

Electric Vehicle Technology (315335)

Model Question Paper — Set C · Model Answers

Q.1

a) Types of EV based on energy source.

2 M

1. **Battery Electric Vehicle (BEV):** runs only on a rechargeable battery and electric motor (e.g. e-scooters, Tata Nexon EV).
2. **Hybrid Electric Vehicle (HEV):** IC engine + electric motor with a small battery charged by engine and regenerative braking.
3. **Plug-in Hybrid Electric Vehicle (PHEV):** hybrid with a larger battery that can also be charged from the grid.
4. **Fuel Cell Electric Vehicle (FCEV):** electricity is produced on board by a hydrogen fuel cell.

(Any four, $\frac{1}{2}$ M each)

b) EV30@30 campaign.

2 M

The **EV30@30 campaign** was launched in 2017 by the Electric Vehicles Initiative (EVI) of the Clean Energy Ministerial (CEM). Its goal is to reach a **30 % sales share of electric vehicles** (battery electric, plug-in hybrid and fuel cell) in passenger cars, light commercial vehicles, buses and trucks **by the year 2030** in the participating countries (India is a participant).

(Meaning 1 M, target 1 M)

c) Ah capacity and energy stored.

2 M

- **Charge (Ah) capacity:** Total charge a battery can deliver from full to cut-off at a given discharge rate, in ampere-hour (Ah). $1 \text{ Ah} = 3600 \text{ C}$.
- **Energy stored:** Energy = nominal voltage $\times$ Ah capacity, in Wh or kWh. E.g. $48 \text{ V} \times 100 \text{ Ah} = 4.8 \text{ kWh}$.

(Each definition 1 M)

d) Need of BMS.

2 M

- Protects cells from over-voltage, under-voltage, over-current and over-temperature (prevents fire / thermal runaway).
- Estimates SOC (fuel gauge) and SOH of the battery.
- Balances cells so that all cells have equal charge — uses full capacity and increases life.
- Controls charging (communicates with charger) and thermal management; reports faults to VCU / driver.

(Any two needs, 1 M each)

e) DC fast charging.

2 M

DC fast charging (Level 3 / Mode 4) is a method in which an **off-board charger** converts the 3-phase AC supply into high-power DC (about 25–350 kW) and supplies it **directly to the battery**,

bypassing the on-board charger. A car battery can be charged to about 80 % in 30–60 minutes; connectors used are CCS2, CHAdeMO, GB/T.

(Meaning 2 M)

f) Location of motor in 4W EV.

2 M

In a four-wheeler EV the motor, with single-speed reduction gear and differential, is mounted on the **front axle** (front-wheel drive), on the **rear axle** (rear-wheel drive) or on both axles (dual-motor AWD). Example: Tata Nexon EV — front-mounted motor driving the front wheels.

(Location 1 M, example 1 M)

g) E-Mobility strategy.

2 M

E-Mobility strategy is a planned, time-bound set of government targets, policies, incentives, regulations and infrastructure development that aims to shift road transport from fossil-fuel vehicles to electric vehicles (e.g. India's National Electric Mobility Mission Plan 2020 and the FAME schemes).

(Definition 2 M)

Q.2

a) BEV vs HEV.

4 M

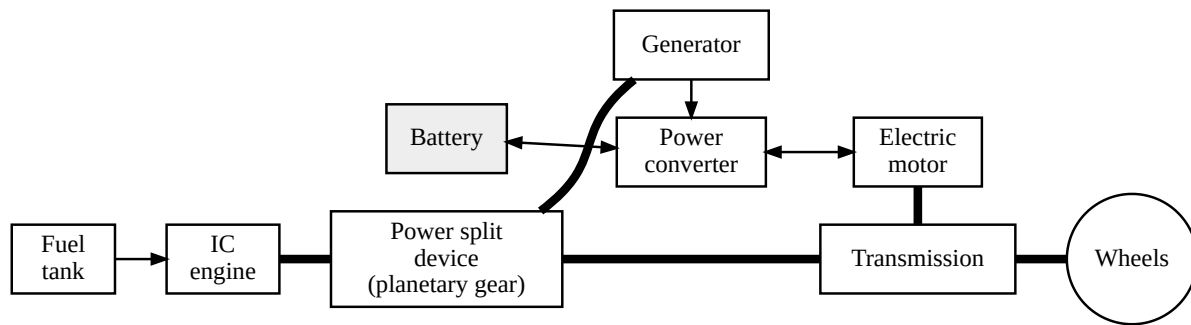
Point	Battery EV (BEV)	Hybrid EV (HEV)
Driving component	Electric motor only.	IC engine + electric motor.
Energy source used	Battery charged from grid (plug-in).	Petrol / diesel; small battery charged by engine and regenerative braking.
Models available in market (examples)	Tata Nexon EV, Tata Tiago EV, MG ZS EV; 2W: Ather 450, TVS iQube.	Toyota Innova Hycross (strong hybrid), Maruti Grand Vitara (strong hybrid), Honda City e:HEV.
Problems	High battery cost, limited range, long charging time, limited charging stations.	Still produces emission; complex drivetrain; higher cost than petrol car; two systems to maintain.

Model names are examples available in India; the market changes every year.

(Each point 1 M)

b) Series-parallel hybrid.

4 M



Legend: — mechanical link —▶ electrical (power) link - - ▶ control / signal

Fig.: Series-parallel (power split) hybrid — planetary gear splits engine power between wheels and generator

Working: A planetary gear set (power split device) connects engine, generator and the drive shaft. Part of the engine power goes mechanically to the wheels and part drives the generator, whose electrical output either charges the battery or feeds the motor. The motor adds torque to the wheels. Thus the vehicle can work in series mode, parallel mode or both (e.g. Toyota hybrid system).

Advantages: combines merits of series and parallel types; engine always near optimum speed; best fuel economy. **Disadvantages:** costly and complex control; needs generator and motor both.

(Diagram 2 M, explanation 2 M)

c) E-rickshaw battery design.

4 M

Given: Range = 100 km, energy consumption = 70 Wh/km, allowed depth of discharge DOD = 80 %, system voltage $V = 48$ V

Step 1 – Energy required at the wheels side (from battery output):

$$E_{\text{req}} = \text{range} \times \text{consumption} = 100 \times 70 = 7,000 \text{ Wh} = 7 \text{ kWh}$$

Step 2 – Battery capacity (energy) considering DOD:

$$E_{\text{batt}} = E_{\text{req}} / \text{DOD} = 7,000 / 0.8 = 8,750 \text{ Wh} \approx 8.75 \text{ kWh}$$

Step 3 – Capacity in ampere-hour:

$$Ah = E_{\text{batt}} / V = 8,750 / 48 = 182.29 \text{ Ah}$$

Step 4 – Number of cells in series: $N_s = V / V_{\text{cell}} = 48 / 3.2 = 15 \rightarrow 15 \text{ cells}$ (pack voltage = $15 \times 3.2 = 48$ V)

Step 5 – Number of parallel strings: $N_p = Ah / Ah_{\text{cell}} = 182.29 / 50 = 3.65 \rightarrow 4 \text{ strings}$ (pack capacity = $4 \times 50 = 200$ Ah)

Step 6 – Total cells = $N_s \times N_p = 15 \times 4 = 60 \text{ cells}$ (15S4P). Actual pack energy = $48 \text{ V} \times 200 \text{ Ah} = 9.6 \text{ kWh}$ ($\geq$ required 8.75 kWh ✓)

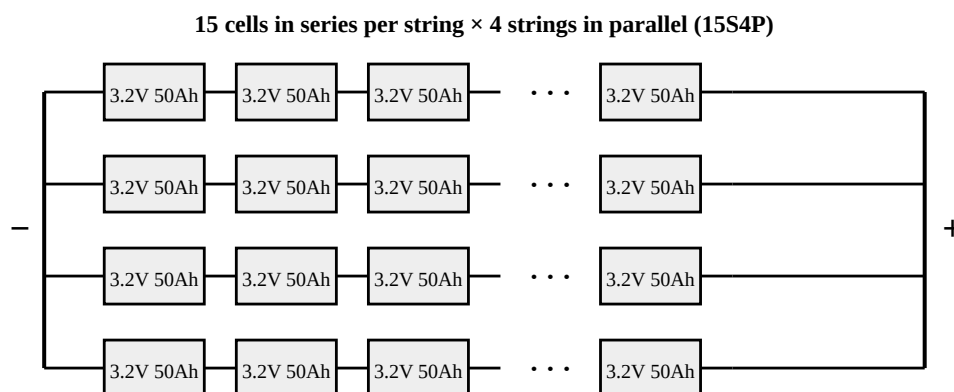


Fig.: Battery pack arrangement (LiFePO₄ cells)

Answer: 8.75 kWh, 182.29 Ah; 15S4P = 60 cells.

(kWh 1 M, Ah 1 M, series 1 M, parallel 1 M)

d) Steps taken by Government of India.

4 M

- **NEMMP 2020** (launched 2013) and **FAME** schemes — FAME-I (2015–2019), FAME-II (2019–2024), followed by EMPS-2024 and the **PM E-DRIVE** scheme (notified 2024) — purchase incentives for e-2W, e-3W, e-buses and support for charging stations.
- **GST** on EVs reduced to 5 % and on chargers / charging stations to 5 % (2019).
- **PLI schemes** for Advanced Chemistry Cell (ACC) battery manufacturing (2021) and for automobile & auto components — to make cells and EVs in India.
- Green number plates; exemption from permits for battery-operated commercial vehicles (MoRTH, 2018).
- Income tax deduction up to ₹1.5 lakh on interest of loans for buying EVs (Section 80EEB, for loans sanctioned 2019–2023).
- Guidelines and standards for charging infrastructure (Ministry of Power, revised 2024); charging is a de-licensed activity.
- State EV policies (e.g. Maharashtra) with road-tax / registration waivers and extra subsidies.

Scheme names and dates as known in 2025–26; schemes are revised from time to time.

(Any four steps, 1 M each)

Q.3

a) Axial flux ironless PM motor.

4 M

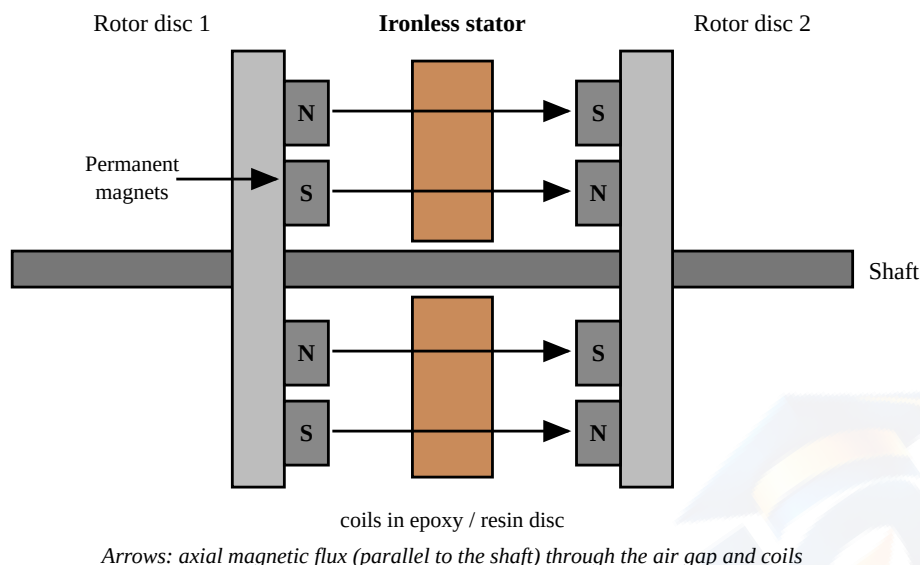


Fig.: Axial flux ironless PM motor (double rotor, coreless stator) — side sectional view

Construction:

- Rotor: one or two steel discs carrying permanent magnets with alternate N–S poles on their faces, fixed on the shaft.
- Stator: "ironless" (coreless) — copper coils embedded in an epoxy / resin disc placed between the two rotor discs; no iron core in the stator.
- Flux travels **axially** (parallel to the shaft) from magnets of one rotor disc through the air gap and coils to the opposite magnets — hence "axial flux".
- Pancake (disc) shape: large diameter, very short axial length — suitable for in-wheel (hub) mounting.

Working: When the stator coils are supplied with currents from the inverter (in proper sequence according to rotor position), the coil currents interact with the axial magnet flux and produce a tangential force ($F = BIl$) on the coils; the reaction torque rotates the rotor discs.

Advantages: very high power and torque density (compact, light); no stator iron hence no iron loss and no cogging torque — smooth and efficient; short axial length, ideal for in-wheel motors.

Limitations: more magnet material — high cost; difficult to maintain the small air gap against axial magnetic pull; heat removal from resin-embedded coils is difficult; low inductance needs high switching frequency.

(Construction & working 2 M, two advantages 1 M, two limitations 1 M)

b) Battery parameters.

4 M

- **Self-discharge rate:** Loss of stored charge when the battery is kept idle (not connected to any load), expressed in % per month. It increases with temperature (Li-ion $\approx$ 2–3 %/month, NiMH much higher).

- **Battery geometry:** Physical shape and size of cells — cylindrical (e.g. 18650, 21700), prismatic or pouch. It decides packing in the vehicle, cooling and mechanical strength.
- **Battery temperature, heating and cooling needs:** Batteries work best within a temperature range (Li-ion $\approx 15\text{--}35\text{ }^{\circ}\text{C}$). High temperature speeds up ageing and may cause thermal runaway; low temperature reduces capacity. Hence heating / cooling (air or liquid) is needed.
- **Deep cycle / number of deep cycles:** A deep cycle is a discharge of the battery to a large depth (typically 80 % DOD or more) followed by full recharge. Battery life is expressed as the number of such deep cycles before capacity falls to 80 % of rated value.

(Each definition 1 M)

c) V2H / V2B system.

4 M

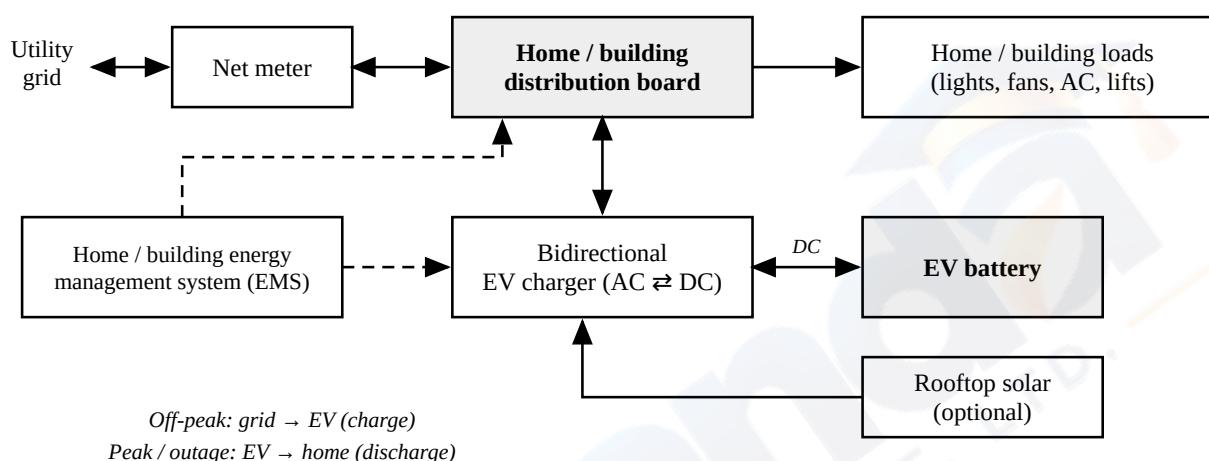


Fig.: V2H / V2B system — EV charges at off-peak time and supplies home / building loads at peak time or during outage

V2H (Vehicle-to-Home) / V2B (Vehicle-to-Building) is a bidirectional charging system in which the EV battery is used as an energy storage unit for a home or building.

- A **bidirectional EV charger** charges the EV battery when grid tariff is low (night / off-peak) or from rooftop solar.
- During peak tariff hours or power failure, the charger works as an inverter and supplies energy from the EV battery to home / building loads.
- An **energy management system (EMS)** decides when to charge or discharge based on tariff, load demand, solar generation and the minimum SOC needed by the owner for driving.
- In V2B, many EVs parked in an office / mall supply the building and reduce its peak demand charges.
- **Benefits:** back-up power, lower electricity bill, better use of solar energy, less stress on grid.
- **Limitations:** costly bidirectional charger, extra battery cycling, needs vehicle support.

(Diagram 2 M, explanation 2 M)

d) Maharashtra EV Policy and urban air pollution; road tax.

4 M

Measures that reduce urban air pollution:

- Target: EVs to be 10 % of new registrations by 2025 — fewer petrol / diesel vehicles on city roads.

- 25 % electrification of public transport and last-mile delivery vehicles in six major urban agglomerations (Mumbai, Pune, Nagpur, Nashik, Aurangabad, Amravati) — these vehicles run the most kilometres in cities.
- 15 % of MSRTC bus fleet to be electric; all new government vehicles electric from April 2022.
- Demand, early-bird and scrappage incentives — old polluting vehicles are scrapped and replaced by zero-emission EVs.
- Incentives for about 2,500 public charging stations in cities and highway corridors so that people can switch to EVs easily.

Road tax provision: Battery electric vehicles are **exempted from road tax** and registration fees in Maharashtra (continued in the Maharashtra EV Policy 2025, which also announced toll exemption for electric four-wheelers on major expressways).

Figures are from Maharashtra EV Policy 2021 (GR dated 23 July 2021). Policies change — check the latest GR.

(Pollution measures 3 M, road tax 1 M)

Q.4

a) Fuel cell — working principle.

4 M

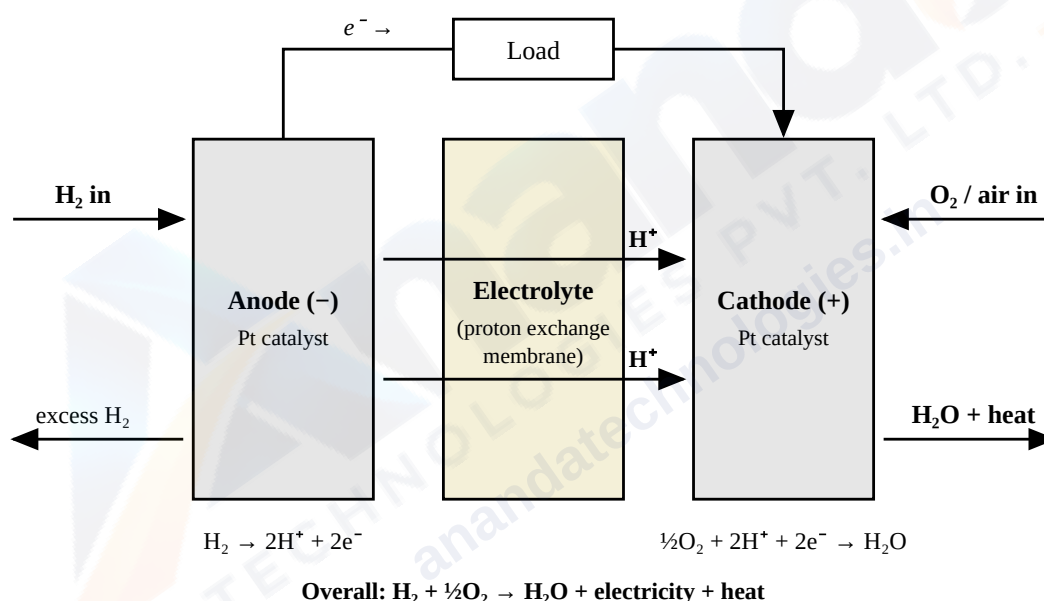


Fig.: Working of a PEM fuel cell

Working (PEM fuel cell): Hydrogen is supplied to the anode, where the platinum catalyst splits it into H^+ ions and electrons. The H^+ ions pass through the electrolyte membrane to the cathode; electrons cannot pass and flow through the external circuit (load) — this is the useful current. At the cathode, oxygen combines with H^+ ions and electrons to form water. Thus chemical energy of hydrogen is directly converted into electricity (and heat) without combustion, as long as fuel is supplied.

Point	Fuel cell	Battery
Energy source	Fuel (hydrogen) supplied continuously from an external tank.	Energy stored inside the battery chemicals.
Recharging / refuelling	Refuelled with hydrogen in 3–5 minutes.	Recharged from electric supply in 30 min to several hours.

(Diagram 1 M, working 2 M, differences 1 M)

b) Regenerative braking.

4 M

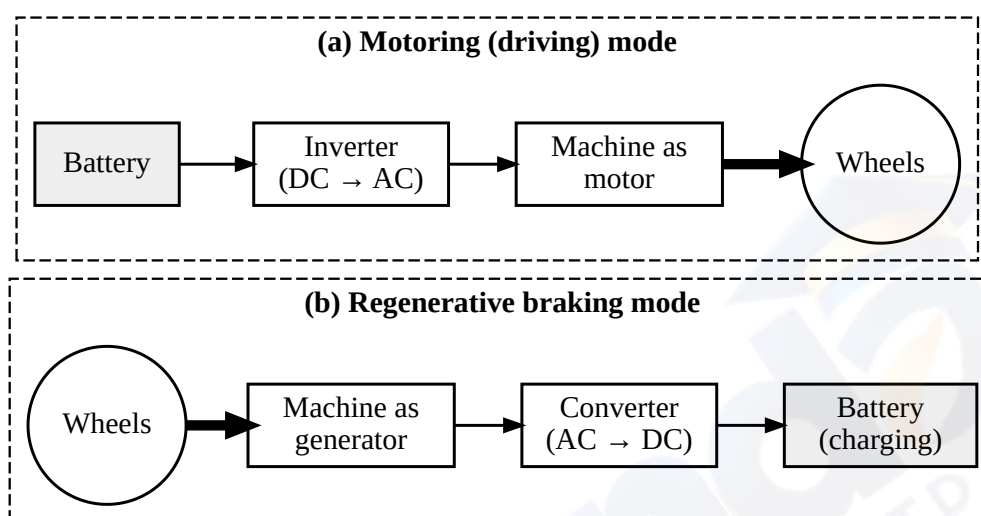


Fig.: Power flow during motoring and regenerative braking

Regenerative braking is the process of recovering the kinetic energy of the moving vehicle during braking / deceleration and storing it back in the battery.

- During normal driving the inverter supplies the motor (motoring mode).
- When the driver releases the accelerator or applies the brake, the controller reverses the torque command; the wheels now drive the machine, which works as a **generator**.
- The generated AC is converted to DC by the inverter (working as a rectifier) / bidirectional DC-DC converter and charges the battery; the generator torque opposes motion and slows the vehicle.
- Mechanical friction brakes are blended in for hard / emergency braking and at very low speed (brake blending).
- **Benefits:** increases range ($\approx 10\text{--}25\%$ in city driving), less brake wear and heat. **Limits:** battery full (high SOC) or very cold battery limits charging current.

(Diagram 2 M, explanation 2 M)

c) Induction motor as EV drive.

4 M

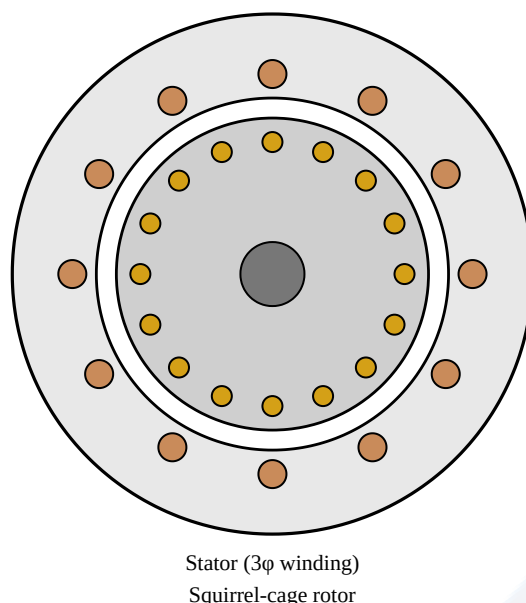


Fig.: Squirrel-cage induction motor cross-section

Principle: 3-phase supply from the inverter produces a rotating magnetic field; it induces EMF and current in the rotor bars (transformer action); the interaction gives torque, and the rotor runs slightly below synchronous speed (slip).

Salient features for EV:

- Rugged, simple and low-cost squirrel-cage construction; no magnets — no rare-earth dependence.
- Wide speed range: with vector control and field weakening, constant-power operation up to 3–4 times base speed.
- No back-EMF problem at high speed (safe if the inverter fails at high speed).
- Needs vector (field oriented) control — costly controller; rotor copper loss gives lower efficiency and rotor heating than PMSM.
- Used in some cars (e.g. early Tesla Model S / X), e-buses and heavy vehicles.

(Any four features, 1 M each)

d) Charging time with home and DC charger.

4 M

Given: Battery = 30 kWh, SOC 15 % $\rightarrow$ 80 %

i) 3.3 kW home AC charger, $\eta = 88$ %

Step 1 – Energy to be supplied to the battery:

$$E = \text{capacity} \times (\text{SOC}_{\text{final}} - \text{SOC}_{\text{initial}}) = 30 \times (0.8 - 0.15) = 30 \times 0.65 = \mathbf{19.5 \text{ kWh}}$$

Step 2 – Effective charging power:

$$P_{\text{eff}} = P \times \eta = 3.3 \times 0.88 = \mathbf{2.904 \text{ kW}}$$

Step 3 – Charging time:

$$t = E / P_{\text{eff}} = 19.5 / 2.904 = \mathbf{6.715 \text{ h} \approx 6 \text{ h } 43 \text{ min}}$$

ii) 25 kW DC charger, $\eta = 92$ %

Q.5

a) BLDC motor — construction, working and torque control.

6 M

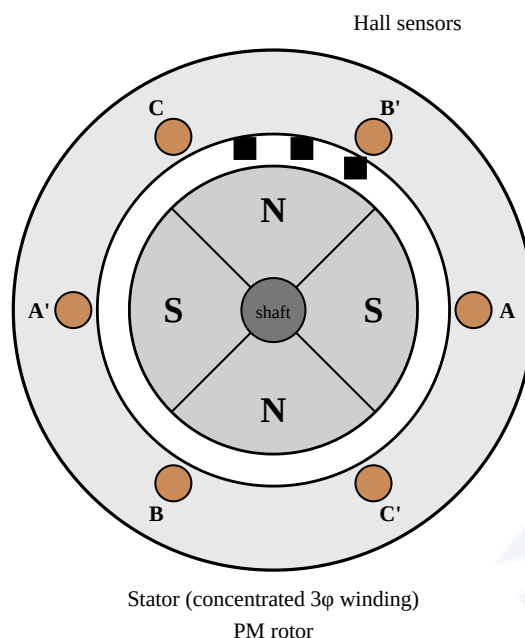


Fig.: Cross-section of a 4-pole BLDC motor (Hall sensors sense rotor position)

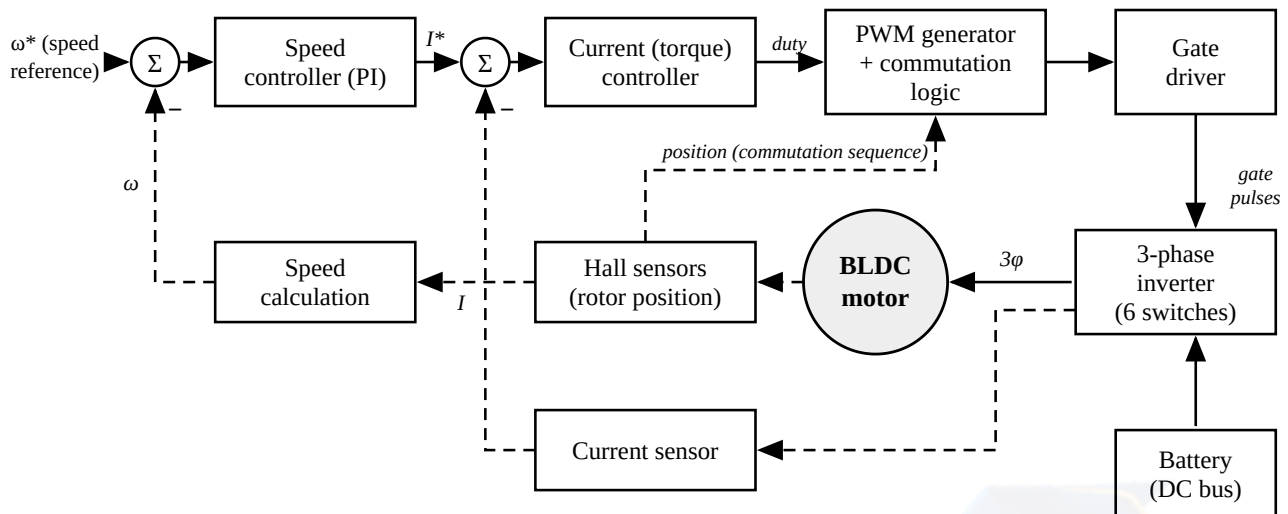
Principle: A BLDC motor works on the same principle as a DC motor — force on a current-carrying conductor in a magnetic field (here the reaction torque acts on the PM rotor). The mechanical commutator of the DC motor is replaced by an **electronic commutator** (inverter). The stator field is switched in steps so that it always stays about 90° ahead of the rotor magnet field; the rotor magnet follows it and produces continuous torque.

Working:

1. Stator has a 3-phase winding; rotor has permanent magnets.
2. Three Hall sensors (120° apart) detect the rotor position and give a 3-bit code.
3. The controller uses this code to switch ON the proper two inverter switches, so two phases conduct at a time (six-step / 120° conduction).
4. The resulting stator field attracts the rotor; as the rotor turns, the next Hall code switches the next pair — the field rotates in 6 steps per electrical cycle.
5. Speed is controlled by varying the average voltage (PWM duty) and torque by controlling the current.

Salient features:

- Permanent magnet rotor and 3-phase concentrated stator winding; no brushes or commutator.
- Commutation is done electronically by an inverter using rotor position from Hall sensors.
- Trapezoidal back-EMF; quasi-square-wave (six-step) currents, two phases conduct at a time.
- High efficiency (no rotor copper loss), high power-to-weight ratio and high starting torque.



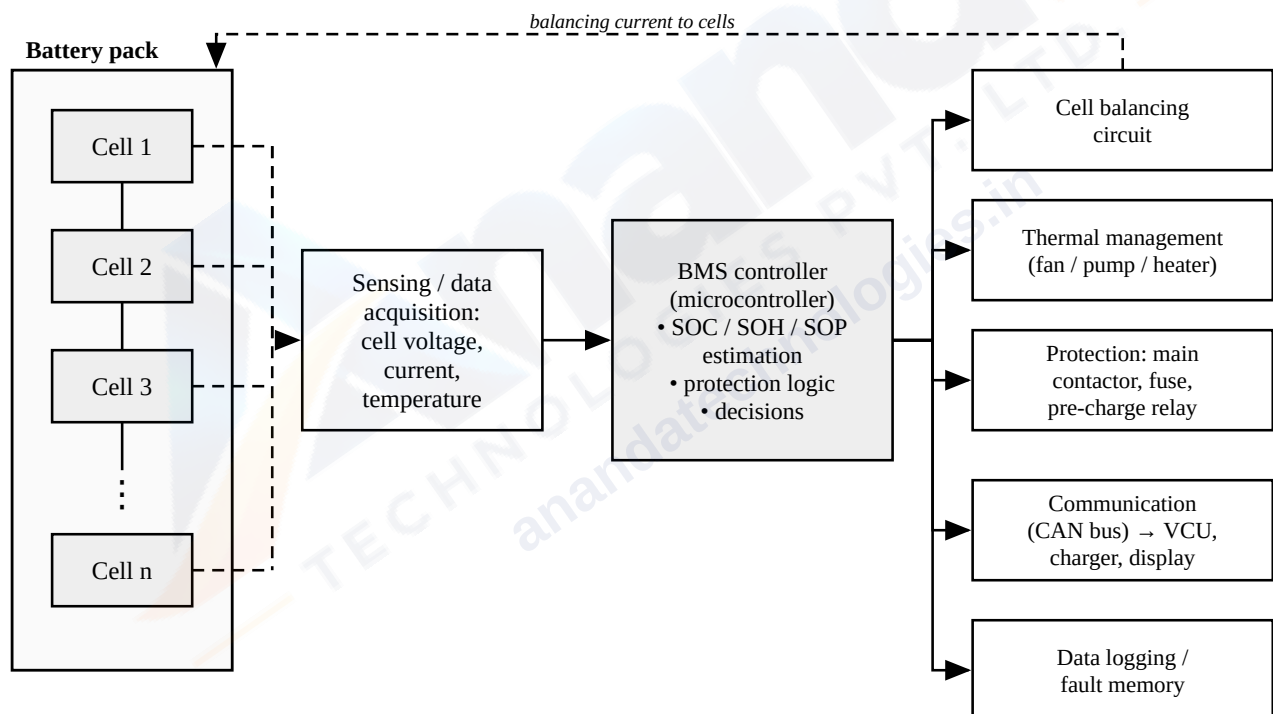
Outer loop: speed control · Inner loop: current (torque) control · Hall sensors decide which two phases conduct

Fig.: Block diagram of torque (current) control of a BLDC motor drive

(Construction & working 3 M, torque control diagram 2 M, features 1 M)

b) BMS, condition monitoring and 3R.

6 M



SOC = state of charge · SOH = state of health · SOP = state of power

Fig.: Block diagram of a Battery Management System (BMS)

Function of each block:

- **Battery pack:** many cells connected in series and parallel to get required voltage and capacity.
- **Sensing / data acquisition:** measures each cell voltage, pack current (shunt / Hall sensor) and temperatures at many points; converts them to digital form (ADC) for the controller.

- **BMS controller (MCU):** brain of BMS — estimates SOC (coulomb counting, OCV method), SOH and available power (SOP); compares values with safe limits and takes decisions.
- **Cell balancing circuit:** equalises cell charges — passive (bleeding extra charge through resistors) or active (transferring charge from higher to lower cells).
- **Thermal management:** controls cooling fan / liquid pump / heater to keep cells within the safe temperature range.
- **Protection (contactor control):** opens main contactors on over-voltage, under-voltage, over-current, short-circuit, over-temperature or insulation fault; pre-charge relay limits inrush current.
- **Communication (CAN):** sends SOC, limits and faults to VCU, charger and dashboard; tells charger how much current to give.
- **Data logging:** stores history and fault codes for diagnosis and warranty.

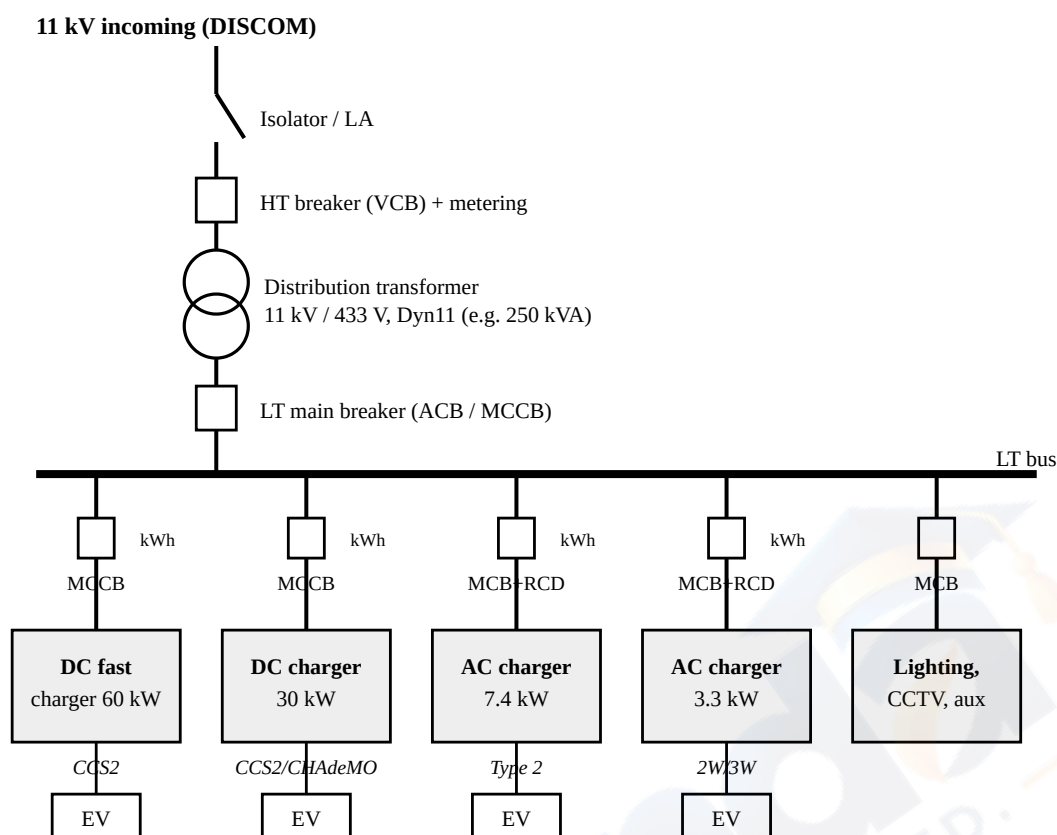
Battery condition monitoring: BMS continuously monitors voltage, current, temperature, internal resistance and SOC / SOH; early warnings (imbalance, rising resistance, temperature rise) allow maintenance before failure.

3R process: Reduce — use the right battery size, avoid over-use of raw materials and extend life with good BMS; **Reuse** — EV batteries at about 70–80 % SOH are reused for 'second-life' stationary storage (solar, UPS); **Recycle** — at end of life, valuable materials (lithium, cobalt, nickel, copper) are recovered by mechanical, pyro- or hydro-metallurgical processes; safe disposal avoids pollution.

(Diagram 2 M, functions 2 M, condition monitoring 1 M, 3R 1 M)

c) Public EV charging station.

6 M



Earthing pit, surge protection and kWh meters (one per charger) are provided as per CEA / DISCOM norms

Fig.: Single line diagram of a public EV charging station

Types of charging stations: home / private (AC), semi-public (offices, apartments), public charging stations (AC + DC), highway fast-charging stations, fleet depots (bus depots), battery swapping stations.

Selection of a public charging station site and sizing:

- Location: traffic density, parking space, easy entry / exit, near highways, malls, petrol pumps; distance between stations.
- Availability of grid supply (LT / HT) and transformer capacity; land cost / lease.
- Vehicle mix (2W / 3W / 4W / buses) decides number and type of chargers (AC / DC, kW rating, connectors).
- Sizing: total connected load = sum of charger ratings; transformer kVA $\approx$ total kW / (power factor $\times$ efficiency) with some margin for future expansion.

Components: HT/LT incoming supply and metering, distribution transformer, LT panel with breakers (ACB / MCCB / MCB, RCD), energy meters, AC and DC chargers with cables and connectors, earthing and surge protection, cable trenches, canopy and lighting, CCTV, network / payment system (app, RFID), fire extinguisher, signage.

(Selection & sizing 2 M, components 2 M, SLD 2 M)

Q.6

a) Comparison of EV motors.

6 M

Point	BLDC motor	PMSM	Induction motor (IM)	SRM
Power-to-weight ratio	High	Very high	Medium	Medium
Torque-speed characteristic	High starting torque; limited constant-power (field weakening) range	High torque; wide speed range with field weakening; smooth torque	Wide speed range with field weakening; constant power region 3–4× base speed	Very wide speed range; high torque ripple and noise
Cost of controller	Low–medium (six-step inverter + Hall sensors)	High (FOC inverter + position sensor)	High (vector control inverter)	Medium (special asymmetric converter)
Cost of motor	High (rare-earth magnets)	High (rare-earth magnets)	Low (rugged, no magnets)	Low (no magnets, no winding on rotor)

(Each point 1½ M)

b) Charging modes as per IEC 61851-1 and connectors.

6 M

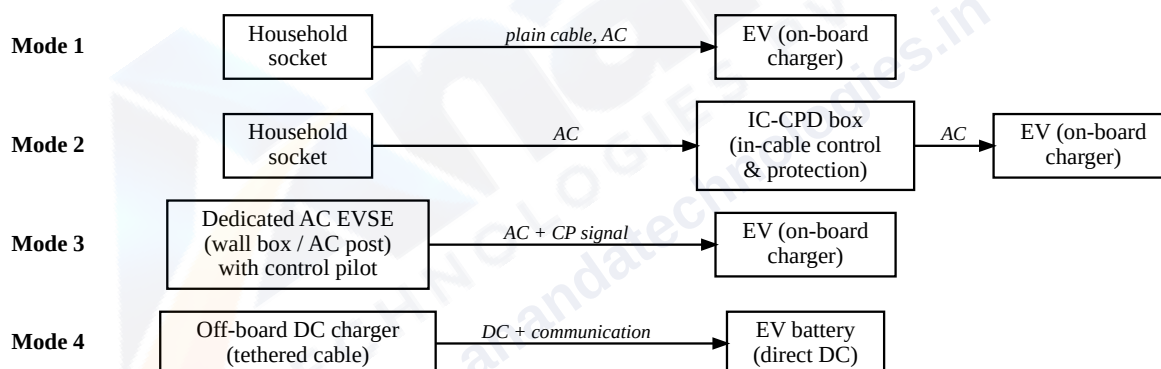


Fig.: Charging modes as per IEC 61851-1

- **Mode 1:** EV connected to a normal household socket with a plain cable; no communication and no special protection in the cable; current up to 16 A (AC). Not recommended / not permitted in many countries.
- **Mode 2:** EV connected to a household / industrial socket through a cable with an **IC-CPD** (in-cable control and protection device) that provides earth-leakage protection and control pilot; up to 32 A AC. Used for portable home charging.
- **Mode 3:** EV connected to a **dedicated AC EVSE** (wall box / AC charging post) permanently connected to the supply; control pilot communication with the vehicle; Type 2 connector; up to about 63 A three-phase (≈ 43 kW).

- **Mode 4: DC charging** — off-board charger converts AC to DC and supplies the battery directly through a tethered cable (CCS2 / CHAdeMO / GB/T) with digital communication between charger and BMS.

Connectors:

Charging	Connectors (standard)
AC	Type 1 (SAE J1772, single-phase); Type 2 (IEC 62196-2, used in India and Europe); Bharat AC-001 (low-power, India); 15 A / 16 A socket for 2W / 3W
DC	CCS2 (Combined Charging System, Type 2 based — most cars in India); CHAdeMO (Japan); GB/T (China); Bharat DC-001 (low-voltage DC, India)

(Four modes 4 M, diagram 1 M, connectors 1 M)

c) Lead-acid battery; comparison with Li-ion.

6 M

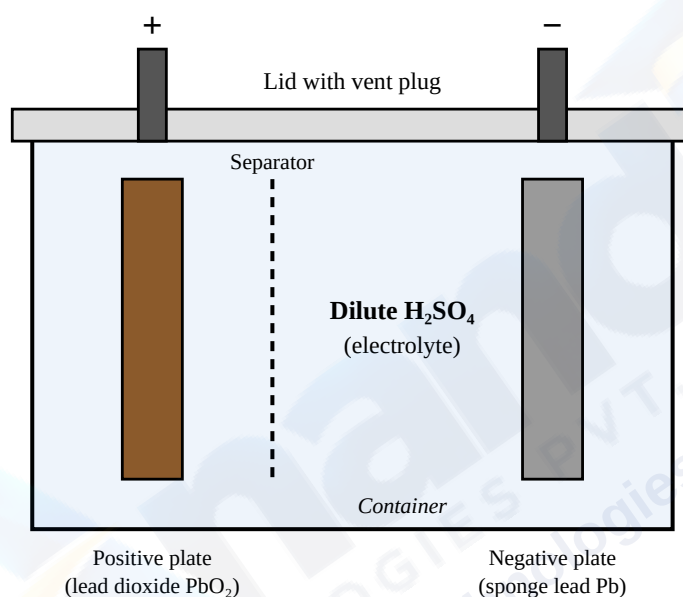
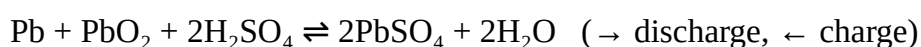


Fig.: Construction of a lead-acid cell

Construction: positive plate of lead dioxide (PbO_2), negative plate of sponge lead (Pb), electrolyte of dilute sulphuric acid (H_2SO_4), porous separators between plates, all in a plastic container; cell voltage 2 V (6 cells give 12 V).

Working: During discharge both plates react with the acid and change to lead sulphate (PbSO_4), and the acid becomes weaker (specific gravity falls). During charging the reaction reverses.



Point	Lead-acid	Li-ion
Cell voltage	2.0 V	3.6–3.7 V (LFP 3.2 V)
Specific energy	30–40 Wh/kg	100–250 Wh/kg
Cycle life	300–500 deep cycles	1000–4000 cycles
Efficiency	≈ 70–80 %	≈ 90–95 %
Cost	Low	High
Maintenance	Water topping (flooded type)	Maintenance-free; needs BMS
Use in EVs	E-rickshaws, 12 V auxiliary battery	Cars, 2W, buses (main traction battery)

(Diagram 1 M, construction & working 2 M, comparison 3 M)

Note: This is a **model question paper prepared by Ananda Technologies** only for practice and exam preparation, based on the pattern of previous MSBTE question papers and the K-scheme syllabus. It is **not an official MSBTE paper**, and it does **not** mean that these questions will come in the exam. Answers follow standard textbook points; marks shown are indicative. Free for students — anandatechnologies.in