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Unit IV: Part - B

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

Faculty In-Charge:

Dr. V L Jagannatha Guptha

Assistant Professor

Department of Mechanical Engineering

Mobile: 9243447122

Email ID: jagannathagvl@rvce.edu.in

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 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.	

Electrical Drives>>

- History
- Well to Wheels Analysis
- Electric Vehicles
- Configurations

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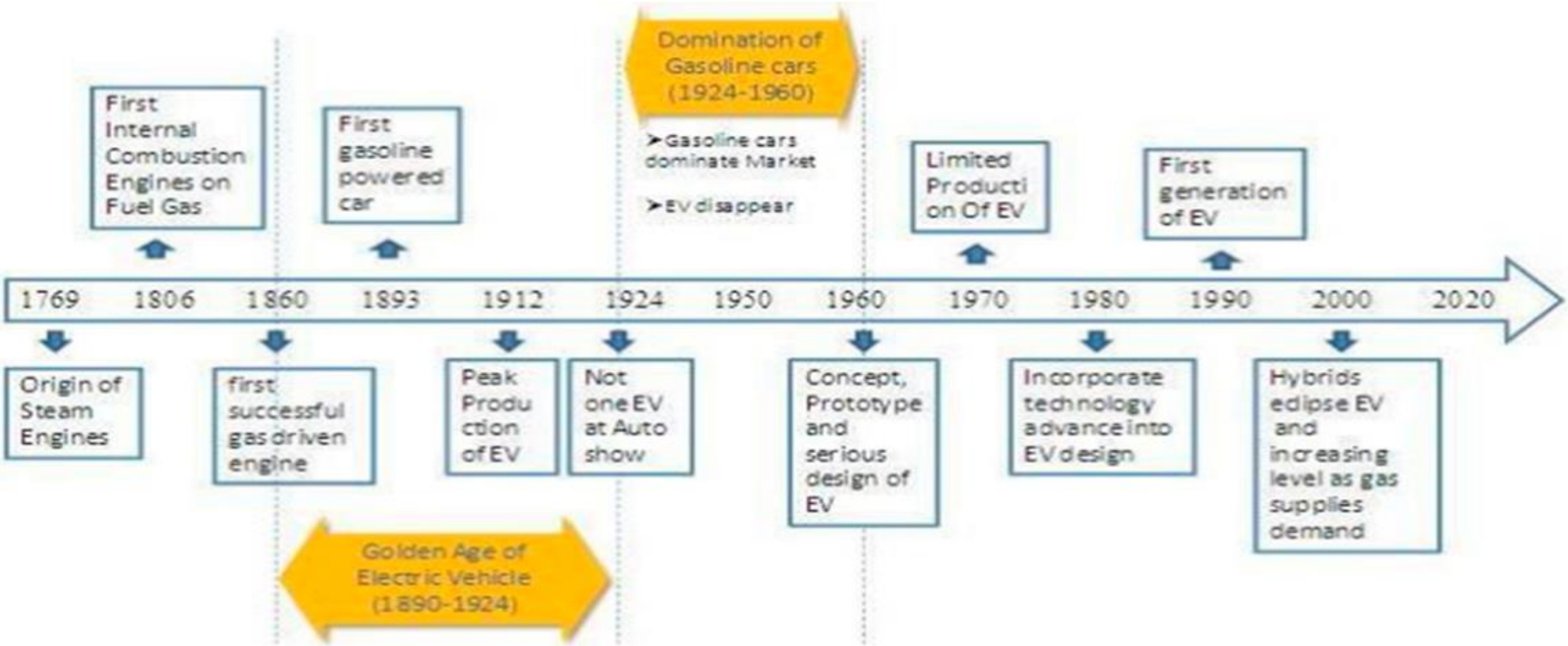
History of Electrical Vehicles>>



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-wheel Analysis** 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.

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

- 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

Fundamentals of Mechanical Engineering

ELECTRICAL DRIVES

Assignment – Unit 4b - 01

<<for Practice>>

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)

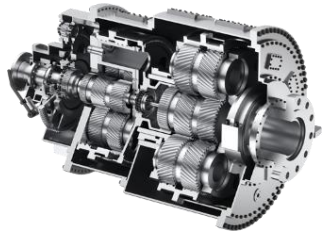
Unit IV

Electrical Drives>>

- EV/ICEV comparison
- Performance
- Traction Motor Characteristics

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 IC and EV >>

Parameter	ICE	EV
Energy source	Fuel 	Battery 
Energy conversion device	IC engine 	Motor 
Gear box	Multi speed 	Single speed 
Energy storage system	Fuel tank 	Battery Pack 

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

Characteristics of Traction Motor >>

- Mechanical
- Electrical

Mechanical Characteristics >>

- Light weight
- Totally enclosed
- Robustness
- Overall Size

- Light Weight
  - High power to weight ratio
  - Lesser the weight of motor, higher the operating efficiency
- Totally Enclosed
  - Protects itself against ingress of dirt, dust, mud water etc.
- Robustness
  - Must be strong enough to withstand continuous vibration and other forces acting during running of train
- 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

Characteristics of Traction Motor >>

- Mechanical
- Electrical

Electrical Characteristics >>

- High Starting Torque
- Parallel Running
- Simple and Easy Speed Control
- Easy Electric Braking
- High Efficiency

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

Fundamentals of Mechanical Engineering

ELECTRICAL DRIVES

Assignment – Unit 4b - 02

<<for Practice>>

Note:

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Electrical Drives>>

- 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.	

Hybrid Electric Vehicles >>

HEVs are the vehicles that have

- two or more energy conversion technologies
- combined with one or more energy storage units

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

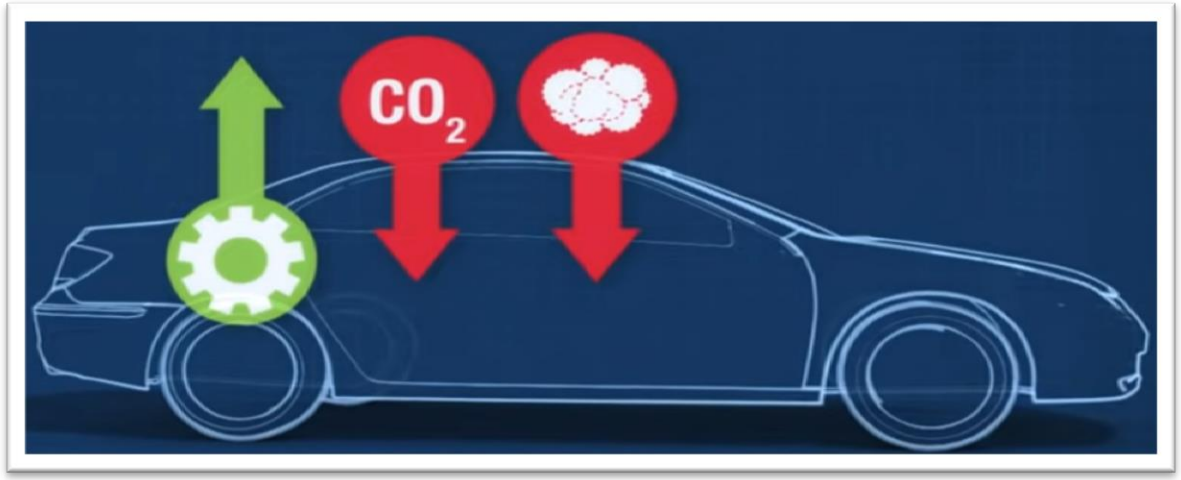
ii) Second source, typically provided by an IC engine

Objectives of HEVs:

They are focused on to :

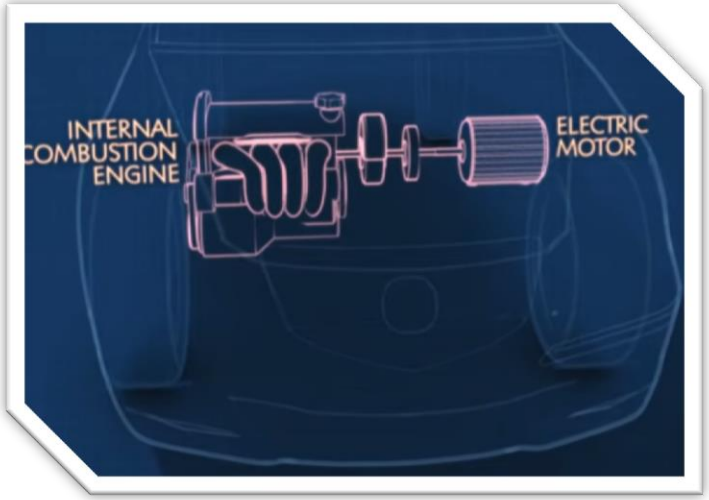
- Maximize fuel economy
- Minimize emissions
- Minimize propulsion system cost to keep affordable
- Maintain acceptable performance with a reasonable cost
- Reduce the conventional car weight

Features of Hybrid Vehicle System >>



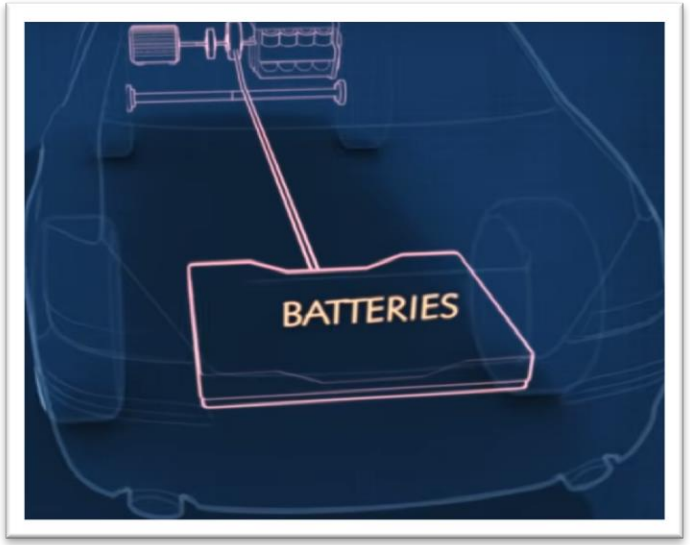
Less pollution,
Lower CO2, Reduced Green House Gas

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
- Lower emissions, meet emission regulations
- Lower fuel consumption

The disadvantage of HEVs >>

- It the is cost (which may come down in the years to come)

Advantages of Hybrid Drive trains >>

- HEVs are vehicles propelled by more than one power source such as an engine and electric motor and are classified by type and level.
- The advantages of HEVs are improved fuel economy, efficiency and reduced emission.

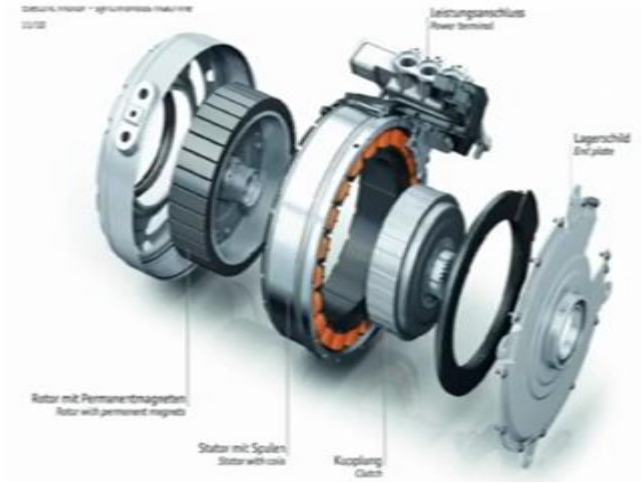
- Hybrid electric vehicles are powered by an internal combustion engine and an electric motor, which uses energy stored in batteries.
- A hybrid electric vehicle cannot be plugged in to charge the batteries.
- Instead, the battery is charged through regenerative braking any by the internal combustion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

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

HEV Advantages over Conventional Engines Vehicles >>

- Regenerative Braking
- Reduction in engine and vehicle weight
- Fuel efficiency is increased
- Emissions are decreased
- Curtail emissions of global warming pollutants by 1/3 or 1/2
- Reduce the dependency on fossil fuels
- Approximately 2 times more efficient than conventional engines

Components of Hybrid Drive trains >>



Electric Motor

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

Electric Battery

Invertor

DC Convertor

Electric Generator

Control Module

Components of Hybrid Drive trains >>

- Electric motor
- Electric battery
- Invertor
- DC/DC convertor
- Electric Generator (exclusive for Series & Series-Parallel hybrids)
- Control Module

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.

Electric battery →

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

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.

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.

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.

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.

Fundamentals of Mechanical Engineering

ELECTRICAL DRIVES

Assignment – Unit 4b - 03

<<for Practice>>

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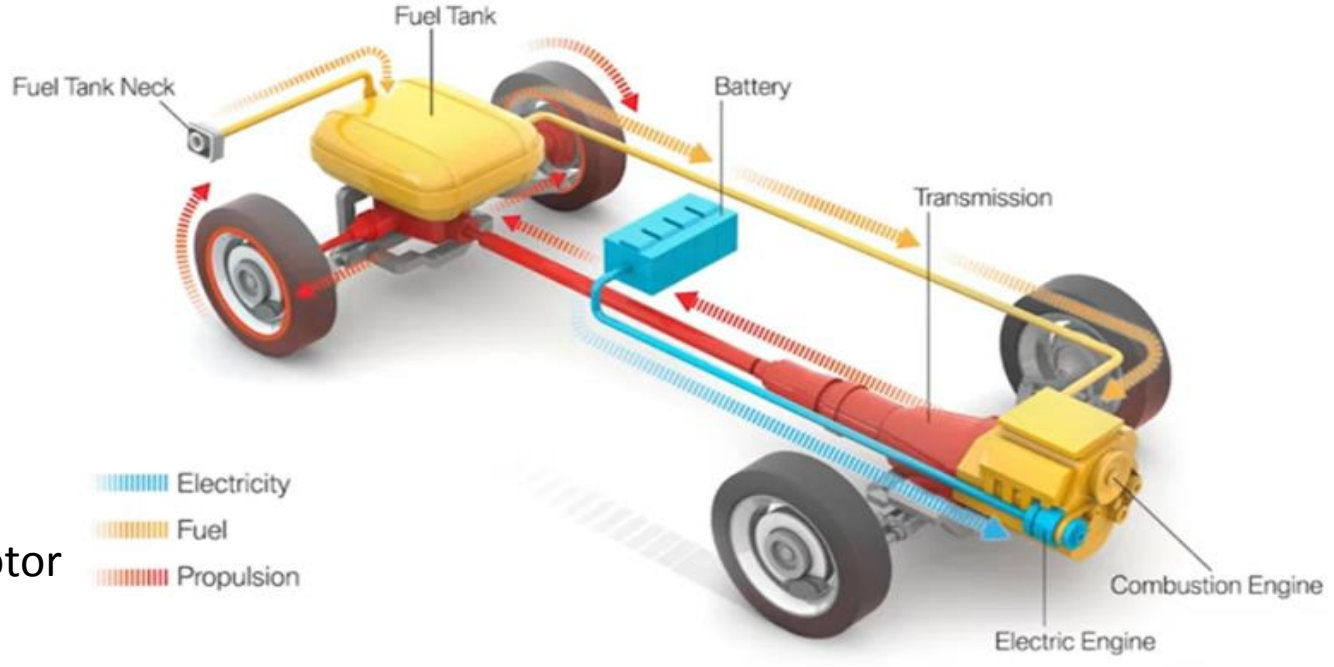
Hybrid electric drive trains >>

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

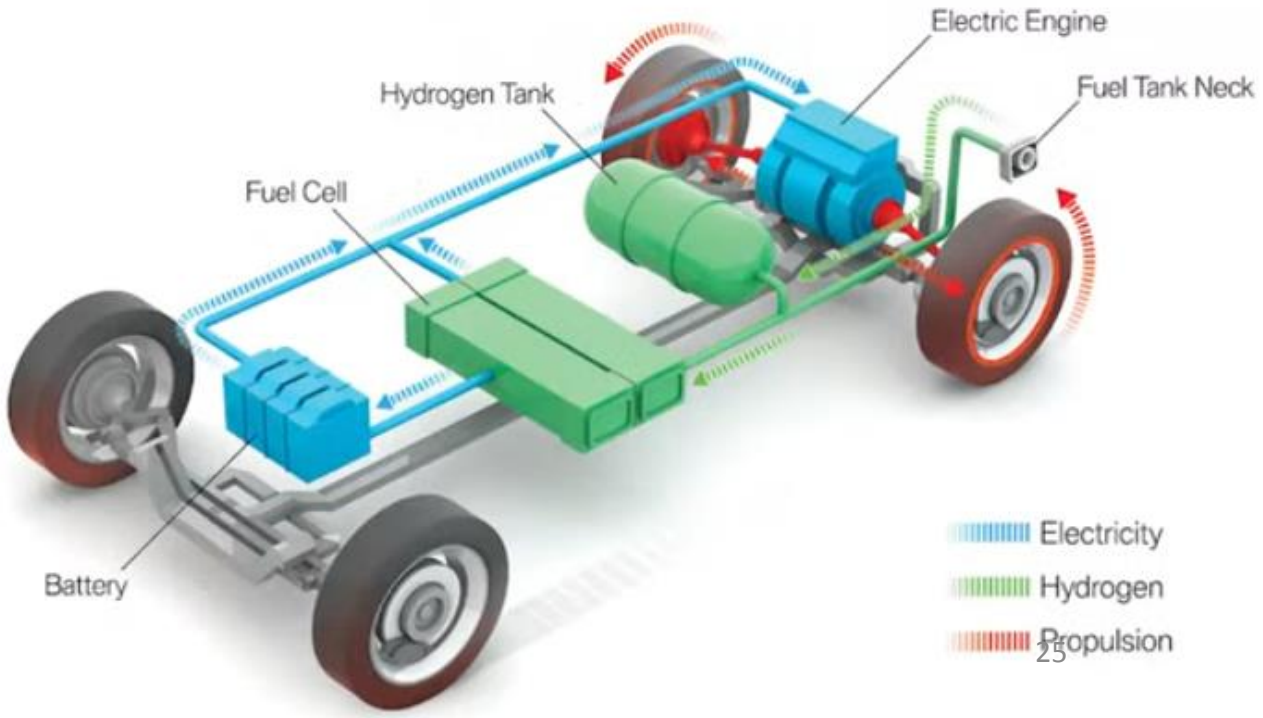
ii) Second source, typically provided by an IC engine

Internal Combustion Hybrid Vehicle>>



- Battery
- IC Engine
- Electric Motor
- Generator

Hydrogen Power Cell Vehicle>>



Classification of Hybrid Electric Vehicles >>

Depending upon the "Structure of Drivetrain"

Hybrid vehicles are further classified as:

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

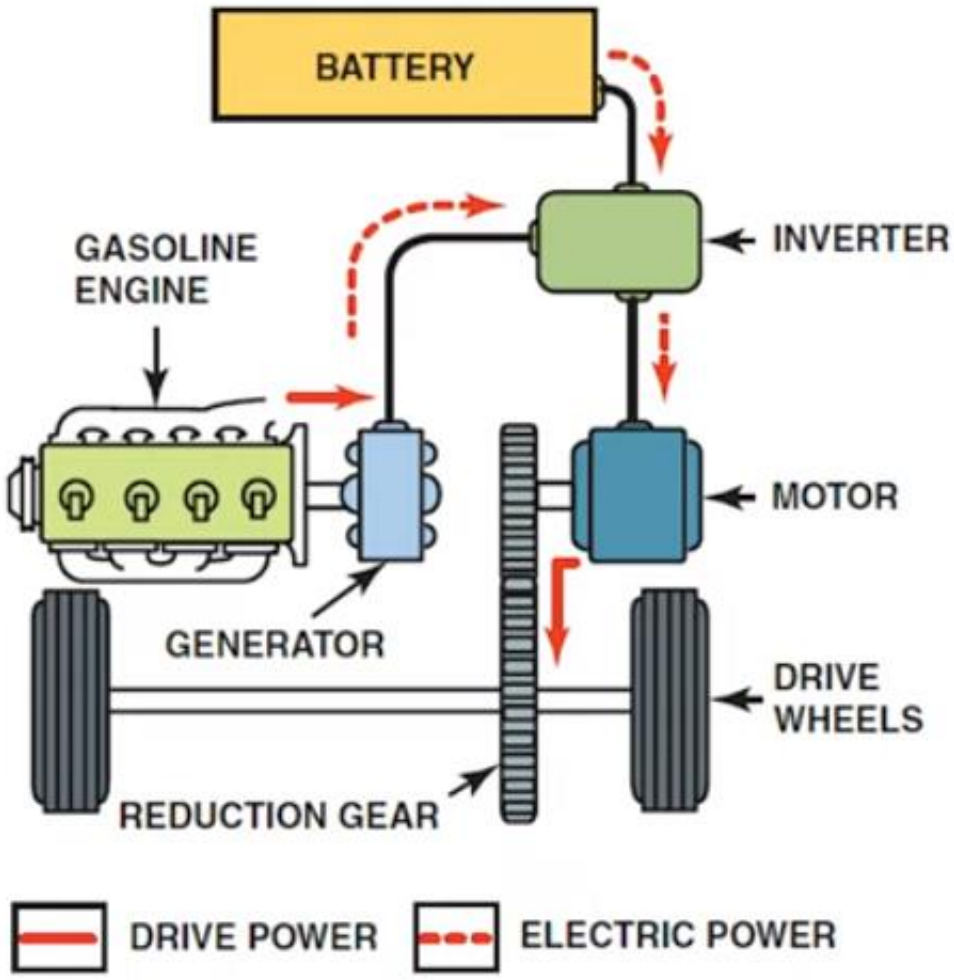
Based on the "Degree of Hybridization"

Hybrids are Classified into Two Groups:

- **Mild Hybrids/Micro Hybrids**
- **Full Hybrids**

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).



Schematic of a Series Hybrid Vehicle

Application:

Heavy commercial vehicles, military vehicles and buses.

Reason:

Large vehicles have space for the bulky engine/generator system

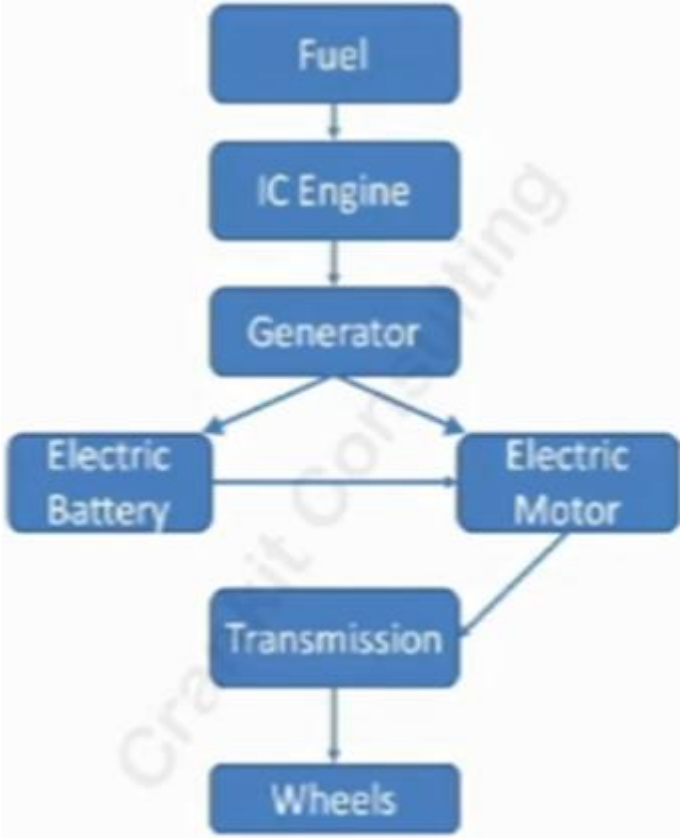
Series Hybrid Vehicle >> working principle>>

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.

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.



Flow chart of a Series Hybrid Vehicle

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.

Series Hybrid Vehicle >> Advantages and Disadvantages>>

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

Disadvantages:

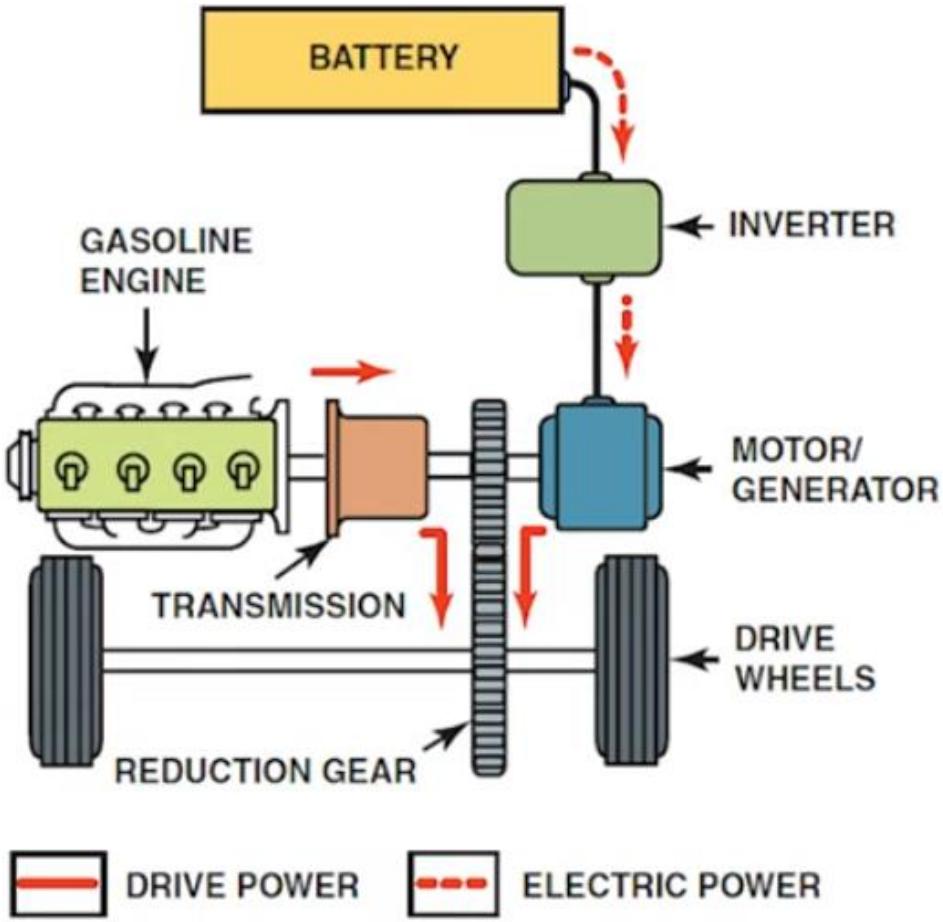
- Energy is converted twice (mechanical to electrical and then to mechanical) and this reduces the overall efficiency
- Two electric machines are needed and a big motor is required because it is the only torque source of the driven wheels
- Completely dependent on battery power

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.



Schematic of a Parallel Hybrid Vehicle

Applications:

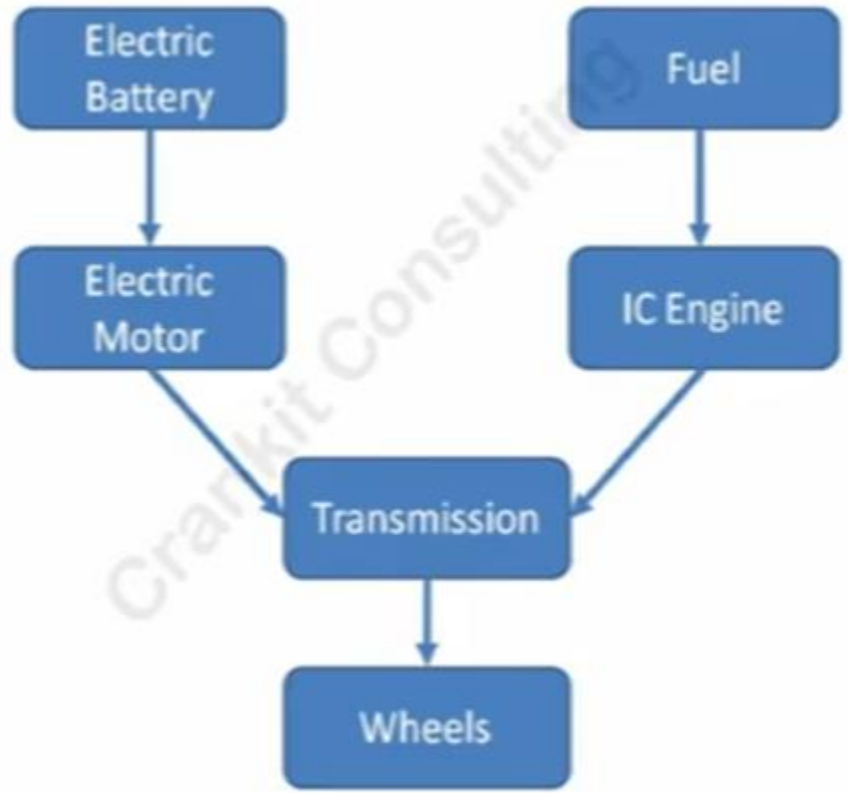
- Due to its compact characteristics, small vehicles use parallel configuration.
- Most passenger cars employ this configuration.

Parallel Hybrid Vehicle >> working principle>>

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.

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.



Flow chart of a Parallel Hybrid Vehicle

Parallel Hybrid Vehicle >> Advantages and Disadvantages>>

Advantages:

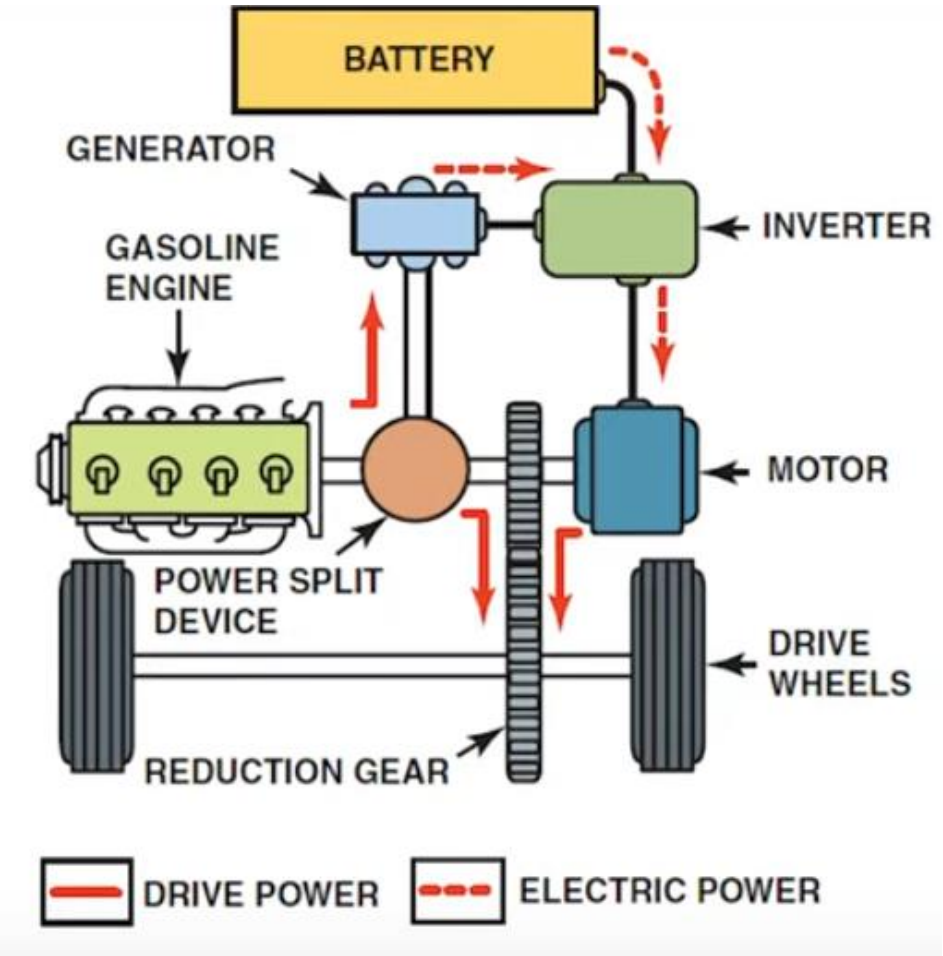
- Both engine and electric motor directly supply torques to the driven wheels and no energy form conversion occurs
- Compactness due to no both energy sources work in tandem leading to significantly less weight

Disadvantages:

- 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

Series-Parallel Hybrid Vehicle or Power split Hybrid Vehicle>>

- In the series-parallel hybrid, 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.
- This is 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 series hybrid vehicle.
- The control module governs the selection of the most suitable mode.



Schematic of a
Series-Parallel Hybrid Vehicle
Or
Power split Hybrid Vehicle

Hybrid Vehicle >> Classification>>

Based on the "Degree of Hybridization",

Hybrids are Classified into Two Groups:

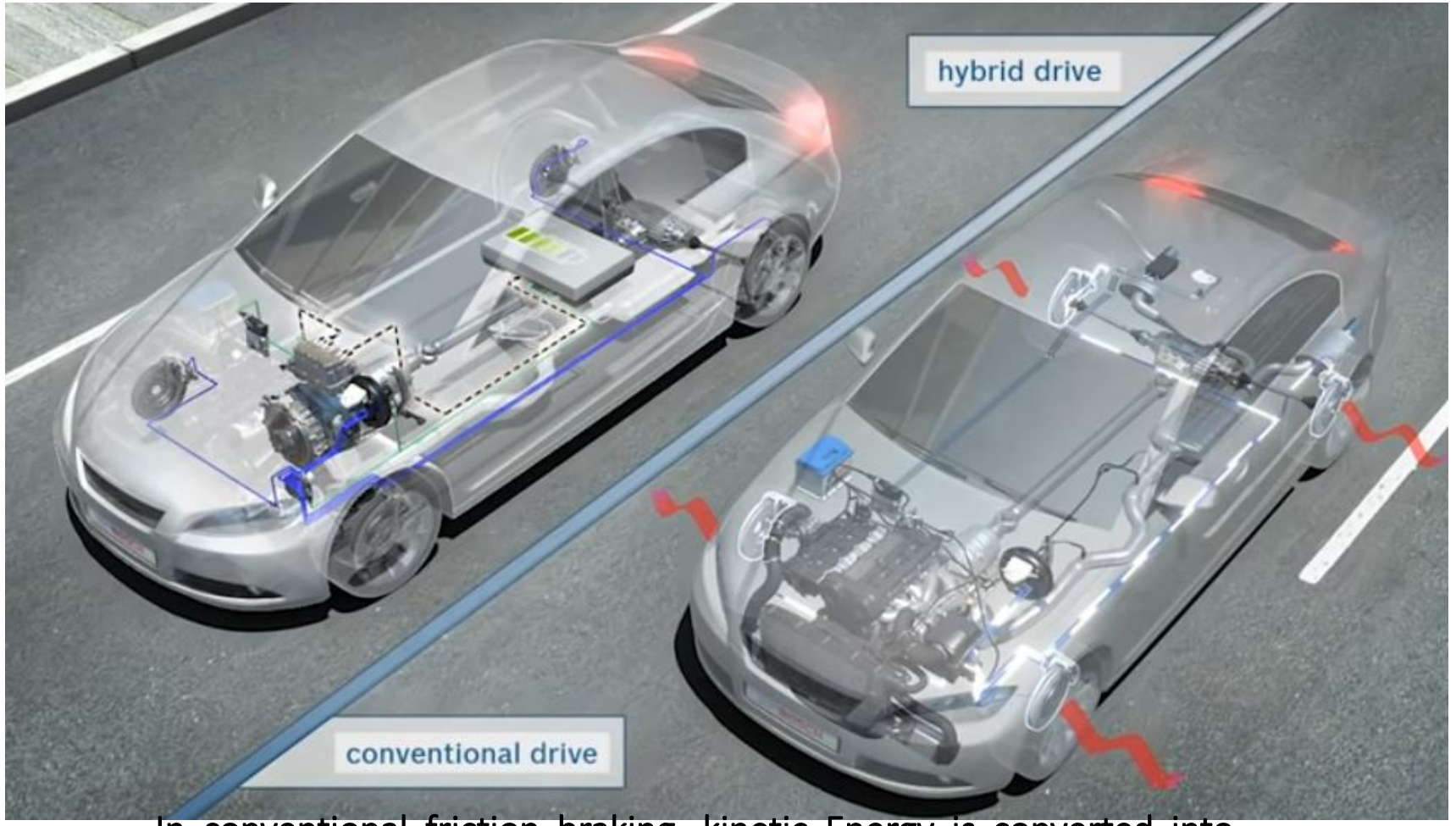
1. Mild Hybrids/Micro Hybrids:

- 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.

2. Full Hybrids:

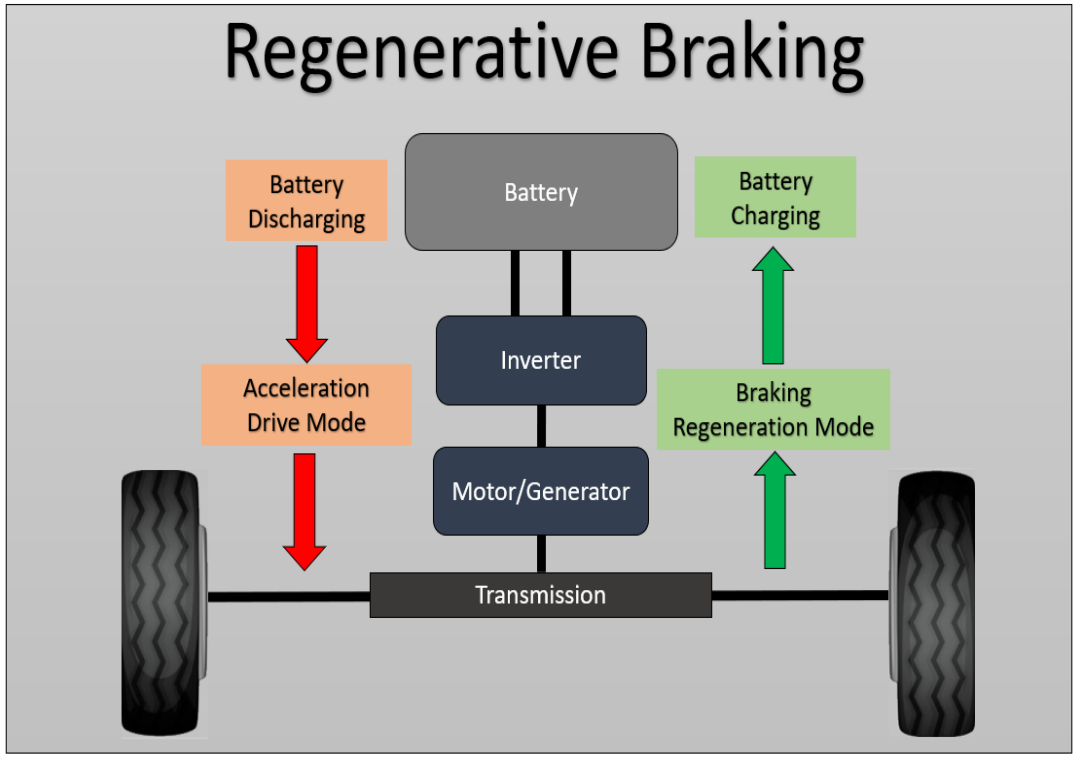
- This vehicle can run on either the IC engine or the electric battery alone as the battery used in them is of a higher capacity.
- Have larger batteries and more powerful electric motors, which can power the vehicle for short distances and at low speeds. These vehicles cost more than mild hybrids but 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

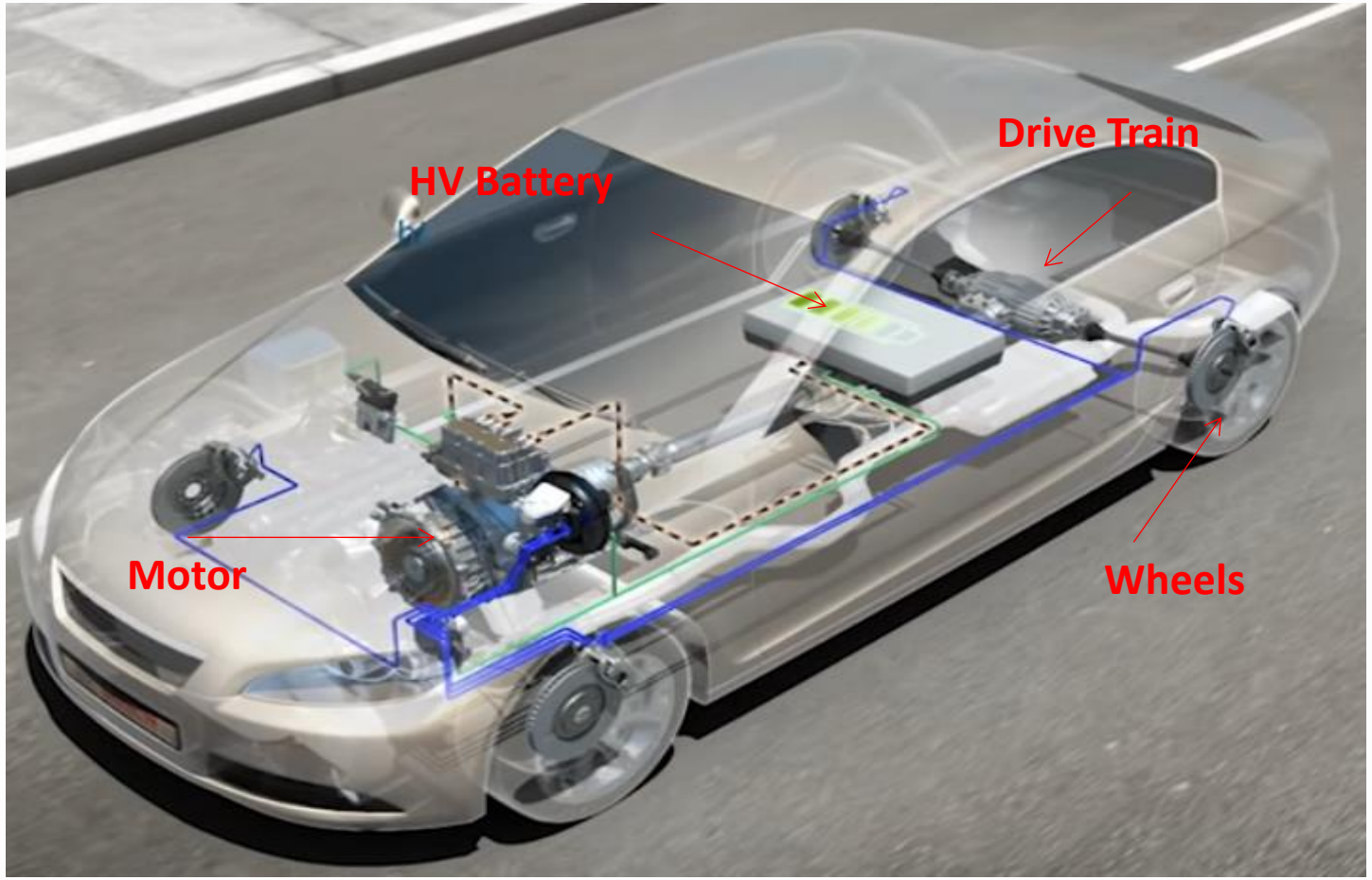


- Regenerative braking is the **recovery of Kinetic Energy (KE)** during braking
- HEV / EV can use the electric motor to **recover a portion of the KE**

Regenerative braking enables

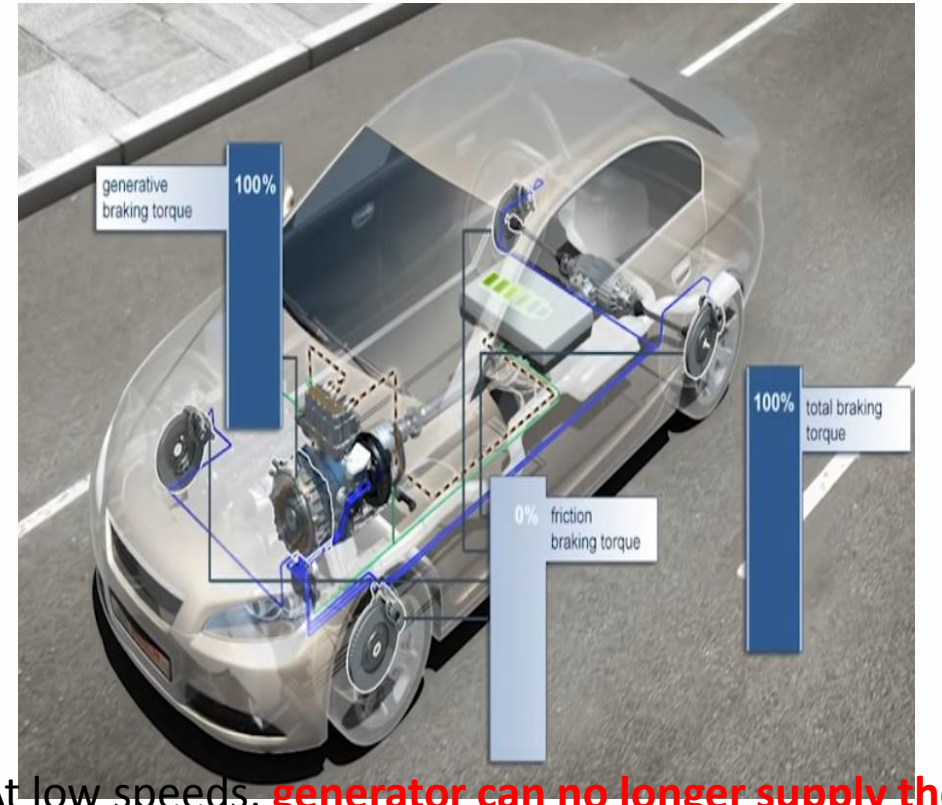
- **Extended range** in electric vehicles
- **Lower fuel consumption** and **Improve CO2 emissions** in hybrid vehicles

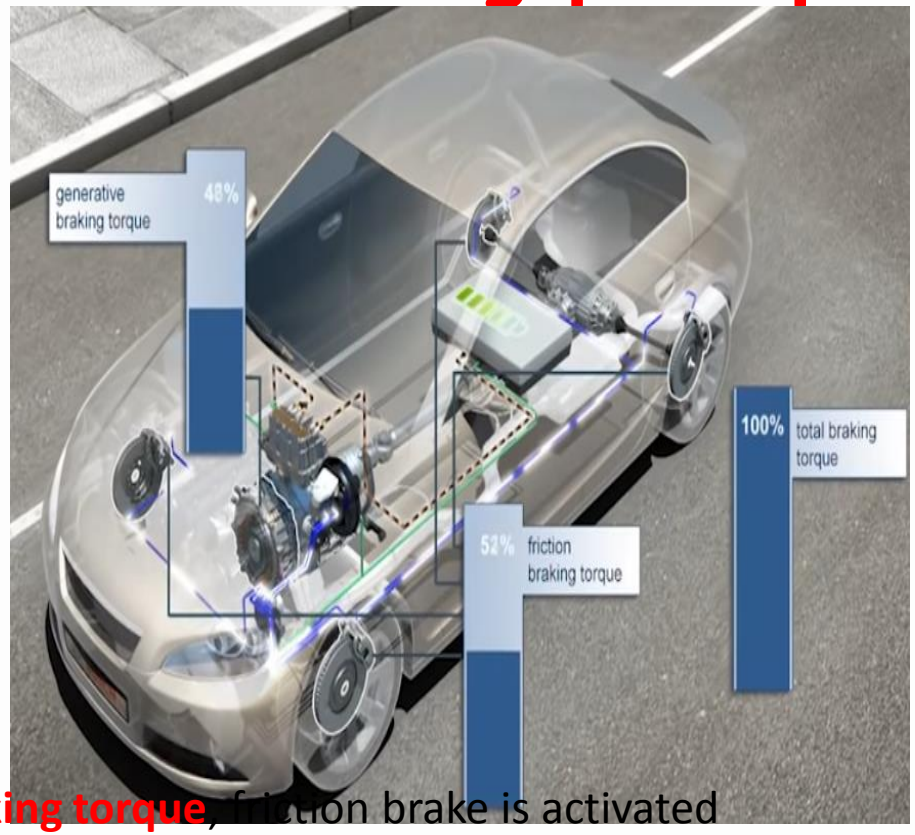
Regenerative Braking principle



- 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

Fundamentals of Mechanical Engineering

ELECTRICAL DRIVES

Assignment – Unit 4b - 04

<<for Practice>>

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2) C. C Chan and K T chau, modern Electric Vehicle Technology, Oxford University Pres, U K , 2001
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http://www.satcon.com/sub/beacon/index.html

http://www.autoalliance.org/hybrids.htm

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, 18th Edition. ISBN 5551234002884
2.	Material Science & Engineering- William D Callister, 2 / 10th Edition, ISBN 978-1-119-45520-2.
3.	Welding Technology (PB), Khanna O P, Dhanpat Rai publication, 4th Edition, ISBN 9383182555.
4.	Electric and Hybrid Vehicles, Design Fundamentals – Iqbal Husain, CRC Press, 2nd Edition, 2010. ISBN – 13-978-1439811757.
5.	Modern Electric, Hybrid Electric & Fuel Cell Vehicles, Fundamentals, Theory and Design - Mehrdad Ehsani, CRC Press, 1st Edition, 2005. ISBN – 13- 978-0849331541.
6.	Mechatronics – Electronic control systems in Mechanical and Electrical Engineering, William Bolton, Pearson, 6th 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-I 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 Prototype models of Robot – 10 marks	**40**	*****
TOTAL MARKS FOR THE COURSE (A+B+C)	**100**	**100**

Prepare & Practice

All The Best