

Automobile Engineering (315372)

MSBTE K-Scheme · Model Question Paper — Set B · Model Answers

Answers are written in MSBTE model-answer style. In the exam, answer only the required number of sub-questions (any FIVE / THREE / TWO).

Q.1

a) Classification of automobiles.

2 M

i) On the basis of load capacity: Light motor vehicles (LMV) — cars, jeeps, scooters; Medium vehicles — mini bus, tempo; Heavy motor vehicles (HMV) — trucks, buses, trailers.

ii) On the basis of drive: Front wheel drive, rear wheel drive, four wheel drive (all wheel drive); also left-hand drive and right-hand drive (position of steering).

(1 M each)

b) Necessity of clutch.

2 M

- An IC engine cannot start under load and has no torque at zero speed; it must be disconnected from the wheels while starting and idling.
- To shift gears, the drive must be disconnected momentarily; otherwise gears will clash.
- To start the vehicle smoothly, engine power must be engaged gradually.
- To stop the vehicle without stopping the engine.

(Any two, 1 M each)

c) Functions of gear box.

2 M

- To provide different torque ratios (high torque at low speed for starting and climbing, low torque at high speed on level road).
- To provide a reverse gear for backward motion of the vehicle.
- To provide a neutral position so that engine can run without moving the vehicle.
- To keep engine speed in its efficient range at different road speeds.

(Any two, 1 M each)

d) Toe-in and toe-out.

2 M

i) Toe-in: When the front wheels are set so that the distance between them at the front (A) is less than at the rear (B), seen from top, it is toe-in. $\text{Toe-in} = B - A$ (about 3–5 mm).

ii) Toe-out: When the distance between the front wheels at the front is more than at the rear ($A > B$), it is toe-out. On turns, the wheels have toe-out because the inner wheel turns through a larger angle (toe-out on turns).

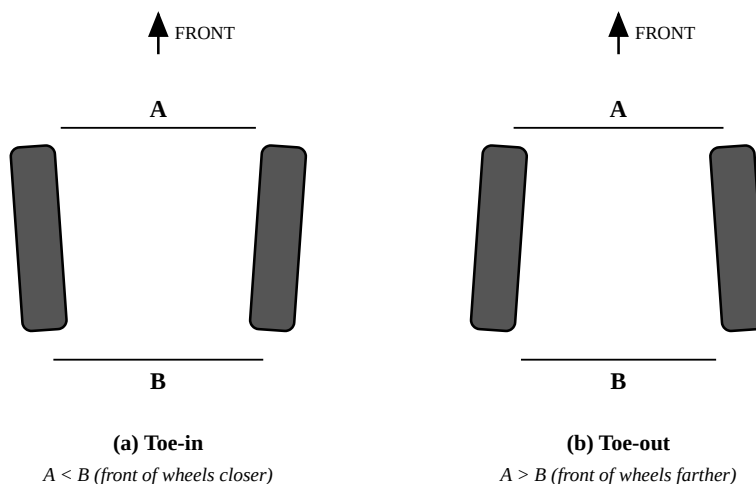


Fig. Toe-in and toe-out (plan view)

(1 M each)

e) Functions of wheel.

2 M

- To support the weight of the vehicle and transfer it to the tyre and road.
- To transmit driving (tractive) torque and braking torque to the road through the tyre.
- To hold the tyre and provide air-tight seat (tubeless) and to allow steering of the vehicle.
- To dissipate heat produced by brakes and tyre.

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

f) Sensors used in automobile.

2 M

Sensor	Application
Oxygen (lambda) sensor	Measures O_2 in exhaust — air–fuel ratio control
Wheel speed sensor	ABS and traction control
Throttle position sensor (TPS)	Engine load / fuel injection quantity
Coolant temperature sensor	Cold start enrichment, cooling fan control
Crankshaft / camshaft position sensor	Ignition and injection timing
MAP / MAF sensor	Measures intake manifold pressure / air flow
Knock sensor	Detects detonation; retards ignition timing

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

g) Sprung and unsprung weight.

2 M

Sprung weight: The weight of all parts of the vehicle which are supported by the suspension springs — body, frame, engine, gear box, passengers and luggage.

Unsprung weight: The weight of parts which are not supported by springs and lie between the springs and the road — wheels, tyres, axles, brake drums/discs, hubs, steering knuckles (and part of springs, shock absorbers and links). Unsprung weight should be as small as possible for good ride and road holding.

(1 M each)

Q.2

a) FERWD layout; advantages over FEFWD.

4 M

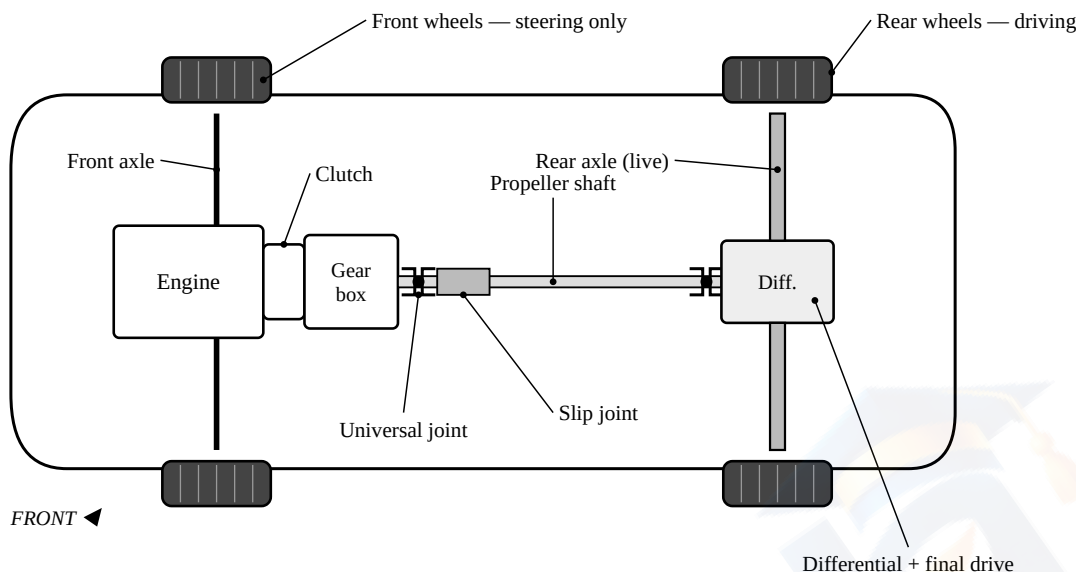


Fig. Front engine rear wheel drive (FERWD) layout — plan view

The engine is mounted longitudinally at the front. Power flows from engine → clutch → gear box → propeller shaft (with universal and slip joints) → differential and final drive → rear axle shafts → rear (driving) wheels. Front wheels only steer. Used in trucks, buses, SUVs and some cars (Mahindra Scorpio, Toyota Innova).

Advantages over FEFWD:

- Better weight distribution between front and rear axles; better traction on hill climbing and while carrying heavy loads (weight shifts to rear wheels).
- Steering is lighter and front wheels are free from driving torque (no torque steer); simpler front suspension.
- Easy access to engine, clutch and gear box for maintenance; suitable for powerful engines and heavy vehicles.

(Sketch 2 M, explanation 1 M, advantages 1 M)

b) Single plate vs multi-plate clutch.

4 M

Basis	Single plate clutch	Multi-plate clutch
Torque capacity	Lower for given diameter — only two friction surfaces.	Higher for same diameter — many friction surfaces (n pairs).
Heat dissipation	Better — dry, open to air; plate is large.	Poorer — plates packed together; wet type uses oil to cool.
Size	Larger diameter for given torque.	Compact, smaller diameter.
Application	Cars, jeeps, buses, trucks.	Motorcycles, scooters, automatic transmissions, racing cars.

(1 M each)

c) Requirements of steering system.

4 M

- It should be **light and easy** to operate; effort at the steering wheel should be small (power steering for heavy vehicles).
- It should be **precise** — vehicle should respond quickly to steering wheel movement, with minimum play (backlash).
- It should have **self-centering (return) action** — wheels should return to straight-ahead position after a turn.
- It should **not transmit road shocks** to the driver's hands, but give 'road feel'.
- It should give **correct steering geometry** (Ackermann) — all wheels roll without slip on turns, so tyre wear is minimum.
- It should be irreversible to a reasonable degree, reliable, and need little maintenance; overall steering ratio should suit the vehicle.

(Any four requirements, 1 M each)

d) Semi-elliptic leaf spring.

4 M

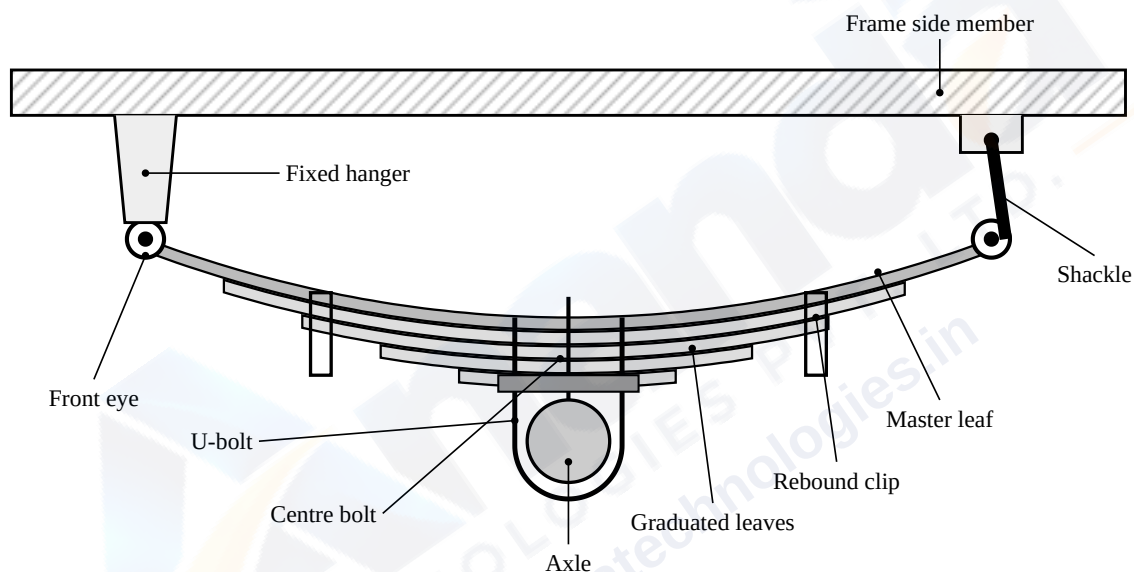


Fig. Semi-elliptic leaf spring (rigid axle suspension)

Construction: It consists of a number of steel strips (leaves) of graduated lengths placed one over the other and held together by a **centre bolt** and **rebound clips**. The longest top leaf is the **master leaf**; its ends are rolled into **eyes**. The front eye is pinned to a fixed hanger bracket on the frame; the rear eye is connected to the frame through a swinging **shackle**. The spring is clamped to the axle at its centre by **U-bolts**.

Working: When the wheel hits a bump, the load bends (flattens) the spring; the leaves slide over each other and the spring absorbs the shock energy. Since the spring length changes when it deflects, the shackle swings to allow this change. Inter-leaf friction gives some damping. The spring also locates the axle and transmits driving and braking thrust to the frame (Hotchkiss drive).

(Sketch 2 M, construction and working 2 M)

Q.3

a) Types of rear axle; fully floating axle.

4 M

Types of rear axle (by method of supporting): 1) Semi-floating axle 2) Three-quarter floating axle 3) Fully floating axle.

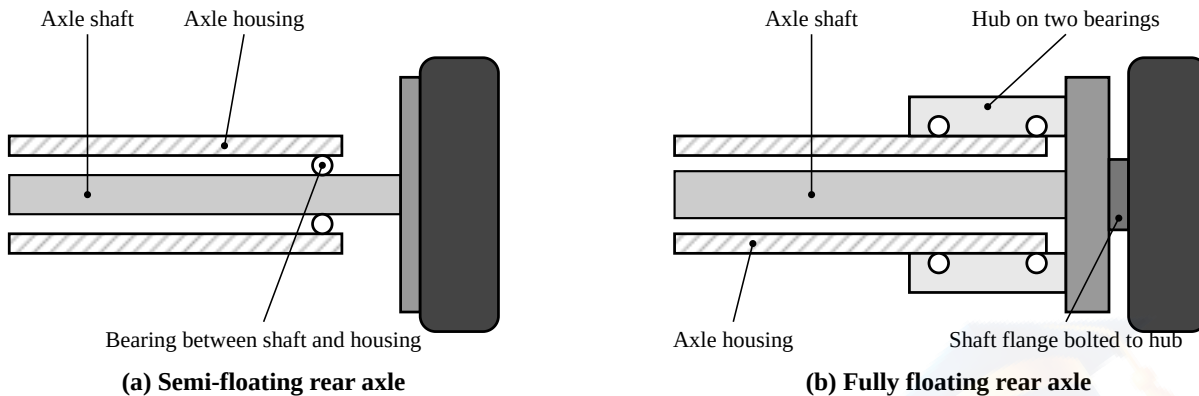


Fig. Types of rear axle (half sections at wheel end)

Fully floating axle: The wheel hub is mounted on two taper roller bearings on the outer end of the axle housing. The axle shaft is bolted to the hub flange and transmits only the driving torque. The whole weight of the vehicle, side thrust and braking reactions are taken by the axle housing. The axle shaft can be withdrawn without removing the wheel or jacking the vehicle, and the wheel does not come off if the shaft breaks. It is costly and heavy; used in trucks and buses.

(Types 1 M, sketch 1½ M, explanation 1½ M)

b) Constant mesh gear box.

4 M

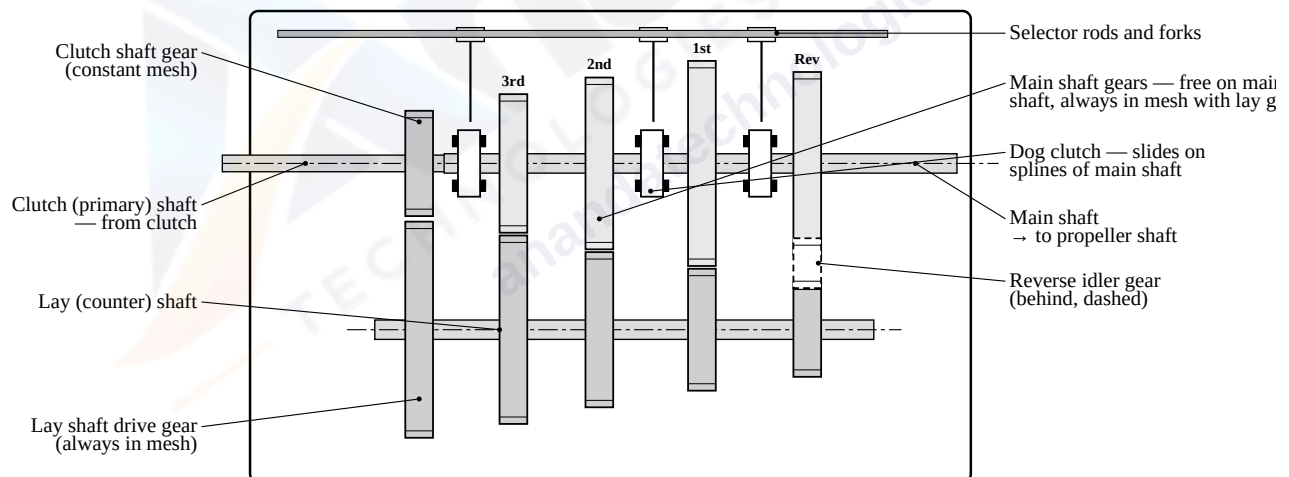


Fig. Constant mesh gear box (4 forward + reverse) — schematic

Construction: It has a clutch (primary) shaft, a lay shaft and a main shaft. The lay shaft gears are fixed to it. Main shaft gears are **free to rotate** on the main shaft and are **always in mesh** with the corresponding lay shaft gears. **Dog clutches**, which slide on splines of the main shaft, are placed between the gears and are moved by selector forks.

Working: All gears rotate continuously when the clutch is engaged, but the main shaft does not turn in neutral. To engage a gear, the driver moves the dog clutch so that its teeth lock with the dog

teeth on the side of the selected gear; that gear then drives the main shaft through the dog clutch. For top (direct) gear, the dog clutch locks the main shaft directly to the clutch shaft. Reverse is obtained through an idler gear. Since only dog clutches slide (not gears), gear changing is easier and helical gears can be used for quiet running; double declutching is used to match speeds.

Example: clutch gear 22 T, lay drive gear 38 T, lay 1st gear 17 T, main 1st gear 35 T → 1st gear ratio = $(38/22) \times (35/17) = 3.556$; at 3000 rpm engine speed, main shaft speed = $3000 / 3.556 = 843.6$ rpm.

(Sketch 2 M, explanation 2 M)

c) Disc brake — construction, working, advantages.

4 M

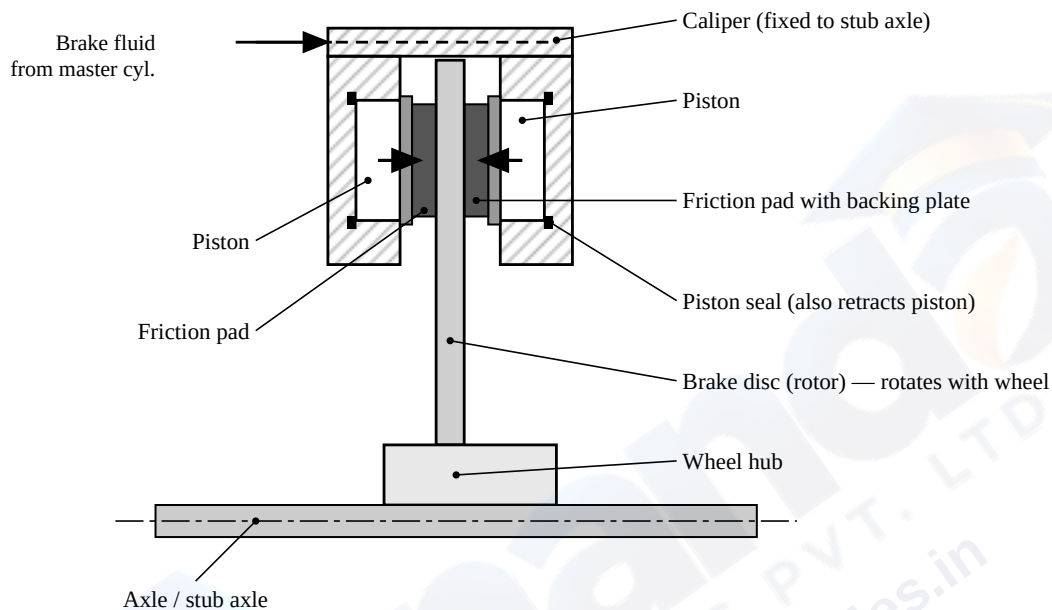


Fig. Disc brake (fixed caliper type) — section

Construction: A cast-iron disc (rotor) is bolted to the wheel hub and rotates with the wheel. A caliper fixed to the stub axle / steering knuckle straddles the disc. The caliper has hydraulic cylinder(s) with pistons; friction pads with steel backing plates are placed on both sides of the disc. Rubber seals prevent leakage and retract the pistons.

Working: When the brake pedal is pressed, fluid pressure from the master cylinder enters the caliper and pushes the pistons; the pads squeeze the rotating disc from both sides. Friction between pads and disc stops the wheel; the heat is dissipated to air. On releasing the pedal, the piston seals pull the pistons back slightly, giving a small clearance.

Advantages over drum brake: better heat dissipation and less brake fade; self-cleaning (water and dust thrown off); easy pad replacement; uniform braking and less pulling to one side.

(Sketch 2 M, construction and working 1 M, advantages 1 M)

d) Types of independent suspension; MacPherson strut.

4 M

Types of independent suspension: 1) Wishbone (double wishbone / parallel link) type 2) MacPherson strut type 3) Trailing link (trailing arm) type 4) Swinging half-axle type 5) Multi-link type (rear).

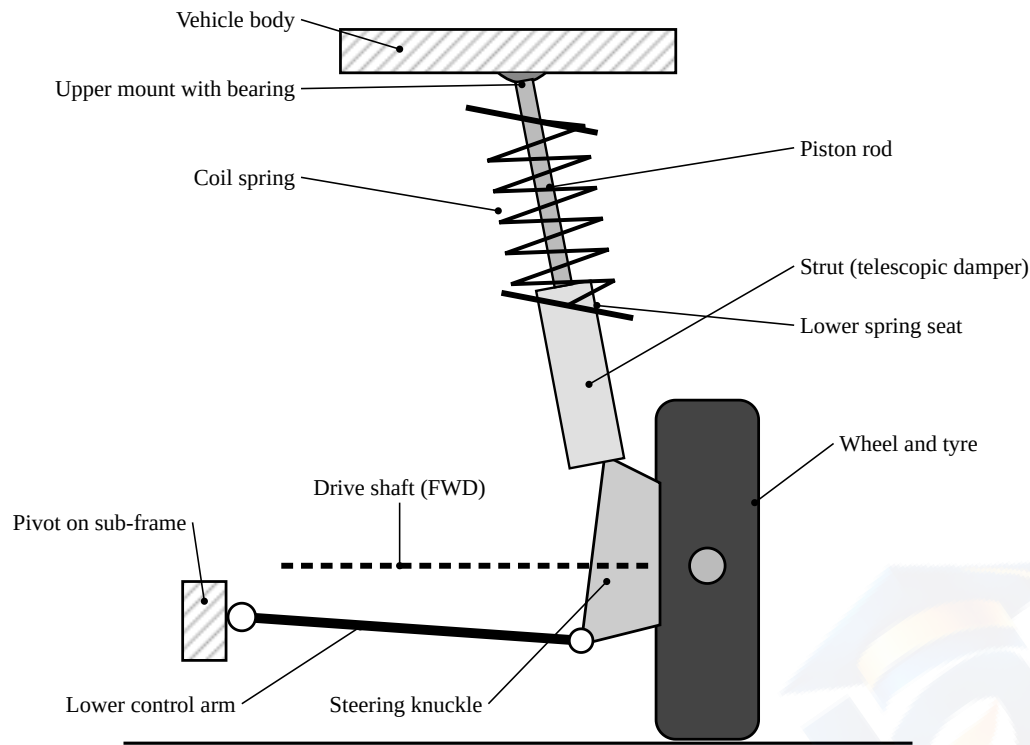


Fig. MacPherson strut type independent front suspension (front view, RH side)

The coil spring is fitted around a telescopic strut (damper). The bottom of the strut is rigidly fixed to the steering knuckle; the top is attached to the body through a rubber mount and bearing. A lower control arm with ball joint locates the knuckle. On a bump the strut telescopes, the spring is compressed and the damper controls oscillation. For steering, the strut rotates about its own axis. It is compact, light and cheap and is used in most front-wheel-drive cars.

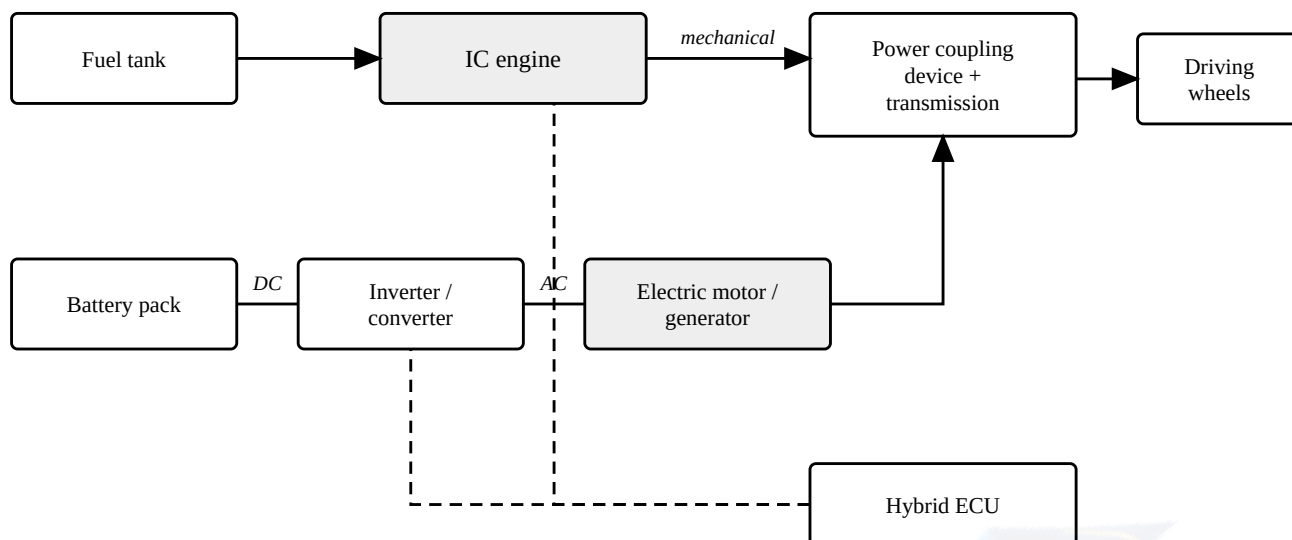
(Types 1 M, sketch 2 M, explanation 1 M)

Q.4

a) Hybrid vehicle — need and components.

4 M

Need: to reduce fuel consumption and emissions of IC engine vehicles; to overcome limited range and long charging time of pure electric vehicles; to recover braking energy; to run engine in its most efficient range.



Engine and motor can drive the wheels separately or together; motor recharges battery during braking

Fig. Parallel hybrid electric vehicle — block diagram

- **IC engine:** main power source for highway driving and charging.
- **Electric motor/generator:** drives the wheels at low speed and assists engine during acceleration; works as generator during braking (regeneration).
- **Battery pack + inverter:** stores electrical energy; inverter converts $DC \leftrightarrow AC$ for the motor.
- **Power coupling device and transmission:** combines engine and motor torque and sends it to wheels.
- **Hybrid control unit:** decides when engine, motor or both should work.

(Need 1 M, block diagram 2 M, components 1 M)

b) Functions of propeller shaft; universal joint.

4 M

Functions of propeller shaft: 1) to transmit torque from gear box to differential (rear axle) in FERWD vehicles; 2) to accommodate change in angle (through universal joints) and change in length (through slip joint) caused by up-and-down movement of rear axle.

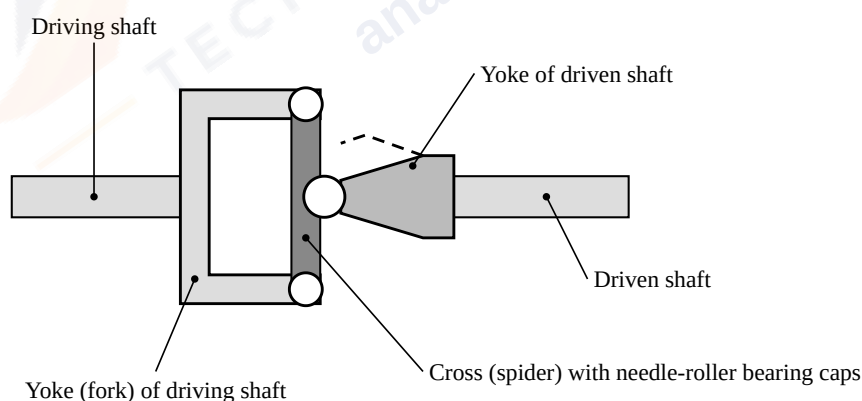


Fig. Universal (Hooke's) joint — cross (spider) type

Universal (Hooke's) joint: It consists of two Y-shaped yokes (forks), one on the driving shaft and the other on the driven shaft, placed at 90° to each other. They are connected by a **cross (spider)** having four arms (trunnions) which run in needle-roller bearing caps fitted in the yoke ends. When

the driving shaft rotates, torque passes through the cross to the driven yoke, even when the two shafts are inclined (up to about 15–20°). The cross pivots in the bearings to accommodate the angle.

(Functions 1 M, sketch 2 M, explanation 1 M)

c) Positive camber and positive caster.

4 M

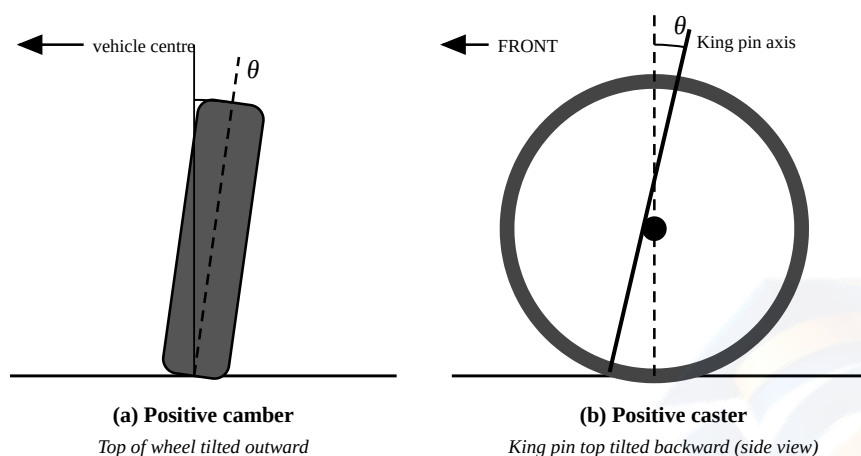


Fig. Positive camber and positive caster

Positive camber: The top of the wheel is tilted outward from the vertical when seen from front ($\frac{1}{2}^\circ$ to 2°). *Effects:* brings the point of tyre contact closer to the king pin axis, so steering becomes easier; prevents the wheels from tilting inward under load; excessive camber causes wear on the outer edge of the tyre and pulling of the vehicle to the side of more camber.

Positive caster: The top of the king pin is tilted backward from the vertical when seen from side (2° – 8°). *Effects:* the point of road contact trails behind the steering axis, giving **directional stability** and **self-centering** (wheels return to straight ahead after a turn); too much caster makes steering heavy, too little causes wandering.

(Sketches 2 M, explanation with effects 2 M)

d) Why tubeless tyres are preferred (advantages).

4 M

- **Safety:** on puncture the air leaks slowly (nail remains in tyre) — no sudden blow-out at high speed.
- **Lighter and cooler running:** no tube, so no friction between tube and tyre; less heat and longer life.
- **Easy puncture repair:** can be repaired by a plug without removing the tyre from the rim.
- **Better air retention:** air-tight inner liner; pressure is maintained longer.
- Less unsprung weight, better fuel economy and better ride; simpler fitting (no pinching of tube).

(Any four, 1 M each)

e) Alternator — functions and working principle.

4 M

Functions: 1) to generate electrical energy when the engine is running; 2) to recharge the battery; 3) to supply current to all electrical loads (lights, ignition, ECU, wipers); the output is controlled by a voltage regulator (about 13.8–14.4 V).

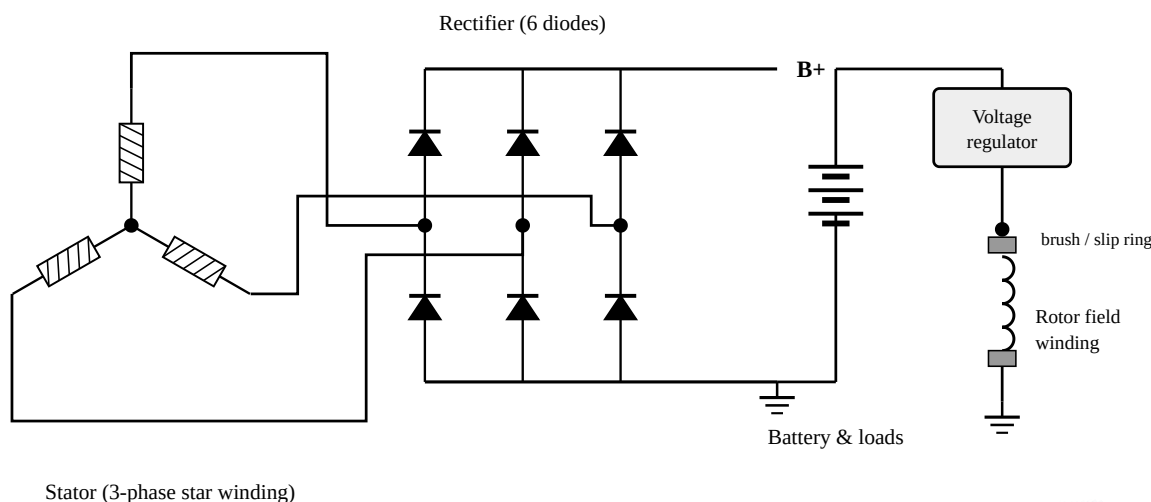


Fig. Alternator — stator, rotor, rectifier and regulator (circuit)

Working principle: It works on Faraday's law of electromagnetic induction. The rotor (field winding on claw poles) is driven by the engine through a V-belt and pulley; DC field current is supplied to it through brushes and slip rings, so it becomes a rotating electromagnet. The rotating magnetic field cuts the stationary three-phase stator windings and induces AC voltage in them. The rectifier (6 diodes) converts this AC into DC for the battery and loads. The voltage regulator controls the field current to keep the output voltage constant at all engine speeds.

(Functions 1 M, sketch 1 M, principle 2 M)

Q.5

a) Necessity and working of differential on a turn.

6 M

Why required: When a vehicle takes a turn, the outer wheel has to travel a longer distance (larger radius) than the inner wheel in the same time, so the outer wheel must turn faster. If both rear wheels are fixed on a solid axle, one wheel would have to skid — causing tyre wear, difficult steering and stress on the axle. The differential allows the two driving wheels to run at different speeds while still transmitting torque to both.

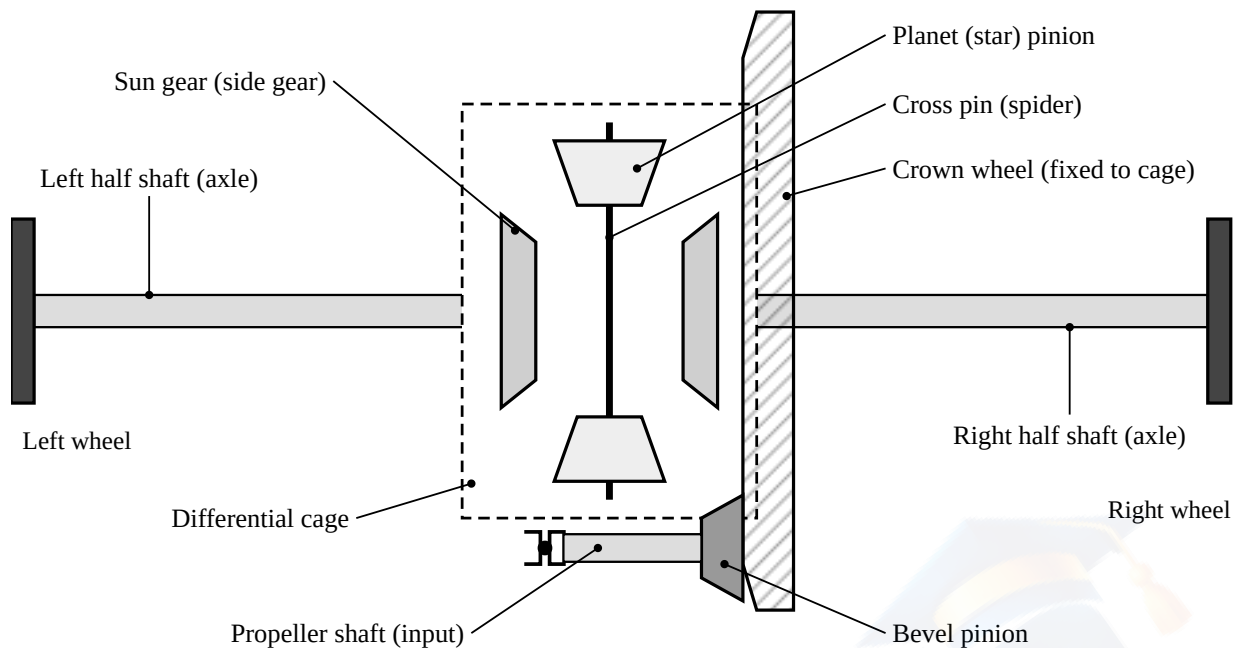


Fig. Conventional differential — plan view (schematic)

Working:

- The propeller shaft drives the bevel pinion, which drives the crown wheel. The crown wheel turns the differential cage, which carries the planet (star) pinions on the cross pin.
- **Straight ahead:** resistance on both wheels is equal; planet pinions do not spin on their pin but carry both sun gears round at cage speed — both wheels have equal speed.
- **On a turn:** the inner wheel slows down because of greater resistance. Its sun gear slows; the planet pinions now start rotating on their pin and 'walk' round the slower sun gear, which makes the opposite (outer) sun gear rotate faster by the same amount.
- Relation: $N_{\text{inner}} + N_{\text{outer}} = 2 N_{\text{cage}}$. Torque is shared equally between the two wheels.

(Necessity $1\frac{1}{2} M$, sketch $2 M$, working $2\frac{1}{2} M$)

b) Telescopic shock absorber — bump, rebound, necessity.

6 M

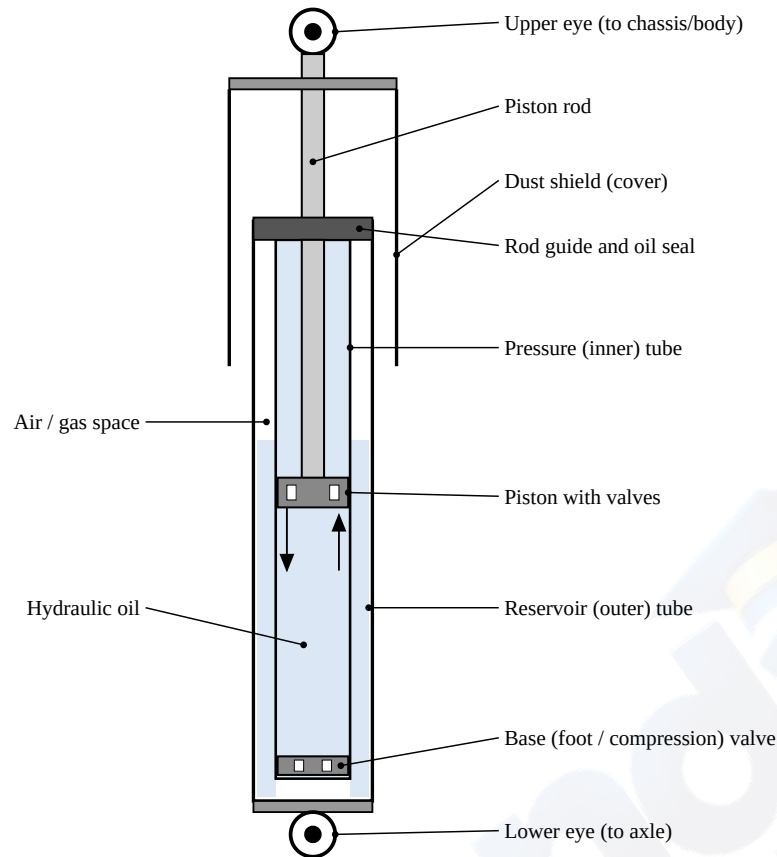


Fig. Telescopic (hydraulic, twin-tube) shock absorber

Necessity: A spring alone, after absorbing a road shock, keeps vibrating (oscillating) for a long time, giving a bouncy, uncomfortable ride and poor tyre–road contact. The shock absorber (damper) damps these oscillations quickly by converting their energy into heat in oil.

Working during bump (compression): the wheel moves up, the outer tube moves up and the piston moves down relative to the pressure tube. Oil below the piston passes through the compression valves in the piston to the upper side; the excess oil displaced by the entering rod flows through the base valve into the reservoir tube. The restriction offered by small valve openings resists the motion lightly so that the spring can absorb the shock.

Working during rebound (extension): the spring pushes the wheel back down and the piston moves up. Oil above the piston is forced through the rebound valves (stronger resistance) to the lower side, and oil is drawn back from the reservoir through the base valve. The large resistance in rebound stops the spring from overshooting, so the oscillations die out quickly.

(Sketch 2 M, bump 1½ M, rebound 1½ M, necessity 1 M)

c) Air (pneumatic) brake system.

6 M

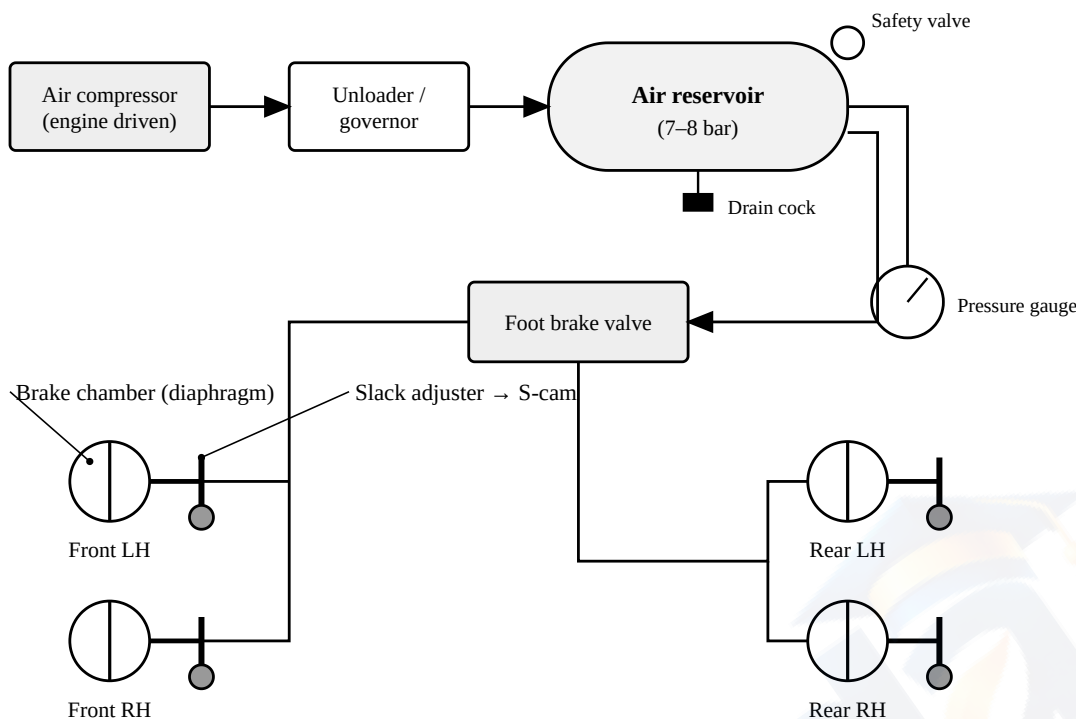


Fig. Air (pneumatic) brake system — layout

Construction: An engine-driven air compressor supplies air through an unloader/governor valve to the air reservoir (7–8 bar), which has a safety valve and drain cock. A foot-operated brake valve controls the flow of compressed air from the reservoir to brake chambers at each wheel. Each brake chamber has a diaphragm and push rod connected through a slack adjuster to the S-cam of the drum brake. A pressure gauge on the dashboard shows the air pressure.

Working: When the driver presses the brake pedal, the brake valve opens and compressed air flows to the brake chambers. The air pressure pushes the diaphragm and push rod, which rotates the slack adjuster and S-cam; the cam expands the brake shoes against the drums and brakes are applied. The force is proportional to pedal travel. When the pedal is released, the brake valve exhausts air from the chambers to atmosphere, return springs bring the shoes back and the brakes are released. The governor unloads the compressor when the reservoir pressure reaches the maximum.

Advantages: very large braking force with small pedal effort — suitable for heavy vehicles; a small air leak does not make the brakes fail suddenly (unlike fluid loss); compressed air can also be used for horns, door opening, tyre inflation; easy coupling of trailer brakes.

(Sketch 2 M, construction and working 3 M, advantages 1 M)

Q.6

a) Classification of frames; conventional ladder frame.

6 M

Classification of chassis frames: 1) Conventional (separate) frame — ladder type, X-type, perimeter, box section; 2) Semi-integral frame (body attached to frame through rigid mountings); 3) Integral / unitized (frameless) construction; 4) Sub-frames; also backbone and tubular (space) frames for special vehicles.

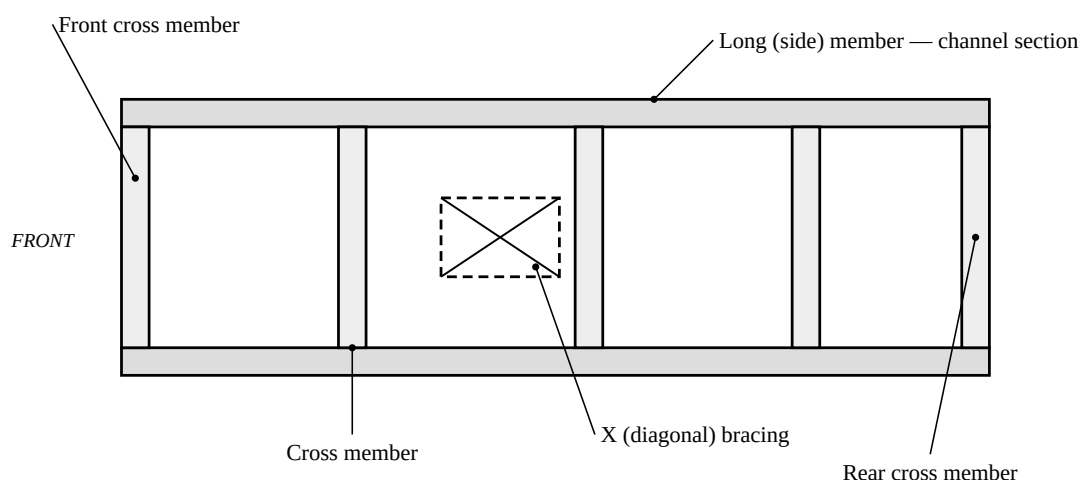


Fig. Conventional ladder type chassis frame

Conventional ladder frame: It consists of two long side members of channel, I- or box section running along the length of the vehicle, joined by several cross members by riveting or welding. It looks like a ladder. X-bracing may be added for torsional stiffness. The frame is narrowed at front for steering lock and kicked up over the rear axle. The body is mounted separately on the frame through rubber pads.

Advantages	Disadvantages
Very strong — suitable for heavy loads and rough roads.	Heavy — more fuel consumption.
Easy to design, manufacture and repair after accident.	Higher floor and centre of gravity — less stability.
Body can be changed; different bodies on same chassis.	Lower torsional stiffness compared to unitized body.
Isolates noise and vibration from body (rubber mounts).	More material and cost per vehicle.

(Classification 1 M, sketch 2 M, explanation 1 M, advantages and disadvantages 2 M)

b) Multi-plate clutch.

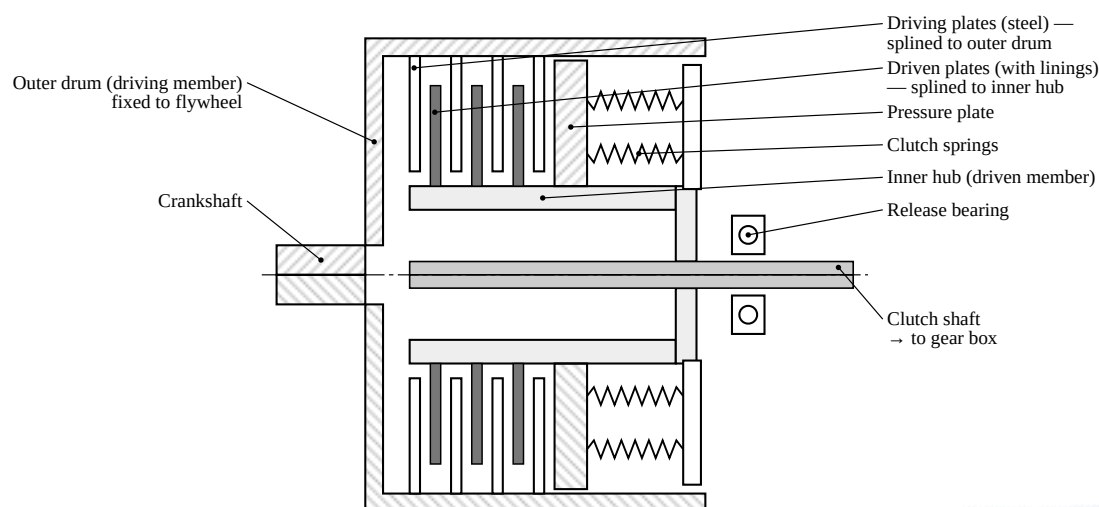


Fig. Multi-plate clutch — half section

Construction: It has a number of clutch plates instead of one. The driving plates (plain steel) are splined on the inside of an outer drum which is fixed to the flywheel (or engine-driven primary gear). The driven plates, carrying friction linings, are splined to an inner hub which is fixed on the clutch shaft. Driving and driven plates are placed alternately. A pressure plate and a set of springs hold the plates pressed together. A release bearing and lever / cable act on the pressure plate. It may be **dry** or **wet** (running in oil for cooling and smooth engagement).

Working: *Engaged* — the springs press all plates together; due to friction on many surfaces the driven plates rotate with the driving plates and torque is transmitted to the clutch shaft. *Disengaged* — when the clutch lever/pedal is operated, the pressure plate is pulled back against the springs, the plates separate and no torque is transmitted.

Torque capacity $T = n \mu W R_m$, where n = number of pairs of contact surfaces — so more torque in small diameter.

Applications: motorcycles and scooters, automatic transmissions (clutch packs), racing cars, heavy vehicles where space is limited.

(Sketch 2 M, construction 2 M, working 1 M, applications 1 M)

c) Lead acid battery — charging/discharging; numerical.

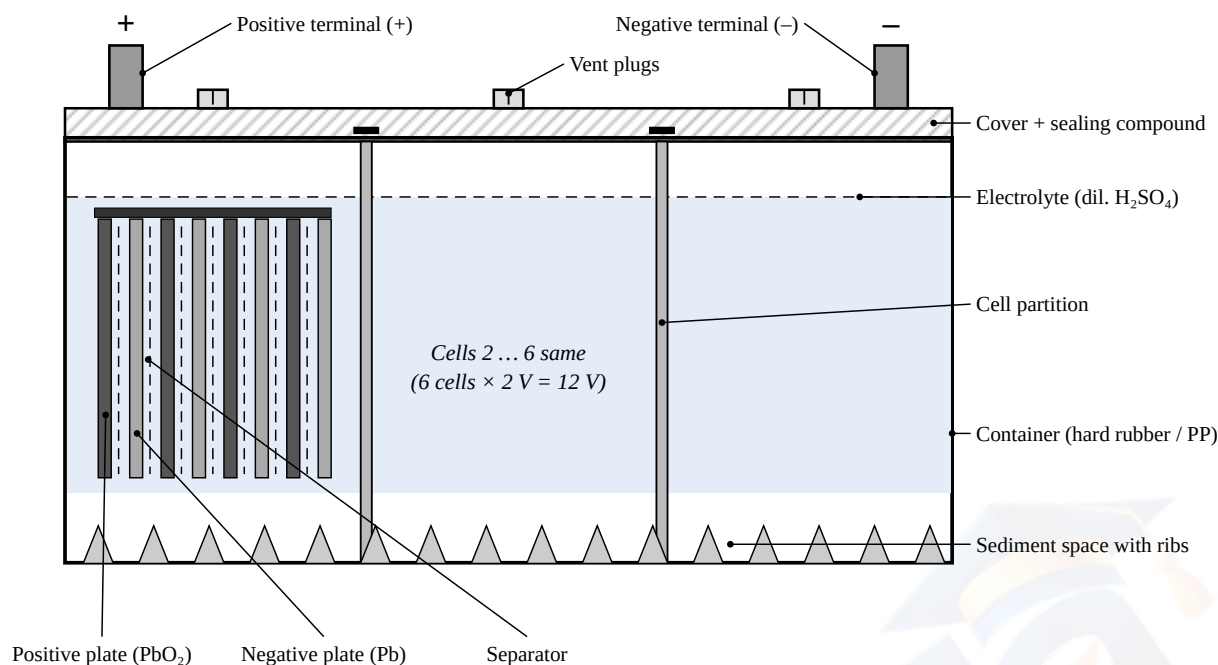
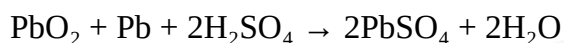


Fig. Construction of a 12 V lead-acid battery (cut-away of one cell)

Discharging: When a load is connected, current flows from + to – terminal through the load. Sulphuric acid reacts with both plates: PbO_2 (positive) and Pb (negative) both change into lead sulphate (PbSO_4), and water is formed. Hence the specific gravity of electrolyte falls (from about 1.28 to about 1.12) and voltage drops.



Charging: A DC supply (alternator) of slightly higher voltage is connected, + to + and – to –. Current flows into the battery in the reverse direction; lead sulphate on positive plate is converted back into PbO_2 and on negative plate into spongy Pb , and sulphuric acid is formed again. Specific gravity rises; near full charge, gassing (H_2 and O_2) starts.



Numerical: Given $V = 12 \text{ V}$, capacity = 75 Ah, load current = 15 A.

Current at 20-hour rate $I = 75 / 20 = 3.75 \text{ A}$

Approximate time on 15 A load $t = 75 / 15 = 5 \text{ h}$ (ideal; the actual time is somewhat less because the usable capacity falls at higher discharge current).

Energy stored $\approx V \times \text{Ah} = 12 \times 75 = 900 \text{ Wh}$.

(Sketch 1 M, discharging $1\frac{1}{2} \text{ M}$, charging $1\frac{1}{2} \text{ M}$, numerical 2 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