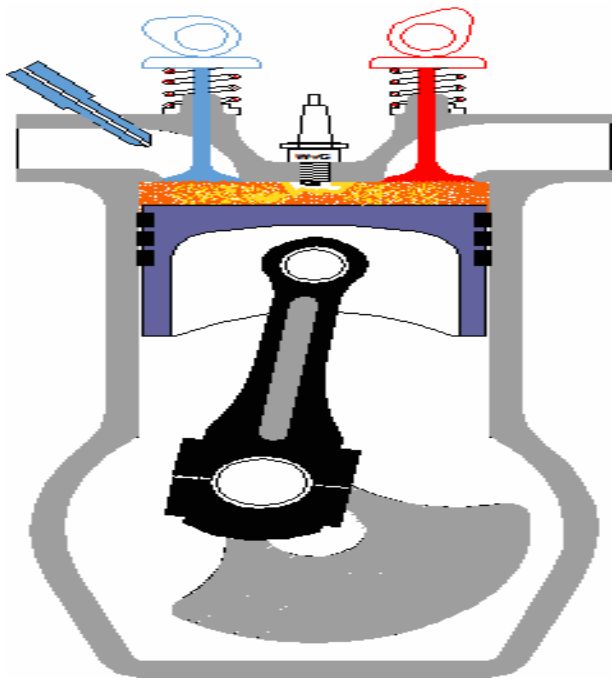
- **Internal Combustion Engine (I.C. Engine)**

- **External Combustion Engine (E.C. Engine)**

Internal Combustion Engine

- In internal combustion engine the burning or combustion of the fuel takes place **inside** the cylinder.

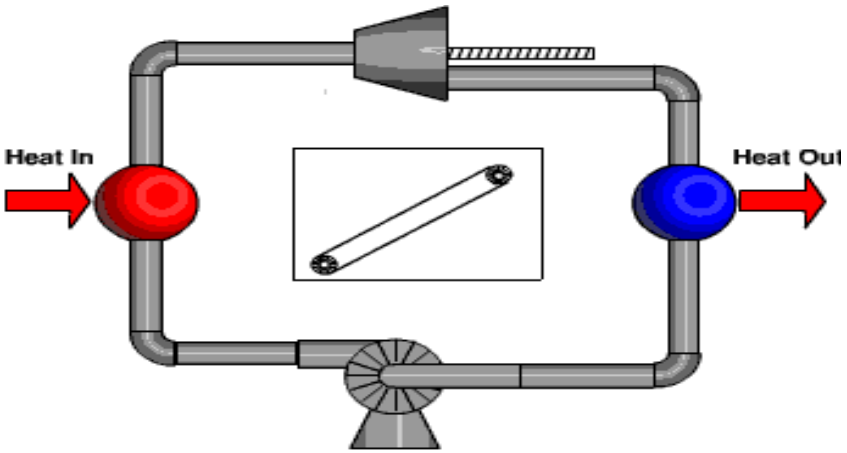
- **Example-** Automobile engines
  - **Petrol engine**
  - **Diesel engine**



External Combustion Engine

- In external combustion engine the combustion of the fuel takes place **outside** the engine.

- **Example- Steam engine, Closed gas turbine etc.**



Differences between ECE and ICE

S. No.	EC Engine	IC Engine
1	Combustion of fuel is outside the engine	Combustion of fuel is inside the engine
2	Bulky due to presence of auxiliary apparatus like boiler and condenser.	It is light and compact
3	High ratio of weight to power output	Low ratio of weight to power output
4	It can use cheaper fuels including solid fuels	High grade fuels are used with proper filtration
5	Higher requirement of water for dissipation of heat	Lesser requirement of water
6	Lower efficiency about 15-20%	Higher efficiency about 35-40%
7	Silent operation due to outside combustion	Very noisy operated engine

Advantages of I.C. Engine

- **These are the advantages of an I.C. Engine-**

- Mechanical Simplicity
- **Low initial cost due to absence of boiler, turbine condenser etc.**
- High efficiency than external combustion engine
- **Power to weight ratio is high**
- Very suitable for small power requirement applications
- **Starting time is very less**
- Requires less maintenance

Disadvantages of I.C. Engine

- **These are the disadvantages of an I.C. Engine-**

- Variety of fuels that can be used is limited to very fine quality gaseous and liquid fuel.
- **Fuel used is very costly like gasoline or diesel.**
- Engine emissions are generally high compared to external combustion **engine**.
- **Not suitable of large scale power generation**.
- In case of reciprocating internal combustion noise is generated due to detonation.

Classification of I.C. Engine

- **On the basis of strokes used**
  - Two Stroke cycle Engines
  - Four Stroke Cycle Engines

- **On the basis of cycle used**
  - Otto Cycle Engines
  - Diesel Cycle Engines
  - Dual Cycle Engines

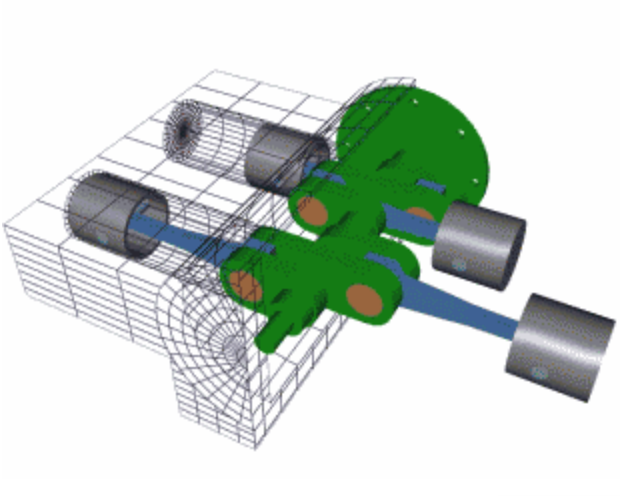
- **On the basis of types of fuel used**
  - Petrol Engines
  - Diesel Engines
  - Gas Engines

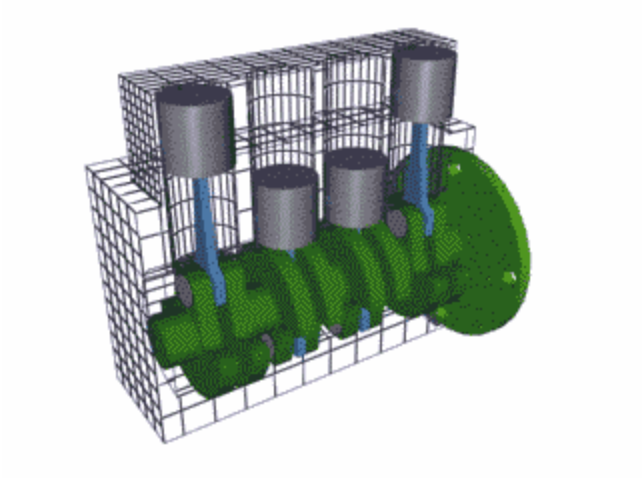
Classification of I.C. Engine……

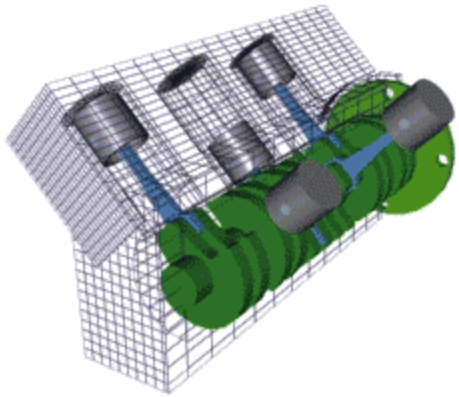
- **On the basis types of Ignition Method :**
  - Spark Ignition (SI)
  - Compression Ignition (CI)

- **On the basis types of cooling system used:**
  - Air cooled engines
  - Water cooled engines

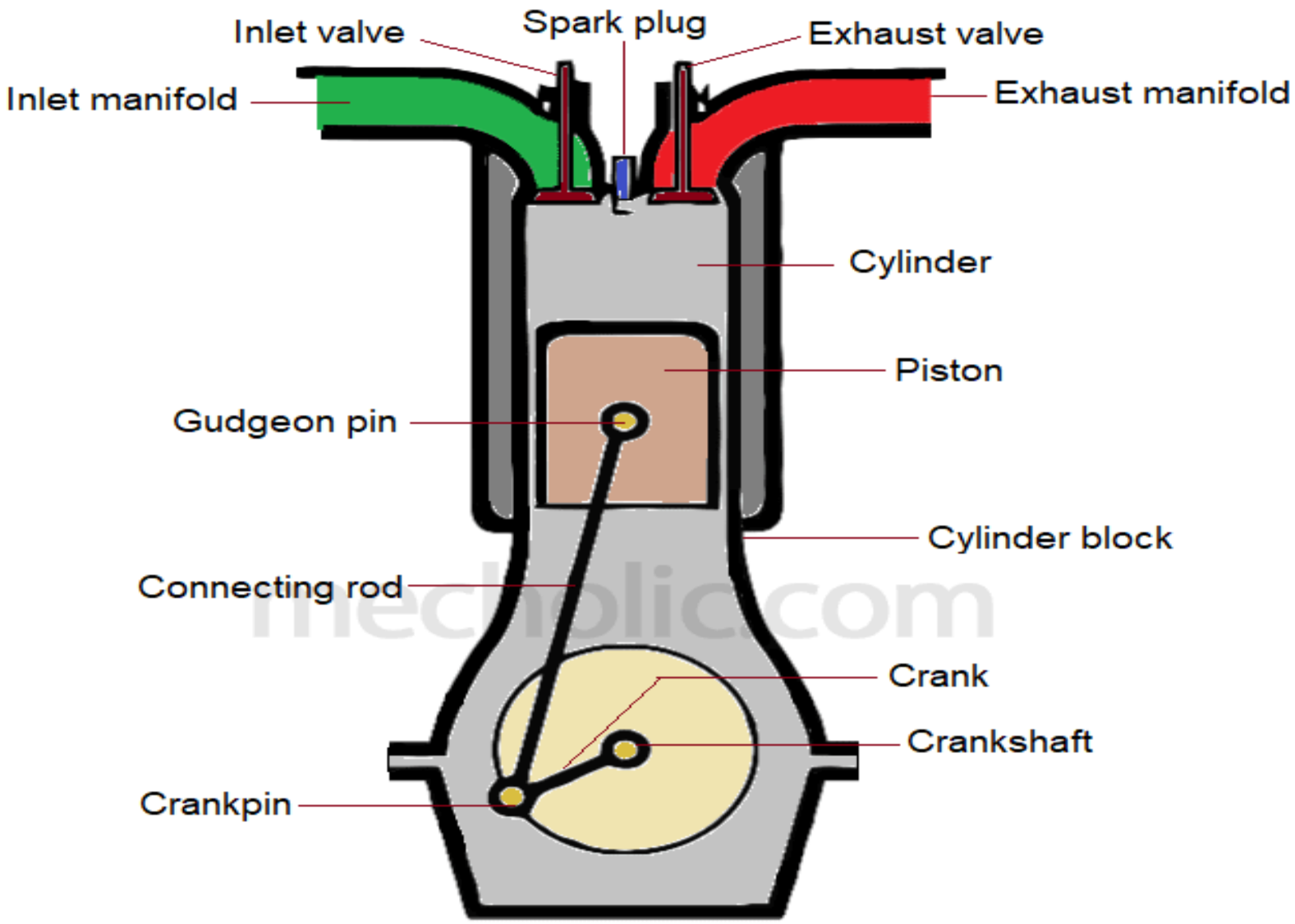
- **On the basis types of different position of cylinder engines:**
  - Horizontal cylinder engines
  - Vertical cylinder engines
  - Inclined cylinder engines







Main Components of I.C.E.



Main Components of I.C.E.....

Lecture No. 10

Lecture No. 10

❖ Content:

- IC Engine terminology
- Construction and Working of four stroke **SI** engine
- Construction and Working of four stroke **CI** engine

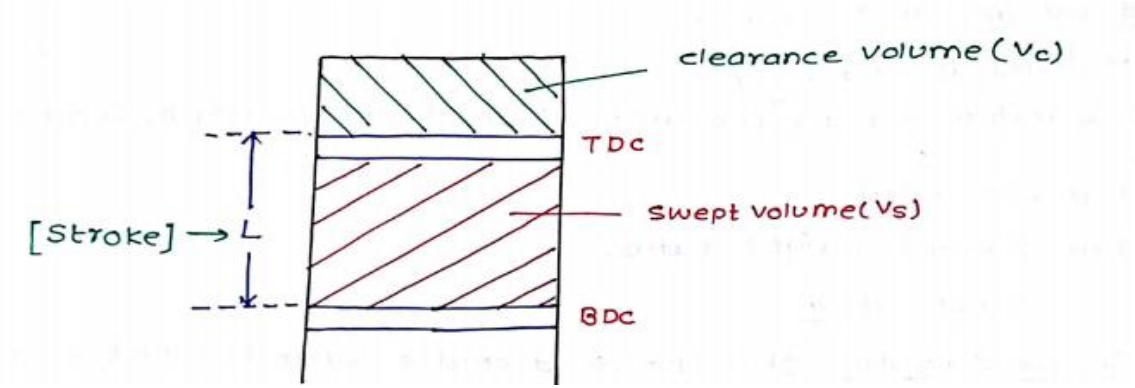
TDC and BDC

Top-Dead-Center (TDC): It is position of the piston when it is farthest from the crank shaft.

Note:-In case of horizontal engine **TDC** is known as inner dead center(**IDC**)

Bottom-Dead-Center (BDC): It is the position of the piston when it is nearest to the crankshaft.

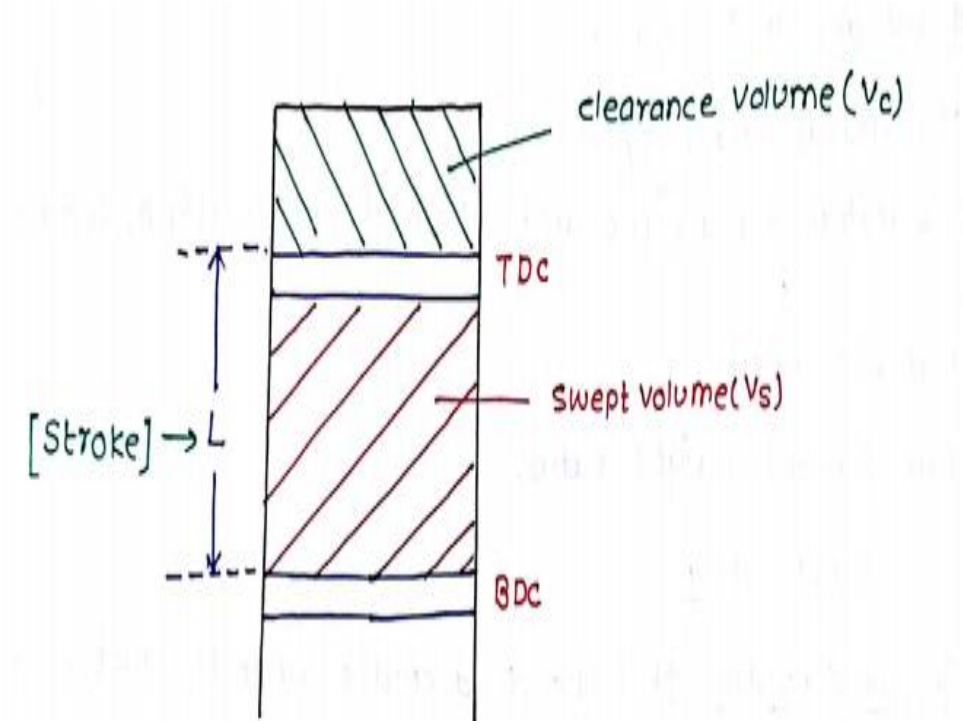
Note:-In case of horizontal engine **BDC** is known as outer dead center(**ODC**)



Stroke and Stroke length

Stroke: When piston moves from **TDC to BDC** or **BDC to TDC** is known as stoke.

Stroke Length (L): It is the distance between TDC and BDC.



Bore, Swept volume and Clearance Volume

Bore (D): Inner diameter of the cylinder or diameter of the piston face.

Swept Volume (V_s): Volume displaced by the piston as it travels through one stroke.

$$V_S = \frac{\pi}{4} D^2 \mathrm{L}$$

If there are K no. of cylinders then total swept volume

$$V_S = K \frac{\pi}{4} D^2 \mathrm{L}$$

Clearance Volume (V_c): It is the volume of the cylinder when piston is at TDC or IDC, therefore it is **minimum volume.**

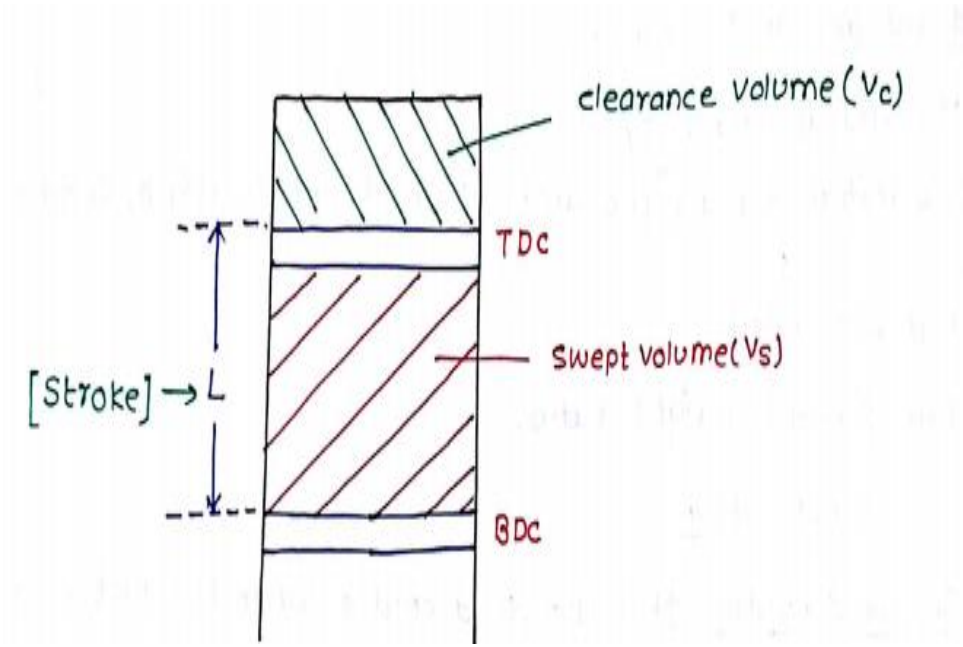
Compression ratio(r)

"It is defined as the ratio of volume before compression to the volume of after compression."

volume before compression = $\mathbf{V_C + V_S}$

volume after compression = $\mathbf{V_C}$

$$\mathbf{r} = \frac{V_C + V_S}{V_C}$$



Four Stroke Engines

- Cycle operations (Intake, Compression, Expansion or power and Exhaust) completed in **four strokes** of the piston or two revolution **(720º)** of the crank.

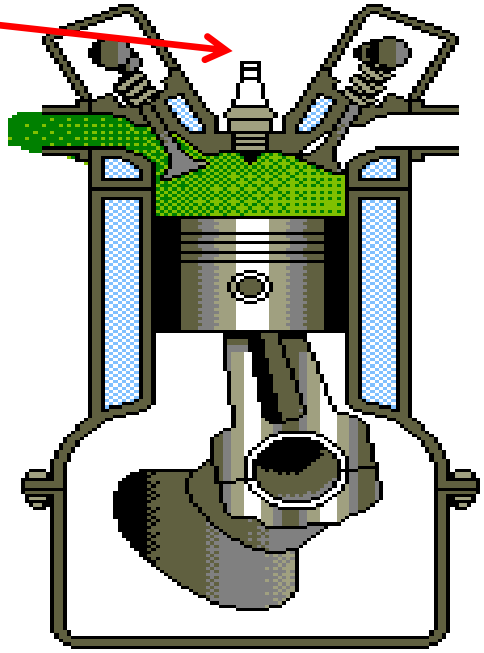
- **Four Stroke Engines may be SI or CI.**

SI : Spark ignition

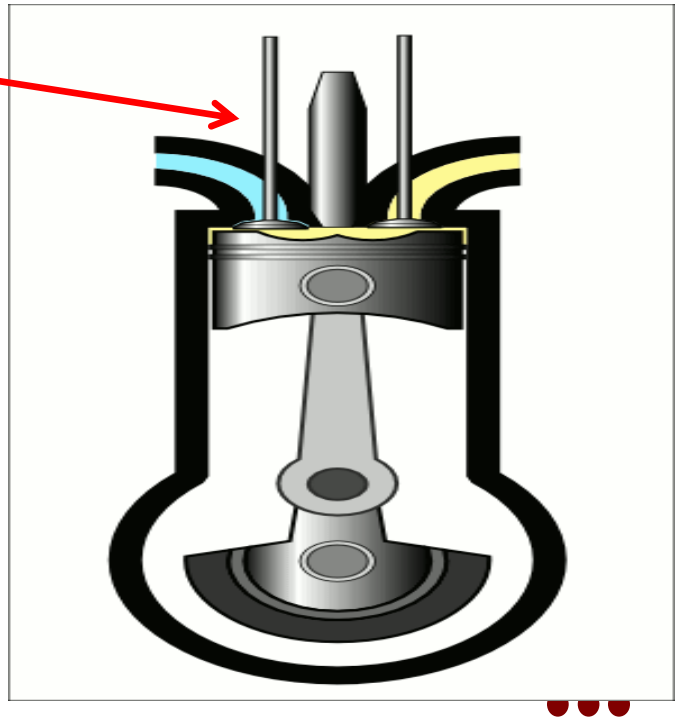
CI : Compression ignition

S.I. & C.I. Engines

Spark Plug



Fuel Injector



Intake

Compression

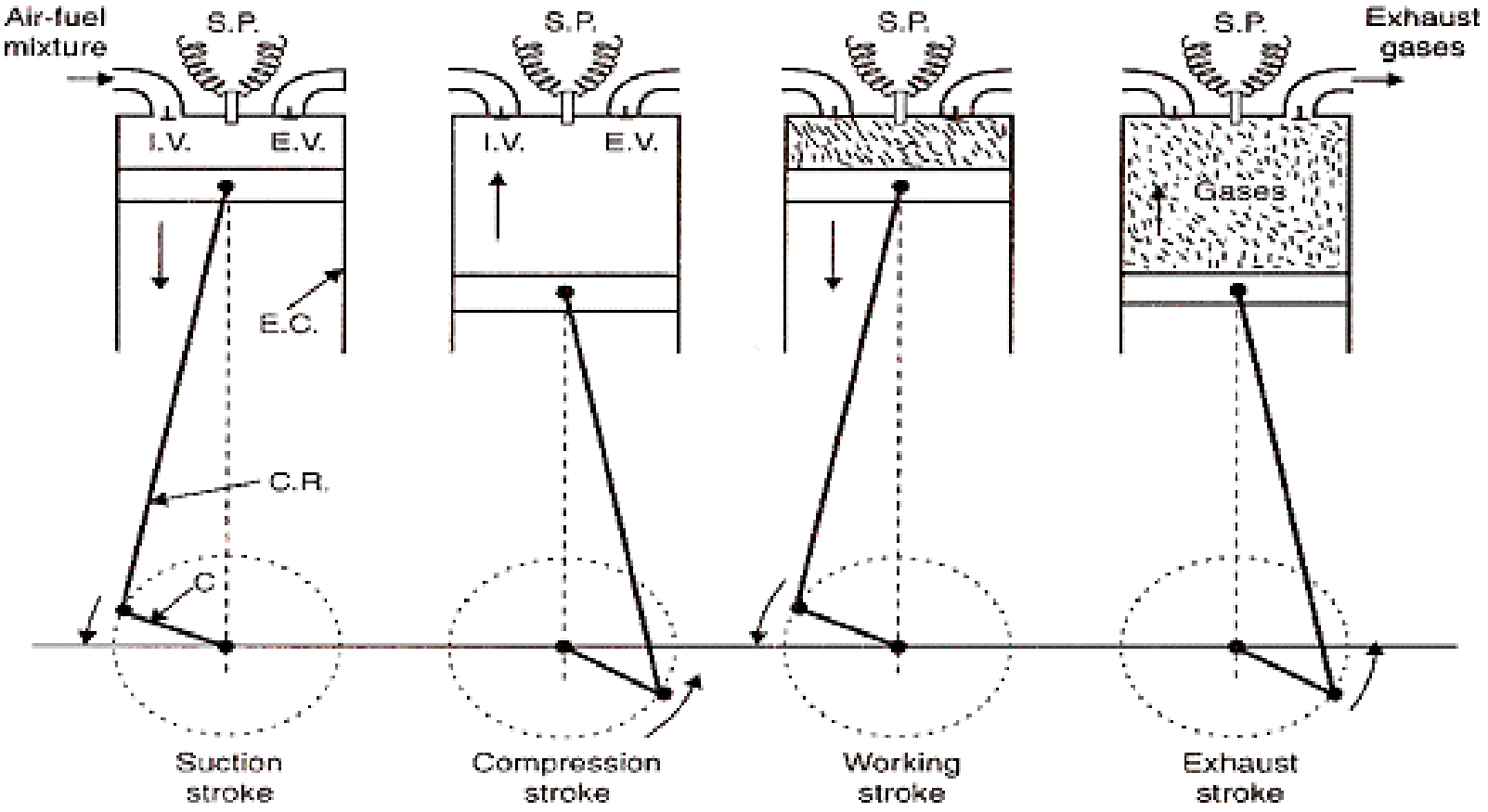
Expansion

Exhaust

Sparked Ignition
S.I. Engine

Compressed Ignition
C.I. Engine

Working of Four Stroke SI Engines



I.V = Intel valve, E.V. = Exhaust valve, E.C. = Engine cylinder, C.R. = Connecting rod
C = Crank, S.P. = Spark plug.

Working

- **Suction Stroke:**
  - Piston moves down from TDC to BDC.
  - **Inlet valve is opened and the exhaust valve is closed.**
  - Pressure inside the cylinder is reduced below the atmospheric pressure.
  - **The mixture of air fuel is sucked into the cylinder through the inlet valve.**

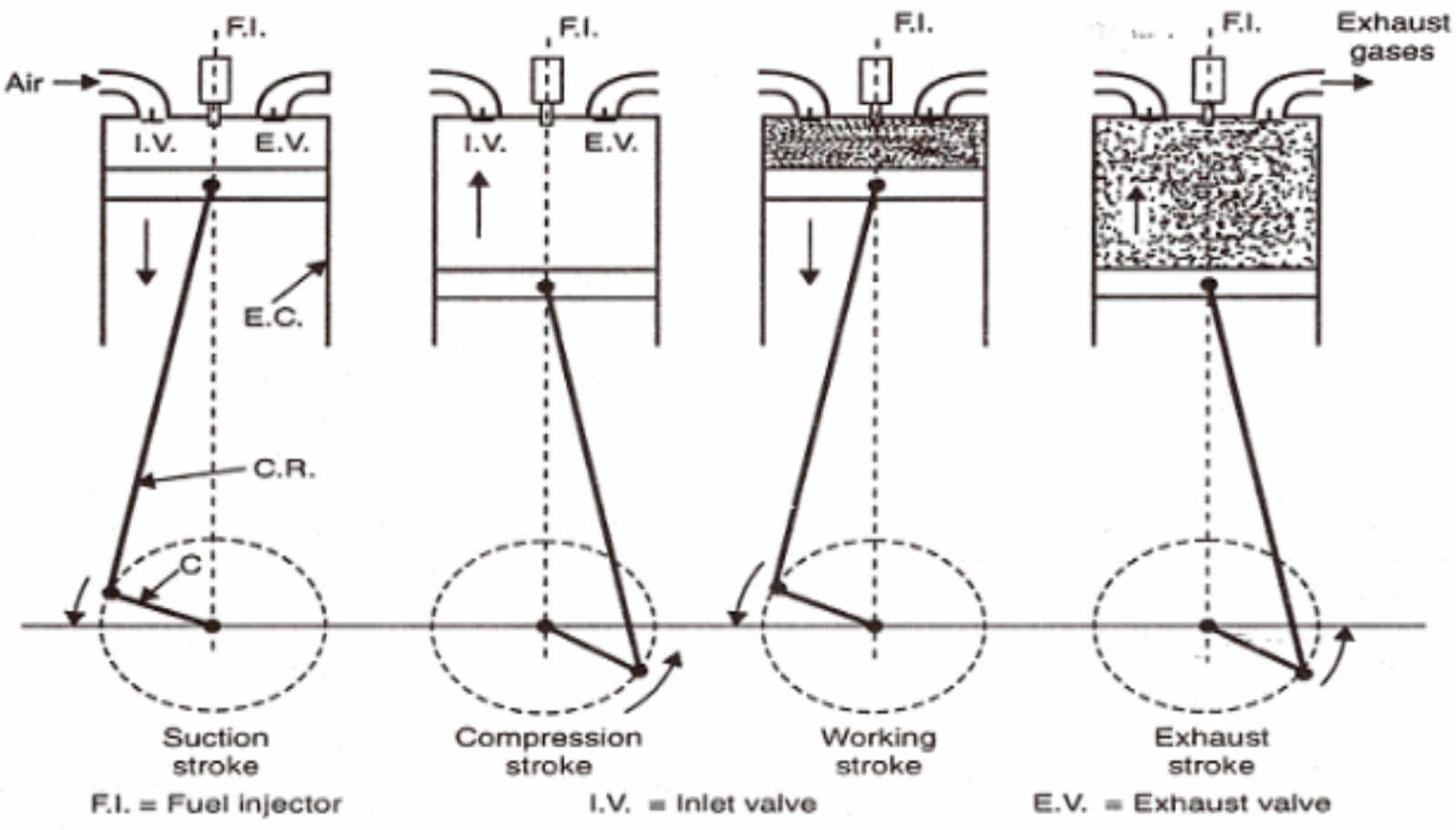
- **Compression Stroke:**
  - Piston moves up from BDC to TDC.
  - **Both inlet and exhaust valves are closed.**
  - Temperature and pressure increased due to compression of air fuel mixture in the cylinder.

Working…….

- **Power or Expansion Stroke:**
- The burning gases expand rapidly.
- Gases exert an impulse (thrust or force) on the piston.
- The piston is pushed from TDC to BDC.
- This reciprocating motion of the piston is converted into rotary motion of the crankshaft through connecting rod.
- **Both inlet and exhaust valves are closed.**

- **Exhaust Stroke:**
- Piston moves upward from BDC to TDC.
- **Exhaust valve is opened and the inlet valve is closed.**
- The burnt gases are forced out to the atmosphere through the exhaust valve.
- The inlet valve opens slightly before TDC and the cylinder is ready to receive fresh charge to start a new cycle.

Working of Four Stroke CI Engines



Working

Suction Stroke:

- Piston moves from TDC to BDC.
- Inlet valve is opened and the exhaust valve is closed.
- The pressure inside the cylinder is reduced below the atmospheric pressure.
- Fresh air from the atmosphere is sucked into the engine cylinder through air cleaner and inlet valve.

Compression stroke:

- Piston moves from BDC to TDC.
- Both inlet and exhaust valves are closed.
- The only air is drawn during suction stroke is compressed to a high pressure and temperature.

Working……

- **Power or expansion stroke:**
- Fuel (**diesel**) is injected inside the cylinder with the help of fuel injector.
- The burning gases expand rapidly and push the piston from TDC to BDC.
- This movement of piston is converted into rotary motion of the crank shaft through connecting rod.
- **Both inlet and exhaust valves are closed.**

- **Exhaust Stroke:**
- Piston moves from BDC to TDC.
- **Exhaust valve is opened the inlet valve is closed.**
- The burnt gases are forced out to the atmosphere through the exhaust valve.
- The inlet valve opens slightly before TDC and the cylinder is ready to receive fresh air to start a new cycle.

Differences between SI Engines and CI Engines

S. No.	SI Engine	CI Engine
1	It works on OTTO Cycle or constant volume heat addition.	It works on DIESEL Cycle or constant pressure heat addition.
2	During the intake or suction process, air and fuel are used.	During the intake or suction process, only air is used.
3	The fuel used Petrol which is highly volatile. Self Ignition temperature is high.	The fuel used Diesel which is low volatile. Self-ignition temperature is low.
4	The fuel is supplied by Carburetor.	The fuel is supplied by Injector.
5	The maintenance cost is low.	The maintenance cost is high.
6	It is used in Small Vehicles.	It is used in Heavy Vehicles.
7	The compression ratio is 6 to 10.	The compression ratio is 16 to 22.
8	The starting of this engine is easy.	Starting is a little difficult comparatively SI engine.
9	It produces less noise.	It produces high noise.
10	Lower thermal efficiency because of the low compression ratio.	High thermal efficiency because of the high compression ratio.

Lecture No. 11

LECTURE-11

Content:

- Construction and Working of two stroke **SI** engine
- Construction and Working of two stroke **CI** engine
- Scavenging process

Two Stroke Engines

- Cycle operations (Intake, Compression, Expansion or power and Exhaust) completed in **two strokes** of the piston or one revolution **(360^o)** of the crank.

- **Two Stroke Engines may SI or CI.**

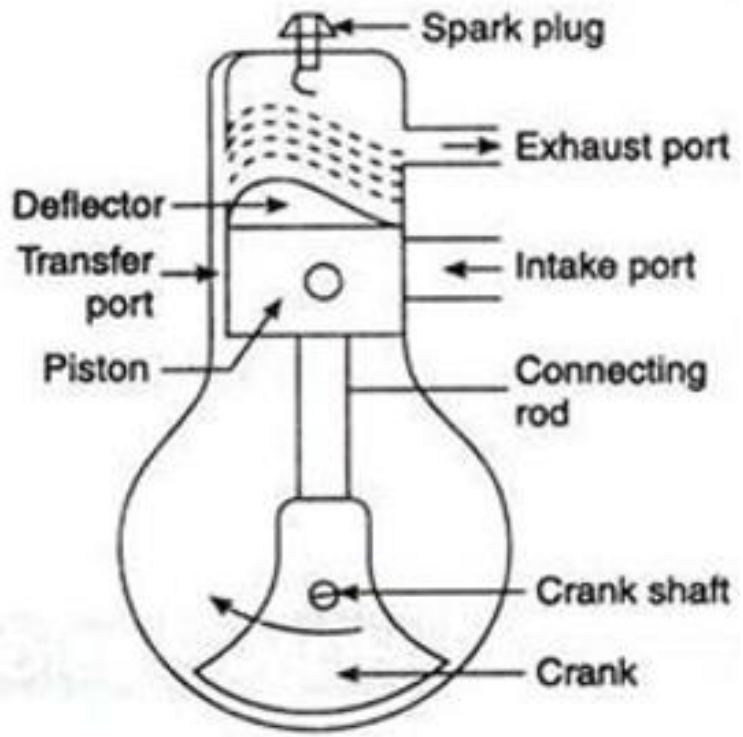
SI : Spark ignition

CI : Compression ignition

Working of Two Stroke SI Engines

❖ Compression and Suction:

- The piston moves from (BDC) to (TDC).
- **Both transfer and exhaust ports are covered by the piston.**
- Air fuel mixture is compressed by moving piston. The pressure and temperature increases at the end of compression.



Working……

❖ Compression and Suction……

- As piston almost reaches the top dead center. The air fuel mixture inside the cylinder is ignited by means of an electric spark produced by a spark plug.

- At the same time, the inlet port is uncovered by the piston. Fresh air fuel mixture enters the crankcase through the inlet port.

Working……

❖ **Expansion and Exhaust:**

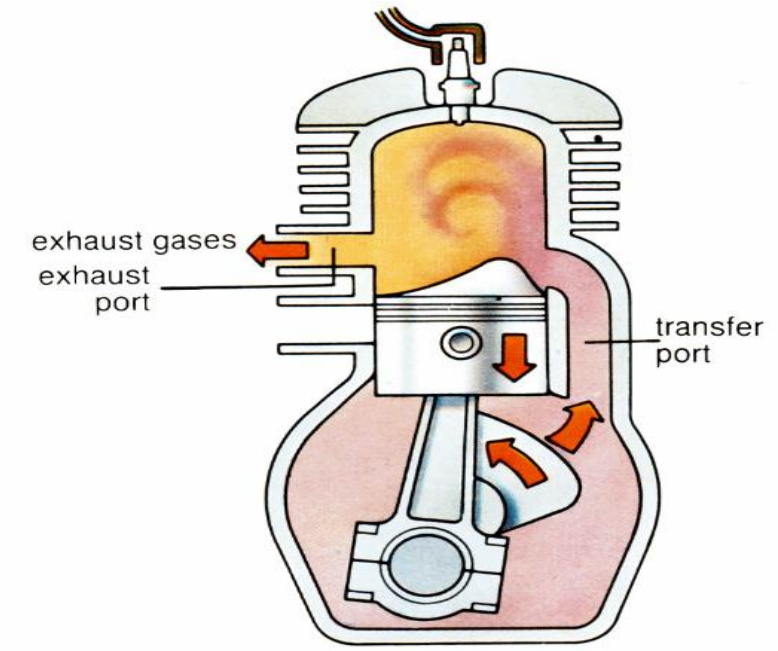
- The burning gases expand in the cylinder. The burning gases force the piston to move down. Thus useful work is obtained.

- **When the piston moves down, the air fuel mixture in the crankcase is partially compressed.**
- This compression is known as crank case compression.

- **At the end of expansion, exhaust port is uncovered. Burnt gases escape to the atmosphere. Transfer port is also opened.**

Scavenging process

- Scavenging is a process of pushing exhaust gases out of the cylinder.
- **This action takes place in the two stroke engine.**
- The charge (air fuel mixture or air) enters the engine cylinder from the crank case at a pressure higher than the exhaust gases.



Scavenging process…..

- This fresh charge forces the burnt gases to the atmosphere through the exhaust port. During the period both the transfer and exhaust ports are kept open for a short period.
- **Hence there is a possibility of the fresh charge escaping out with the burnt gases.**
- This is over- come by designing the piston to have a deflected shape.
- **This shape of piston deflects the fresh charge upward in the engine cylinder. It also helps out in forcing out the burnt gases to atmosphere.**

Differences between 4-stroke and 2-stroke engines

S. No.	4-stroke	2-Stroke
1	Four stroke of the piston and two revolution of crankshaft	Two stroke of the piston and one revolution of crankshaft
2	One power stroke in every two revolution of crankshaft	One power stroke in each revolution of crankshaft
3	Power produce is less	Theoretically twice power
4	Heavier flywheel due to non-uniform turning movement	Lighter flywheel due to more uniform turning movement
5	Lesser cooling and lubrication requirements	Greater cooling and lubrication requirements
6	Contains valve and valve mechanism	Contains ports arrangement
7	Volumetric efficiency and Thermal efficiency is high	Volumetric efficiency and Thermal efficiency is low
8	Heavy and bulky	Light and compact

Lecture No. 12

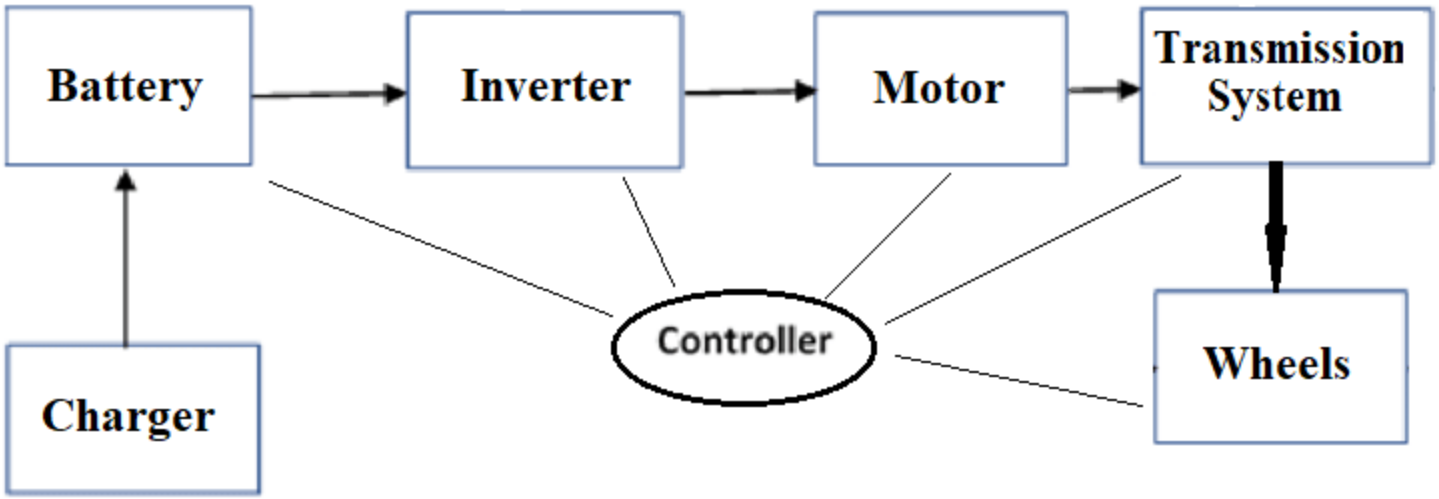
LECTURE- 12

Content:

- Components and working of an EV
- EV batteries, chargers

Electric vehicle

- An electric vehicle (EV) is a vehicle that uses one or more electric motor for propulsion.
- The electric motors are the replacement of ICE.
- **Main components of electric vehicle are** Battery, Inverter, Electric motor, transmission drive & controller.



Working of an Electric Vehicle

- Power is converted from the DC battery to AC for the electric motor.
- When the accelerator pedal is pressed, it sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor.
- The motor connects and turns the wheels througha transmission system.
- When the brakes are pressed, the motor becomes an alternator and produces power, which is sent back to the battery. This I known as regenerative braking.

Advantages and Disadvantages of EVs

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Advantages:

- Better for the environment.
- Electricity is less expensive than fuels.
- Less maintenance at a lower cost.
- Produce less noise.

Disadvantages:

- EVs have short ranges for driving.**(100 to 400 km)**
- Charging can take a lot of time.
- Initial investment is high.
- Charging stations are not available everywhere.

Lecture No. 13

Types of Batteries Used in Electric Vehicles(EV's):

- Lithium-ion batteries
- Lead-acid batteries
- Nickel-Metal Hydride batteries
- Ultra-capacitors

Lithium-ion Batteries

- Li-ion batteries are most commonly used in electric light motor vehicles because of their high power-to-weight ratio, good high-temperature performance, excellent specific energy, and low self-discharge rate.
- Lithium-ion batteries are better than other batteries at maintaining the ability to hold a full charge over time.
- These battery parts are recyclable so it is a good option regarding the environmental aspect.
- They have long cycle life even they support higher energy costs, exceptional power efficiency, longer service life, and eco-friendliness.
- They are designed to be discharged up to 90% of total capacity.
- Li-ion batteries-based cars give better mileage due to their lightweight. A car has to overcome its inertia. When someone has to accelerate the car from zero, lithium-ion can better propel the vehicle and can discharge faster and supply more power, which is very beneficial for HEV.

Lead-acid Batteries

- Lead-acid battery technology is still in the development phase.
- These batteries have a comparatively wide operating temperature range and have low energy density.
- They are easier to recycle. About 95% of the content of the battery can be reused, which is better for the environment.
- Lead-acid batteries have a relatively low depth of discharge so it directly impacts their cycle life. These batteries tend to be expensive because they don't last as long so they often need to be replaced within 4 to 15 years depending on their type.
- Lead-acid batteries do not discharge more than 30-40%. Which typically go on to damage the battery.

Nickel-Metal Hydride Batteries

- In a Nickel-Metal Hydride battery, one pole has Nickel alloy whereas another pole has Nickel oxy hydroxide with the electrolyte of Potassium hydroxide.
- It is usually slower to charge and discharge the battery, and it contains less power per weight so it takes a longer time to charge the battery.
- In extreme heat Ni-MH batteries can deteriorate faster.
- These batteries have a wide operating temperature range.
- They are also reliable and safe. Ni-MH batteries have a typical cycle life of over 3000 cycles. .
- These batteries are widely used in automotive batteries, computers, medical instruments as well as equipment, and electric razors.

Ultracapacitors

- Unlike batteries, Ultracapacitors hold the charge as static energy. They can provide a higher current so they have a far higher specific power.
- Ultracapacitors don’t have any heating problems.
- The main advantage of ultracapacitors is that they can do millions of charging cycles.
- They are already used in multiple applications for instance in buses, trains, and microgrids. Nevertheless, these technologies will continue to improve and over time we might see changes in electric vehicles.

Why lithium-ion batteries are best for electric vehicles?

- Lithium-ion batteries have a high power-to-weight ratio,
- high energy efficiency, and
- good high-temperature performance.
- Having a low self-discharge rate.

On-board Charger

- There are two main types of charging stations:

  AC charging stations and DC charging stations.
- Batteries can only be charged with DC electric power, while most electricity is delivered from the power grid as AC; For this reason, most electric vehicles have a built-in AC-to-DC converter, commonly known as the "onboard charger".
- At an AC charging station, AC power from the grid is supplied to this onboard charger, which produces DC power to charge the battery.

EV’s Charger

- Rapid Charger
- Fast Charger
- Slow charger

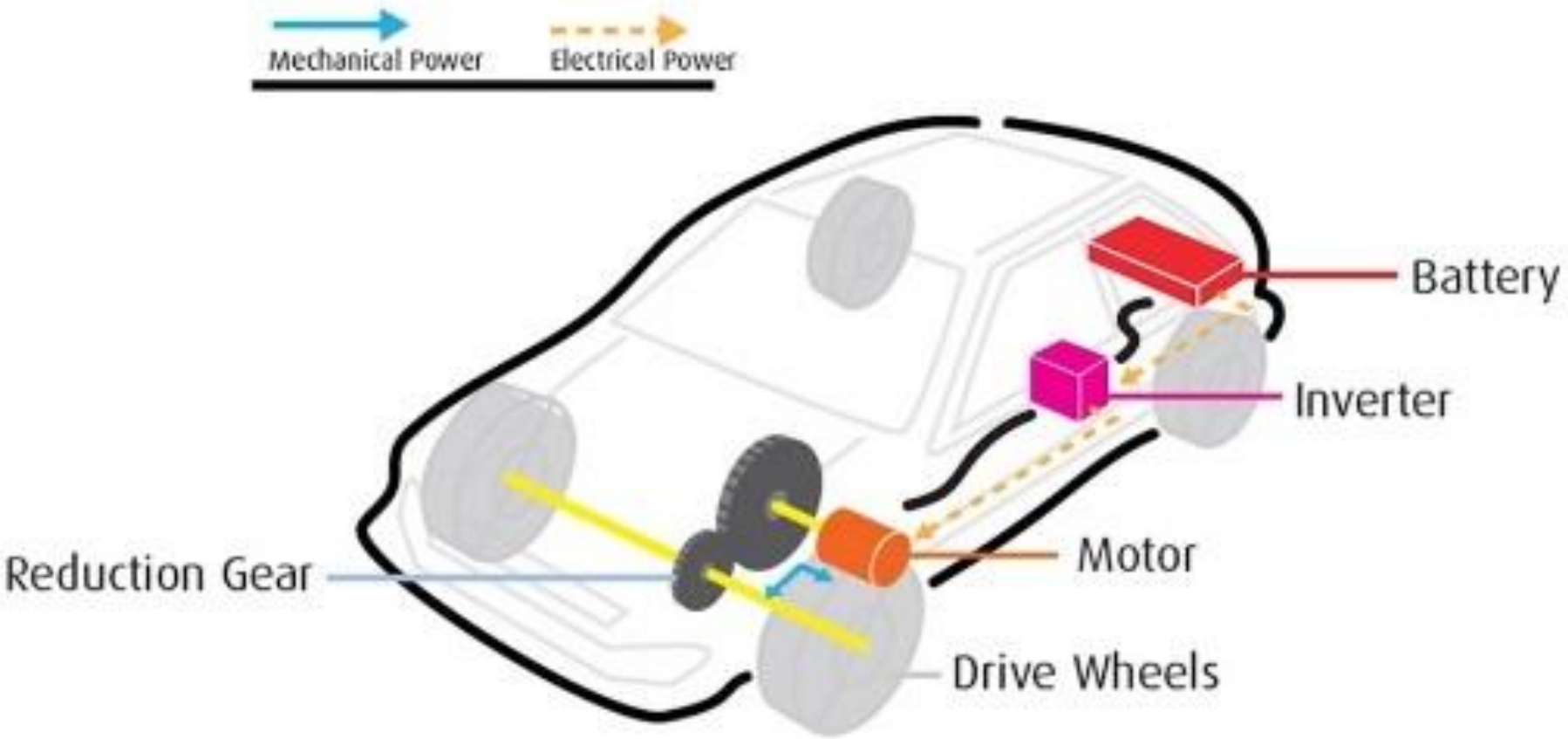
Lecture No. 14

LECTURE- 14

Content:

- EV drives, transmission and power devices
- Advantages and disadvantages of EVs

EV Drives


Mechanical Power
Electrical Power
Battery
Inverter
Motor
Reduction Gear
Drive Wheels

EV Transmission

- The transmission can be simply defined as the transfer of power generated from source to the wheels of the vehicle.
- There are two types of transmission in electric vehicles-

➢ Single Speed Transmission

➢ Multi Speed Transmission

(Two Speed Transmission)

Single Speed Transmission

Advantages-

1. It has direct drive.
2. Its operation is very smooth and also it generates instant torque when coupled with motor.
3. No complex gear system required.
4. It occupies less space.

Limitation-

1. It has a fixed gear ratio.

Two Speed Transmission

- This is multi-speed transmission system used in electric vehicles. Mostly only two speed transmission is used.
  The transmission is comprised of a compound planetary gear system.

- Advantages-
  1. Due to the two degrees of freedom of the compound planetary gear system. two different gear ratios can be achieved.
  2. Efficiency can be optimized.
  3. Top speed of vehicle can be achieved.

  Limitations-
  1. These transmissions are too heavy and large.
  2. It has very high cost.

EV Power Devices:

- The main devices of power electronics required in an electric vehicle are:-

- **1. Rectifiers**
- **2. Power Converters**
- **3. Controller and Sensors**
- **4. Inverters**

Rectifiers:

- A rectifier is an electronic device that converts an alternating current into a direct current by using one or more P-N junction diodes. A diode behaves as a one-way valve that allows current to flow in a single direction. This process is known as rectification.

- The rectifiers are used in AC-DC conversion stages of Plug-in EVs, where the grid electricity is firstly met with this device.

Power Converters

- Power converters are classified according to their input and output types namely DC-DC Converters and AC-AC Cyclo-converters.

- DC-DC Converters are designed to increase or decrease the input voltage stage to desired value at the output. Therefore, a device known as Buck Converter or step-down converter decreases the output value according to a high input voltage while Boost Converter or step-up converter generates an increased output voltage.

- The cyclo-converters are used to convert input power at one frequency to output power at a different frequency. This can also be achieved by an inverter.

Controller and Sensors:

- The required control signals are generated by **Microcontrollers** and commutate power electronic devices with switches to provide fixed speed or torque.

Inverters:

- In EVs, Inverters are used for **DC-AC conversions.**
- They are used to provide the required AC voltage and current for AC motors from DC battery supply.

Lecture No. 15

LECTURE-15

Content:

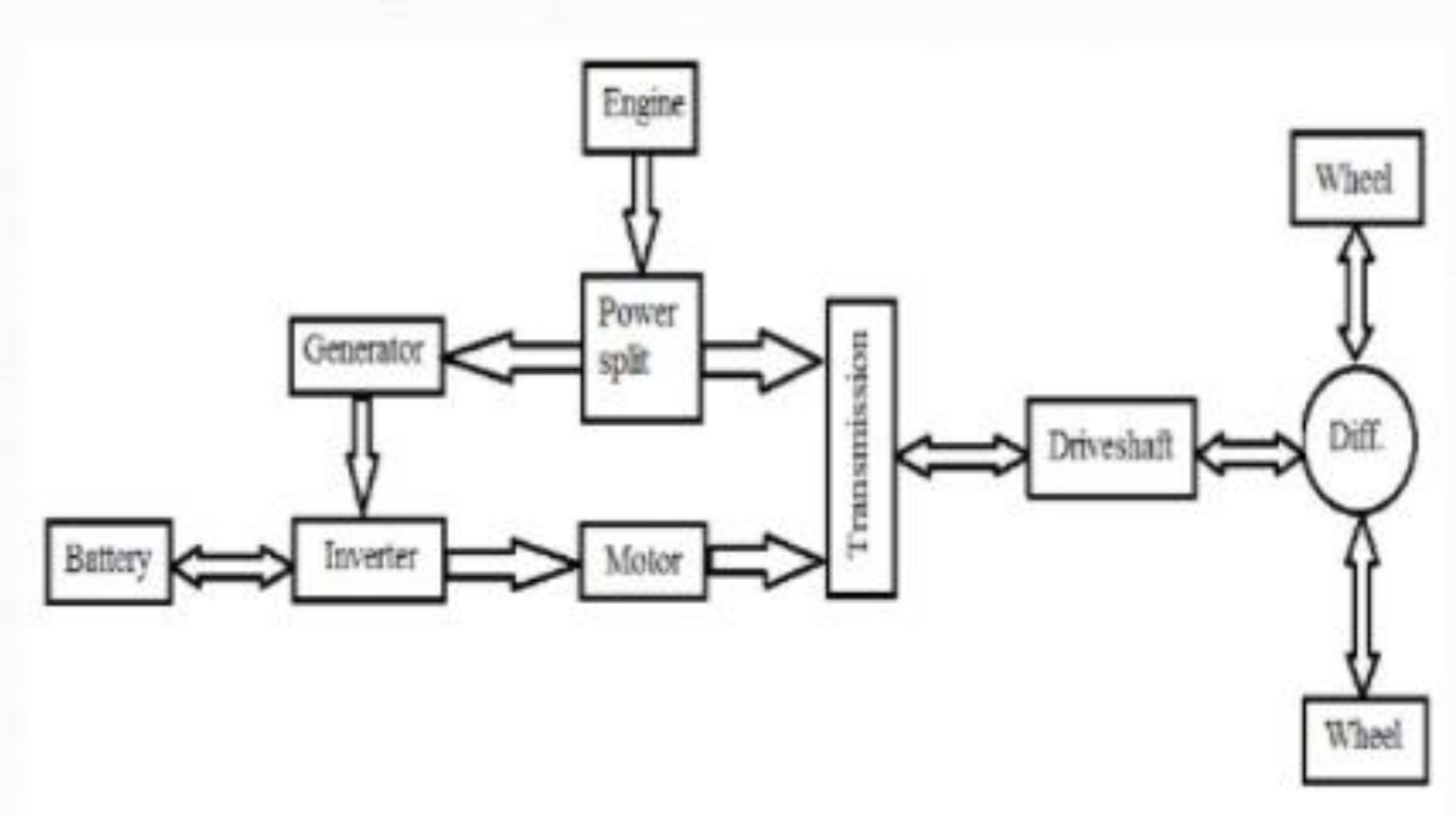
- Hybrid Electric Vehicles
- Advantages of HV.
- Disadvantages of HV.

Hybrid Vehicle

- A hybrid electric vehicle (HEV) is a type of hybrid vehicle that combines a conventional internal combustion engine (ICE) system with an electric propulsion system .

- **Modern HEVs make use of efficiency-improving technologies such as regenerative brakes which convert the vehicle's kinetic energy to electric energy, which is stored in a battery or super-capacitor.**

Block diagram of Hybrid Electric Vehicle



Advantages of Hybrid Cars

- **Cleaner Emission:** Compared to the **ICE** engine, hybrid cars produce less emissions and it is environmental friendly.

- **Less Fuel Dependency:** With an electric motor to support the primary petrol engine, there is additional power available. Hence, there is less dependency on fossil fuel.

- **Smaller and Efficient Engine:** Petrol engines used in hybrid cars are smaller in size and comparatively fuel efficient.

Disadvantages of Hybrid Cars

- **Lower Performance:** Since the main motive is to increase the fuel efficiency or range of the hybrid car, the power or acceleration can lag behind a conventional internal combustion engine car.

- **Expensive to Buy:** Although car companies are trying to bridge the gap in pricing between a conventional vehicle and hybrid, hybrids continue to demand higher costs.

- **High Maintenance Cost:** With several mechanical parts in the cars and with two sets of engines powering the hybrids, the maintenance continues to be on the higher side. Also, not all mechanics are trained to repair a hybrid car.

HEV DRIVETRAINS

- Drivetrain or Powertrain refers to the set of components that generate the power required to move the vehicle and deliver it to the wheels.
- Based on the HEV drivetrains, an HEV can be categorized as -

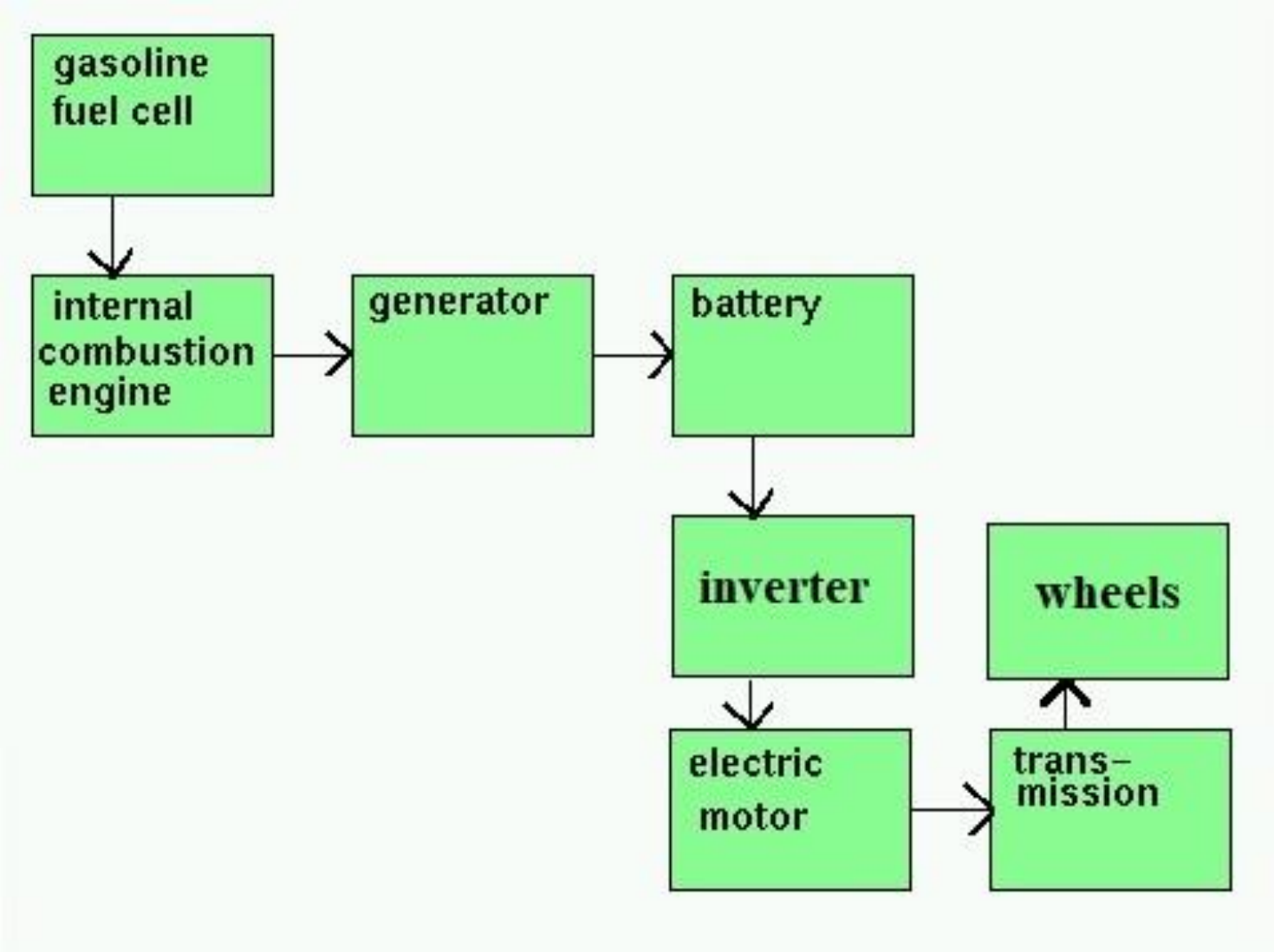
➢ **Series Hybrid Vehicle**

➢ **Parallel Hybrid Vehicle**

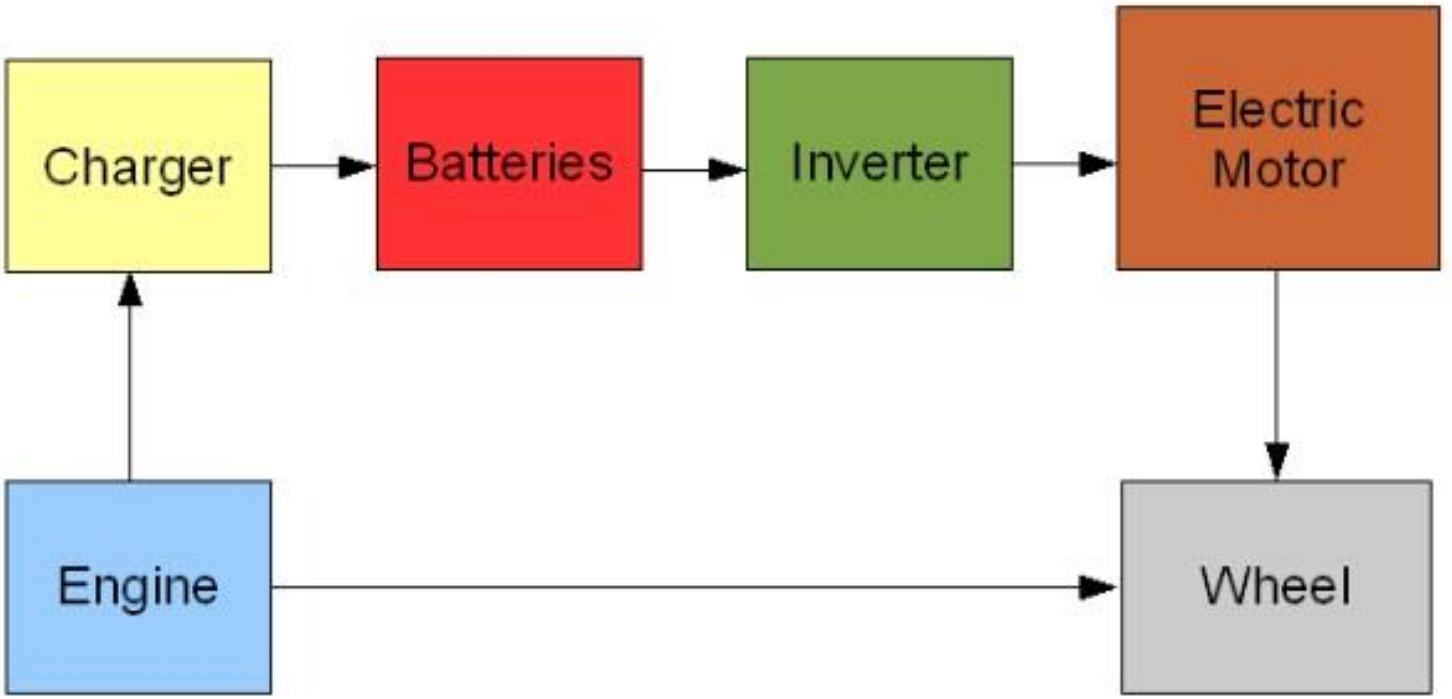
➢ **Plug-in Hybrid Vehicle**

➢ **Mild-Hybrid Vehicle**

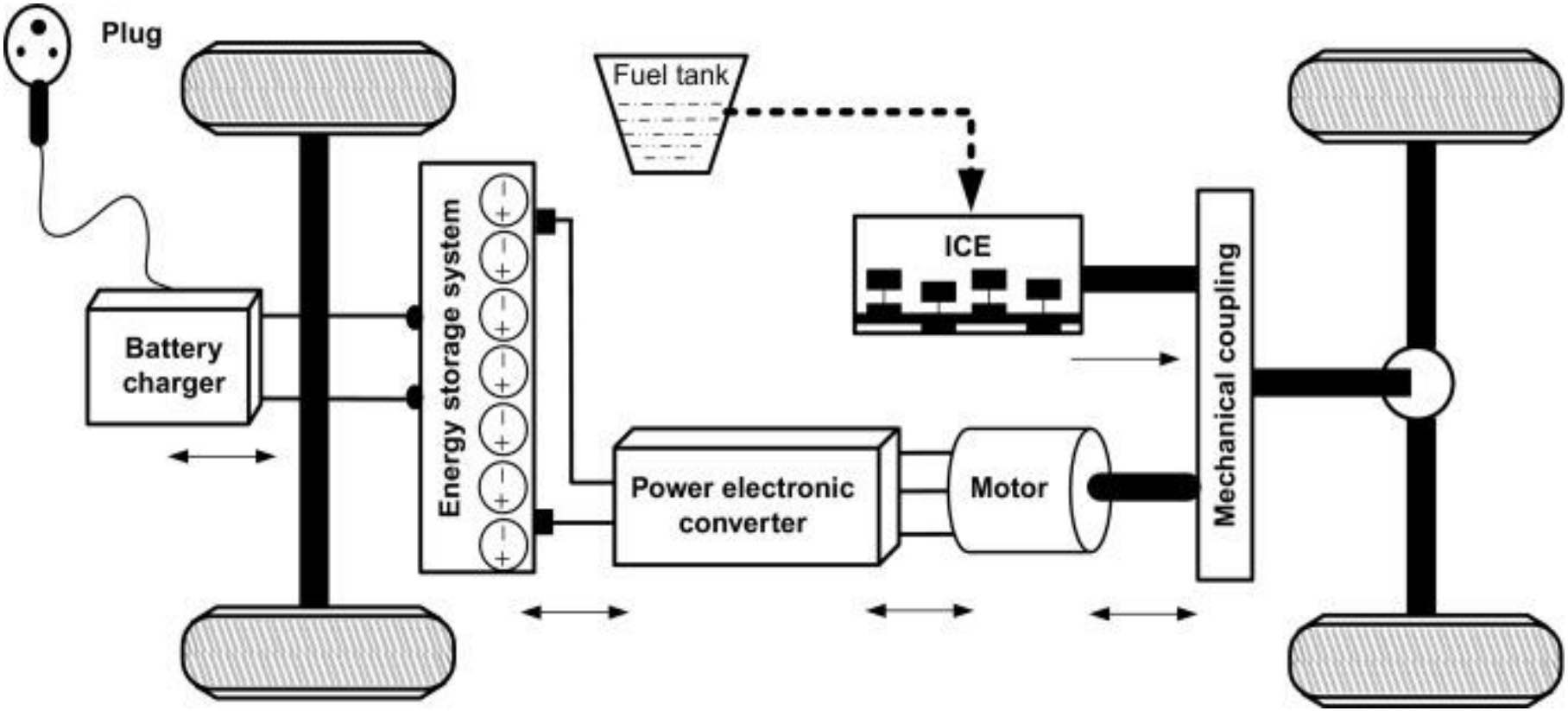
Series Hybrid Vehicle



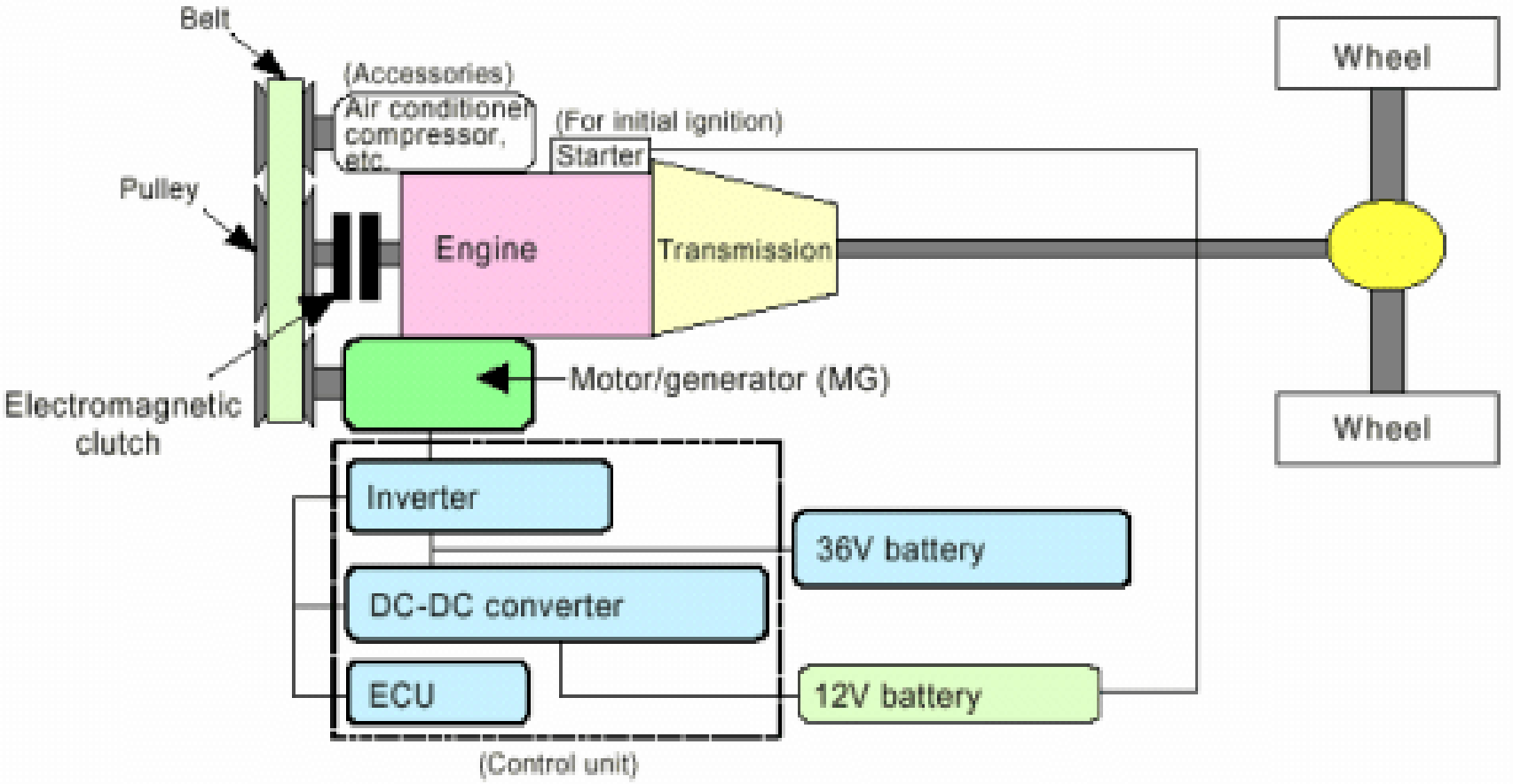
Parallel Hybrid Vehicle



Plug-in Hybrid Vehicle



Mild Hybrid Vehicle



Examples of HEV drives

MIET GROUP OF INSTITUTIONS

- **Parallel Hybrid**
  - Toyota Camry, Honda Accord, Toyota Prius, Hyundai Sonata, etc.
- **Series Hybrid**
  - BMW i3, Kia Optima, Ford Fusion, Chevrolet Volt, etc.
- **Plug-in Hybrid**
  - BMW 330e, Hyundai Ioniq Plug-in Hybrid, Volvo XC40
- **Mild-Hybrid**
  - Maruti Suzuki Ertiga, Ciaz, Baleno, etc.

Comparison among IC Engine, Electric and Hybrid Vehicles

	Electric Vehicles	Hybrid Electric Vehicles	I.C.Engines
Power/Fuel Source	Electricity Through Battery Pack (DC)	Electricity and Fossil Fuel (Petrol and Diesel etc)	Fossil Fuel (Petrol and Diesel etc)
Engine	Electric Motor(s)	Internal Combustion Engine and Electric Motor(s)	Internal Combustion Engine
Fuel Efficiency	Depends on Battery Range	Combination of ICE and Battery Range	Internal Combustion Engine
Emission Levels	Lower Compared to ICE and Hybrid vehicles	Higher Compared to Electric vehicles	High
Price Range	High	Similar to Conventional ICE vehicles	Low as compared to EVs
Charging	Required	Not required	Not required