

Automobile Engineering (315372)

MSBTE K-Scheme · Model Question Paper — Set A · 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) Define automobile. Enlist its major components.

2 M

Automobile: An automobile is a self-propelled vehicle which carries its own power source (engine or electric motor) and is used for transporting passengers and goods on road. Examples: car, bus, truck, motorcycle.

Major components: 1) Basic structure — chassis frame and body; 2) Power plant — engine (or motor); 3) Transmission system — clutch, gear box, propeller shaft, differential, axles; 4) Control systems — steering and brakes; 5) Suspension system, wheels and tyres; 6) Electrical system — battery, starting, charging, ignition and lighting.

(Definition 1 M, components 1 M)

b) Functions of clutch.

2 M

- To connect and disconnect the engine power from the gear box (transmission) as and when required.
- To allow the engine to be started and run while the vehicle is stationary.
- To permit smooth (gradual) engagement so that the vehicle starts without jerk.
- To allow gear changing by disengaging the drive, and to damp out vibrations / act as a safety slip under overload.

(Any two/four functions, ½ M each)

c) Functions of universal joint and slip joint.

2 M

Universal joint: It connects two shafts whose axes are inclined and transmits torque even when the angle between the gear box output shaft and propeller shaft changes due to up-and-down movement of the rear axle on springs.

Slip joint: It allows change in the *length* of the propeller shaft (by sliding of splined shaft in splined sleeve) when the rear axle moves up and down.

(1 M each)

d) Define camber and caster.

2 M

i) Camber: The angle between the centre line of the wheel and the vertical line, seen from the front of the vehicle, is called camber. If the top of the wheel is tilted outward it is positive camber; inward is negative camber. (Usually $\frac{1}{2}^\circ$ to 2° .)

ii) Caster: The angle between the king pin (steering) axis and the vertical line, seen from the side of the vehicle, is called caster. If the top of the king pin is tilted backward it is positive caster. (Usually 2° to 8° .)

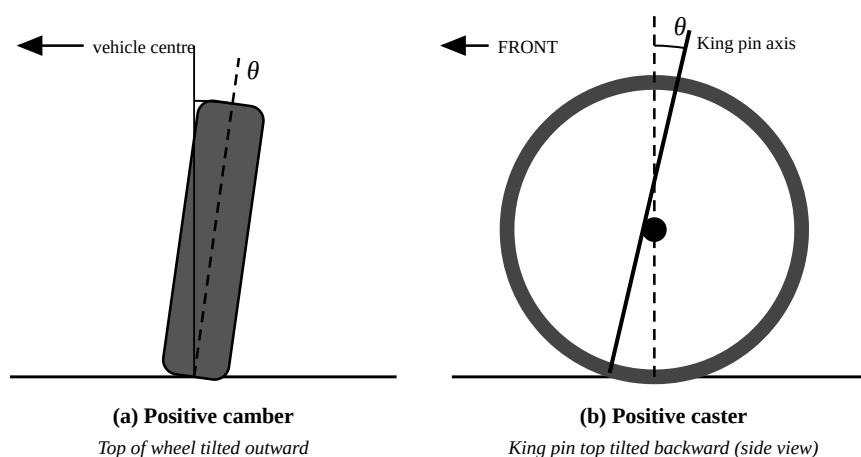


Fig. Camber and caster

(1 M each)

e) Tube type vs tubeless tyre.

2 M

Tube type tyre	Tubeless tyre
Air is held in a separate inner rubber tube.	No tube; air is held between tyre and rim by an air-tight inner liner.
Punctured tube deflates suddenly — unsafe at high speed.	Deflates slowly after puncture — safer.
Heavier; more heat is generated due to tube-tyre friction.	Lighter and runs cooler.
Can be used with ordinary (spoke/split) rims.	Needs an air-tight rim with valve fitted in the rim.

(Any two points, 1 M each)

f) Battery rating; current at 20-hour rate.

2 M

Battery rating: It is the specification of the electrical capacity of a battery — the amount of current it can supply for a stated time at a stated temperature before the cell voltage falls to 1.75 V. The common rating is the **ampere-hour (Ah) capacity at 20-hour rate**; other ratings are cold cranking amperes (CCA) and reserve capacity (RC).

Given: $V = 12 \text{ V}$, capacity = 60 Ah, rate = 20 h

Discharge current $I = \text{Capacity} / \text{time} = 60 / 20 = 3 \text{ A}$ (the battery can supply 3 A for 20 hours).

(Definition 1 M, calculation 1 M)

g) Functions of chassis frame.

2 M

- To support the weight of the engine, transmission, body, passengers and goods.
- To withstand static and dynamic loads (bending, torsion, braking and inertia loads) without undue deflection.
- To provide mounting points for the suspension, steering, axles and other components.
- To keep all components in correct alignment and to absorb shocks on collision.

(Any two, 1 M each)

Q.2

a) FEFWD layout and advantages.

4 M

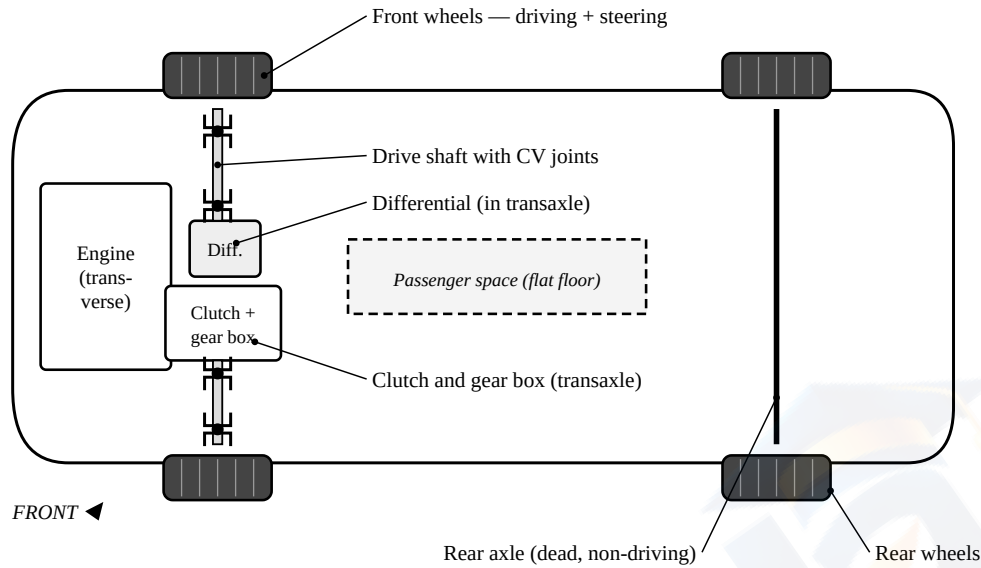


Fig. Front engine front wheel drive (FEFWD) layout — plan view

In FEFWD layout the engine (usually transverse), clutch, gear box and differential (together called a **transaxle**) are placed at the front. Power goes through two drive shafts with constant velocity (CV) joints to the front wheels, which are both driving and steering wheels. The rear axle is a dead axle. Example: Maruti Swift, Hyundai i20.

Advantages:

- No propeller shaft — flat floor and more passenger/boot space.
- Compact and lighter power unit; lower cost of transmission.
- Engine weight is on the driving wheels — better traction on wet and slippery roads.
- Good directional stability; vehicle is pulled rather than pushed (tends to understeer, which is safer).

(Sketch 2 M, any four advantages 2 M)

b) Single plate coil spring clutch.

4 M

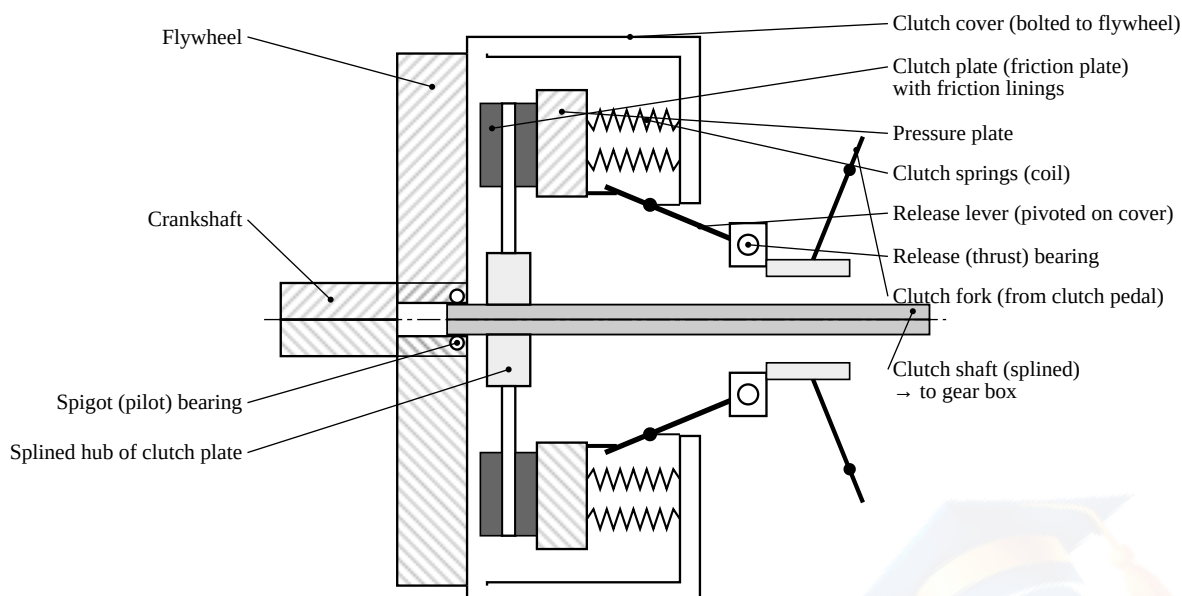


Fig. Single plate clutch with coil springs (engaged position)

Construction: The flywheel is bolted to the crankshaft. The clutch (friction) plate, having friction linings on both sides, is mounted on the splines of the clutch shaft. The pressure plate presses the clutch plate against the flywheel with the help of a number of coil springs placed between the pressure plate and the clutch cover. The cover is bolted to the flywheel. Release levers are pivoted on the cover; a release (thrust) bearing operated by the clutch pedal through a fork acts on the inner ends of the levers.

Working:

- **Engaged:** When the pedal is released, the springs press the pressure plate so that the clutch plate is gripped between flywheel and pressure plate. Due to friction the clutch plate rotates with the flywheel and power goes to the clutch shaft.
- **Disengaged:** When the pedal is pressed, the release bearing pushes the inner ends of the release levers. The levers pull the pressure plate back against the spring force, the clutch plate becomes free and no power is transmitted.

(Sketch 2 M, construction and working 2 M)

c) Disc brake vs drum brake.

4 M

Point	Disc brake	Drum brake
Construction	Rotating disc gripped by pads in a caliper.	Shoes expand against inside of a rotating drum.
Heat dissipation	Disc is exposed to air — better cooling, less brake fade.	Heat is trapped inside the drum — more fade.
Self-energising	Not self-energising; needs more pedal force (servo used).	Leading shoe is self-energising; less effort.

Water / dust	Water and dust are thrown off — recovers quickly.	Water and dust collect inside the drum.
Maintenance	Pads are easy to inspect and replace.	Drum must be removed to inspect linings.
Weight / cost	Lighter, costlier.	Heavier, cheaper; easy to fit parking brake.
Use	Front wheels of cars, motorcycles.	Rear wheels of cars, trucks.

(Any four points, 1 M each)

d) MacPherson strut suspension.

4 M

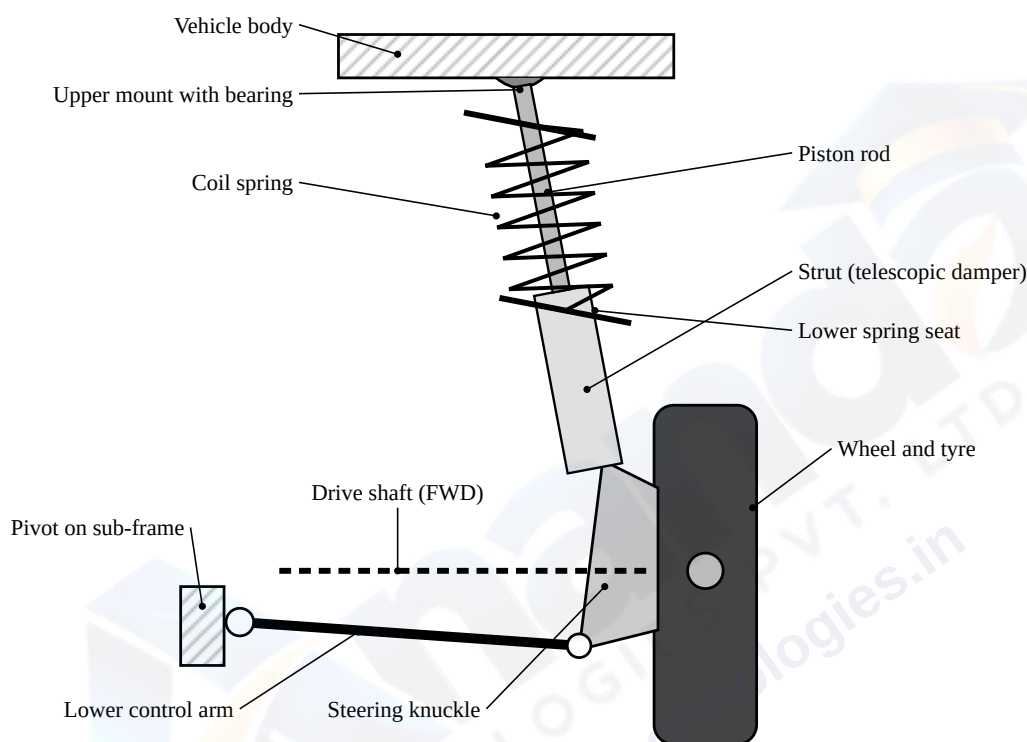


Fig. MacPherson strut type independent front suspension (front view, RH side)

Construction: It is an independent front suspension. A telescopic strut (shock absorber) is rigidly fixed to the steering knuckle at the bottom; its upper end is fixed to the body (strut tower) through a rubber mount and a thrust bearing. A coil spring is fitted around the strut between lower and upper spring seats. The bottom of the knuckle is located by a lower control arm (wishbone) through a ball joint; the arm is pivoted on the sub-frame.

Working: When the wheel goes over a bump, the knuckle and strut lower tube move up, compressing the coil spring which absorbs the shock; the damper in the strut controls the oscillations of the spring. The lower arm swings about its pivot. While steering, the whole strut rotates about the line joining the upper mount and lower ball joint (this is the steering axis).

Advantages: few parts, light and cheap; occupies less space — suitable for FWD cars; wide engine compartment; less unsprung weight.

(Sketch 2 M, explanation 2 M)

Q.3

a) Types of frame.

4 M

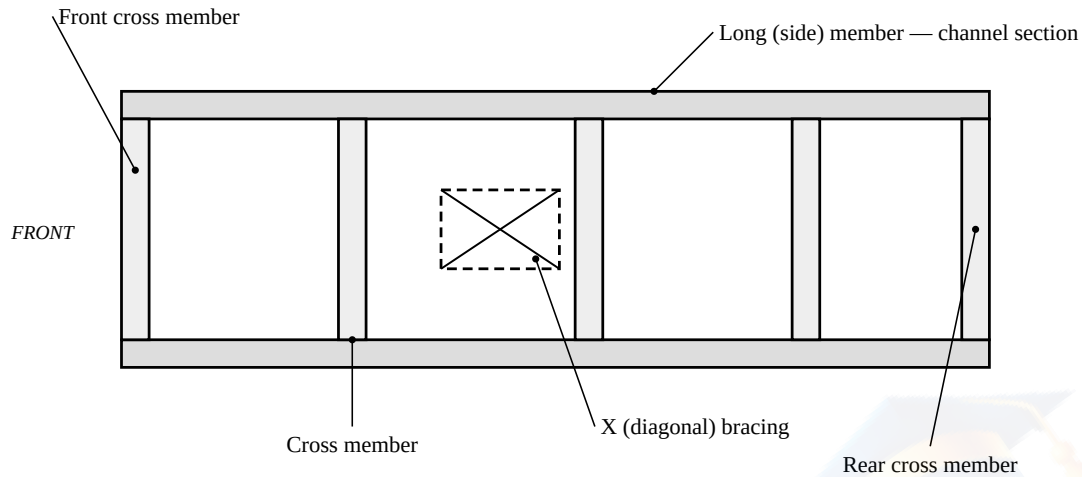


Fig. Conventional ladder type chassis frame

i) Conventional (ladder) frame: Two long side members of channel or box section joined by a number of cross members (riveted or welded). It forms a separate chassis on which body is mounted. It is strong and easy to repair; used in trucks, buses and SUVs. It is heavy and the vehicle is higher.

ii) Sub-frame: A small separate frame on which the engine, front suspension or rear axle is mounted. The sub-frame is attached to the main frame or body through rubber mountings. It isolates vibration and noise from the body and makes assembly easier.

iii) Unitized (frameless / integral) construction: No separate frame; the body itself is made of pressed steel panels welded together and acts as the load-carrying structure. All components are mounted on the body. It is light, rigid, cheaper in mass production and gives lower floor; it is difficult to repair after accident. Used in almost all modern cars.

(Each type with features $1\frac{1}{3}$ M)

b) Torque converter.

4 M

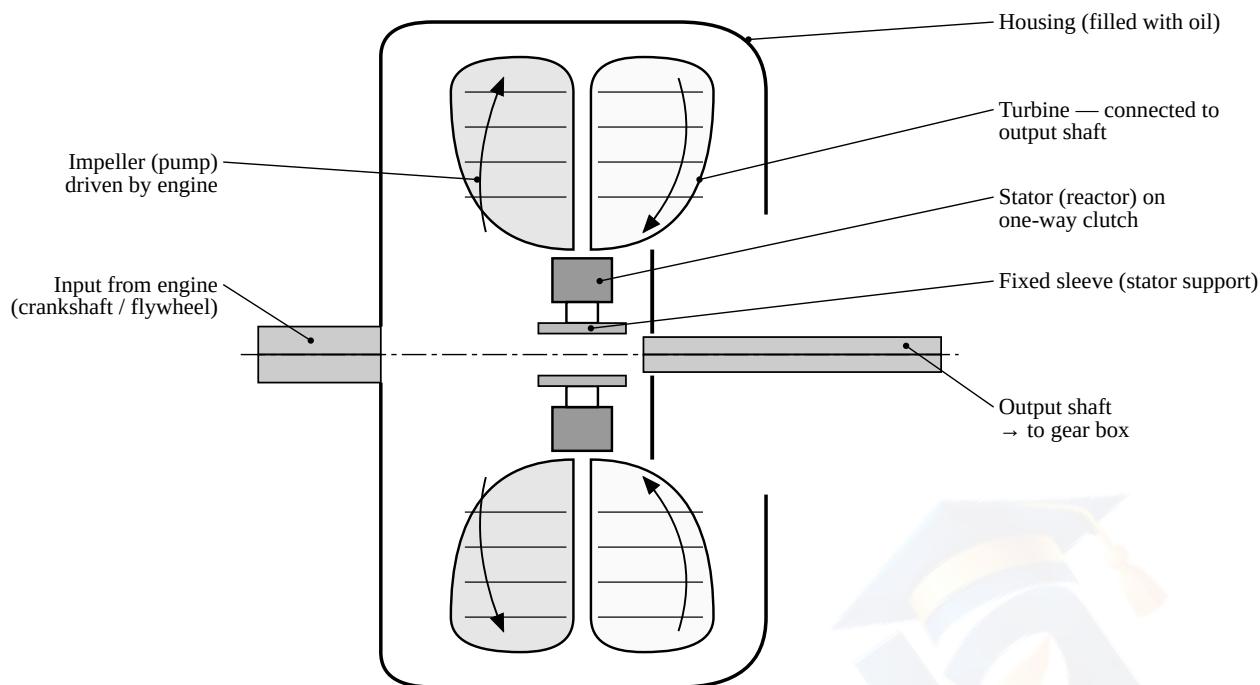


Fig. Torque converter — half section

A torque converter is a fluid coupling with an extra member (stator) which **multiplies torque**. It is used in automatic transmission in place of a clutch. It has three elements:

- **Impeller (pump):** connected to the engine flywheel/housing; it throws oil outward by centrifugal action.
- **Turbine:** connected to the output (gear box input) shaft; oil from impeller strikes its curved blades and rotates it.
- **Stator (reactor):** mounted on a one-way clutch on a fixed sleeve between turbine outlet and impeller inlet.

Working: At low turbine speed (starting), oil leaving the turbine is redirected by the stator blades in the direction of impeller rotation. This helps the impeller and torque on the turbine becomes up to about 2 to 2.5 times engine torque. As turbine speed approaches impeller speed, oil strikes the back of stator blades; the one-way clutch lets the stator freewheel and the unit works as a simple fluid coupling (torque ratio 1:1).

(Sketch 2 M, explanation 2 M)

c) Steering requirements; rack and pinion gear box.

4 M

Requirements (any two): steering must be light and easy to operate; it should be precise and self-centering (wheels return to straight-ahead after a turn); road shocks should not be transmitted to the driver; it should give correct turning (true rolling) of all wheels; the steering ratio should give good control.

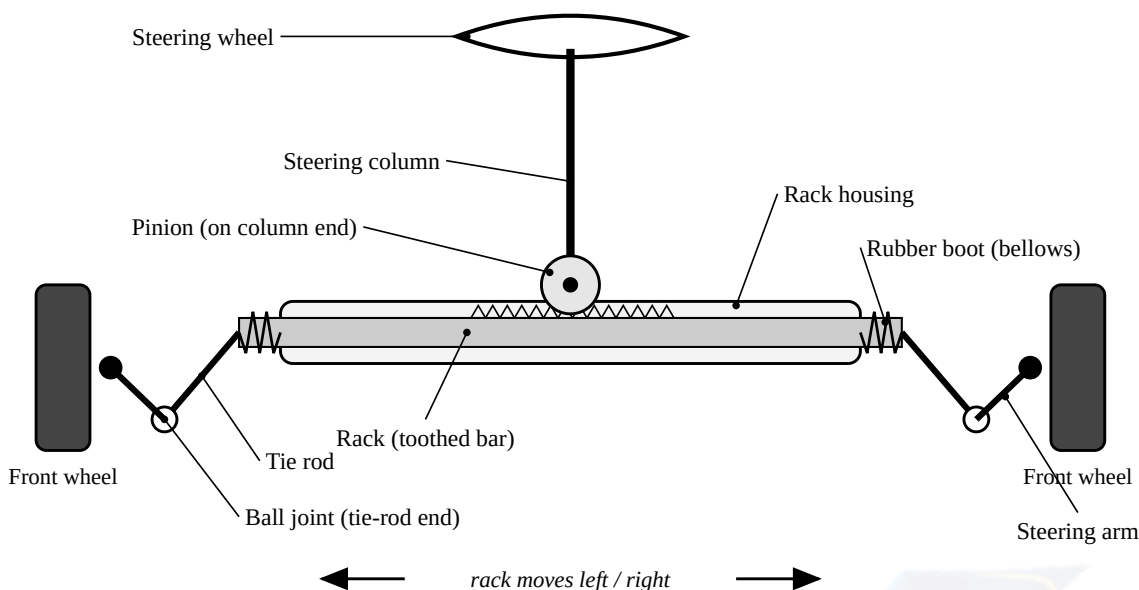


Fig. Rack and pinion steering gear — plan view

Construction: A pinion fixed at the lower end of the steering column meshes with a toothed rack. The rack slides in a tubular housing fixed to the body. Both ends of the rack are connected through ball joints and tie rods to the steering arms of the front wheels. Rubber boots (bellows) keep dirt out.

Working: When the steering wheel is turned, the pinion rotates and moves the rack to the left or right. The rack pushes/pulls the tie rods and steering arms and the wheels turn about the king pin axes.

Applications: passenger cars and light vehicles (Maruti, Hyundai, Tata cars) — simple, light, direct and precise.

(Requirements 1 M, sketch 2 M, working 1 M)

d) Wheel balancing — purpose and procedure.

4 M

Purpose: If the mass of the wheel and tyre is not uniformly distributed about the axis, the wheel is unbalanced. Wheel balancing is done to remove wheel hop and wobble (shimmy), vibration of steering wheel, uneven and fast tyre wear and wear of suspension and steering parts, and to give a comfortable ride.

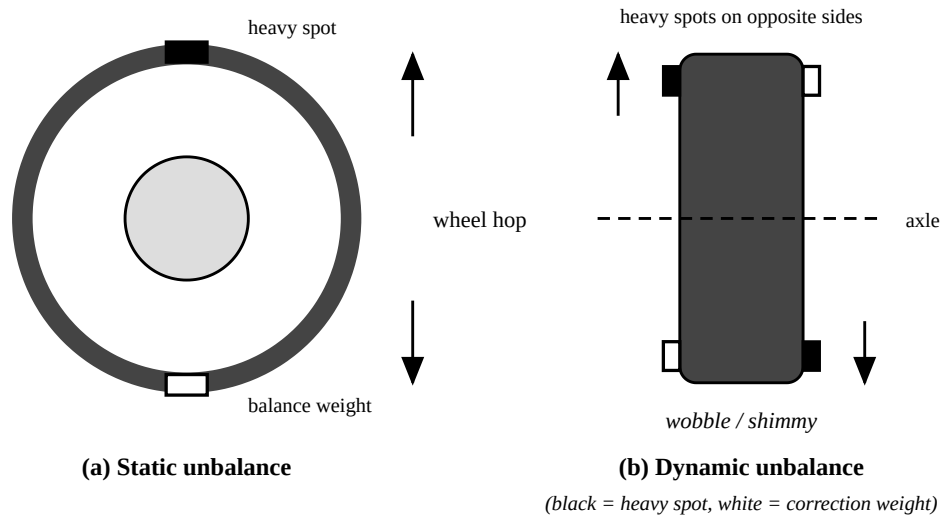


Fig. (a) Static unbalance and (b) dynamic unbalance of a wheel

Procedure (computerised off-car wheel balancer):

1. Remove the wheel; clean it, remove old balance weights, stones from tread; check tyre pressure.
2. Mount the wheel on the balancer shaft with the correct cone and tighten with the wing nut.
3. Enter wheel data — rim diameter, rim width and distance of rim from the machine.
4. Lower the guard and spin the wheel. The machine measures static and dynamic unbalance and shows the weight (grams) and position for inner and outer rim planes.
5. Rotate the wheel to the indicated position and fix the clip-on or stick-on weights at 12 o'clock on inner and outer sides.
6. Spin again to check that the reading is zero (within limit), then refit the wheel and tighten nuts to specified torque.

(Purpose 1 M, procedure 3 M)

Q.4

a) Loads acting on chassis frame.

4 M

- **Static (vertical) loads:** weight of body, engine, passengers and cargo — produces **bending** of the side members.
- **Short duration (impact) loads:** while crossing a bump or pot hole — vertical shock loads.
- **Torsional loads:** when one front wheel rises and the diagonally opposite rear wheel falls, the frame is twisted.
- **Inertia loads:** due to sudden application of brakes or acceleration — longitudinal loads; also lateral (side) loads during cornering.
- **Impact loads due to collision:** sudden heavy loads on the front or rear of the frame.
- **Engine torque reaction and overload:** reaction of engine/transmission torque at the mountings; loads when the vehicle is overloaded.

(Any four loads with explanation, 1 M each)

b) Construction of propeller shaft.

4 M

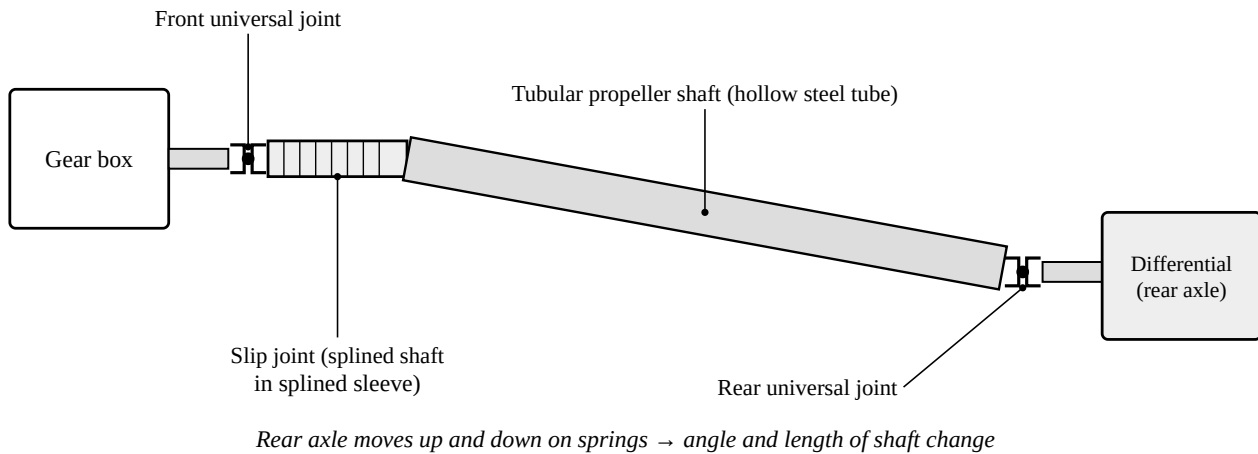


Fig. Propeller shaft with universal joints and slip joint

Construction: The propeller shaft connects the gear box output shaft to the differential pinion shaft in a FERWD vehicle. It is made of a **hollow steel tube** (high torsional strength, light weight, high whirling speed). A **universal joint** is fitted at each end of the tube to allow change of angle. A **slip joint** (splined shaft sliding in a splined sleeve) is provided at the front end to allow change of length. Long shafts are made in two pieces with a centre support bearing. The shaft is dynamically balanced.

Working: Torque from the gear box is transmitted through front universal joint, slip joint, tube and rear universal joint to the differential. As the rear axle moves up and down, the universal joints take care of change in angle and slip joint takes care of change in length.

(Sketch 2 M, construction 2 M)

c) ABS — concept with block diagram.

4 M

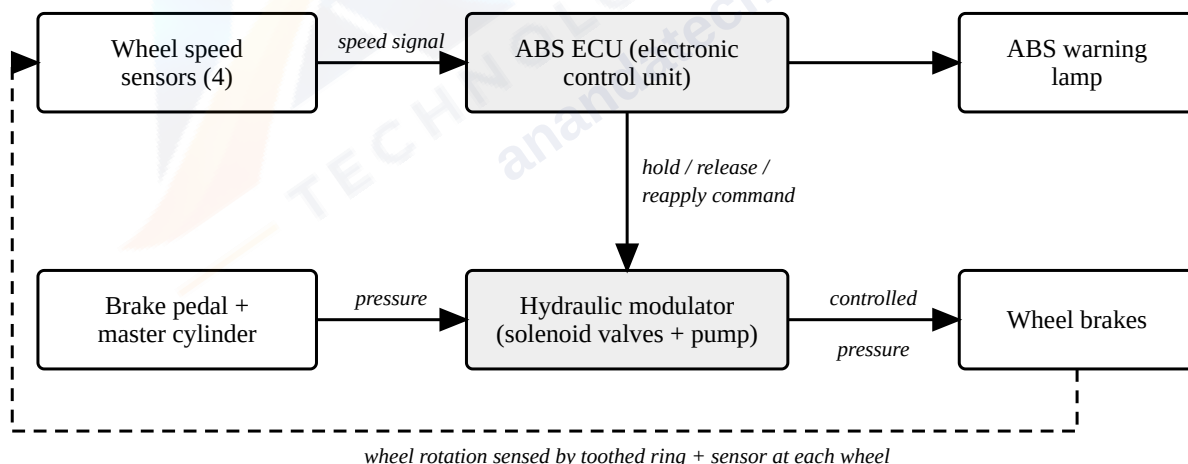


Fig. Antilock brake system (ABS) — block diagram

Concept: During hard braking on slippery road, wheels may lock and skid. A locked wheel gives less braking force and the driver loses steering control. ABS prevents wheel lock-up and keeps wheel slip in the best range (about 10–20 %).

- **Wheel speed sensors** at each wheel send speed signals to the ECU.

- **ECU** compares wheel speeds with vehicle speed; when a wheel is about to lock (rapid deceleration), it commands the modulator.
- **Hydraulic modulator** (solenoid valves and pump) first *holds* the pressure, then *releases* it and again *re-applies* it to that wheel brake — many times per second.
- Thus the wheel keeps rotating, giving shorter stopping distance and steering control. A warning lamp shows ABS faults.

(Block diagram 2 M, explanation 2 M)

d) Construction of lead acid battery.

4 M

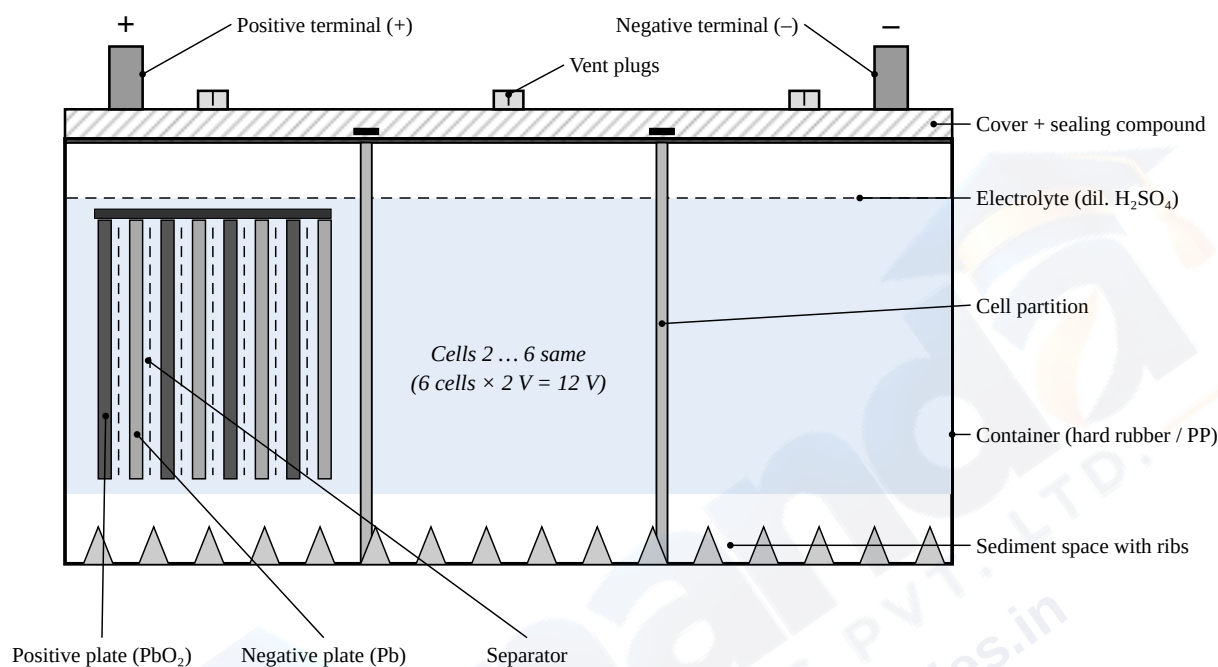


Fig. Construction of a 12 V lead–acid battery (cut-away of one cell)

- **Container:** made of hard rubber or polypropylene, divided by partitions into 6 cells (each about 2 V, total 12 V). Ribs at the bottom form a sediment space.
- **Plates:** positive plates of lead peroxide (PbO_2 , chocolate brown) and negative plates of spongy lead (Pb, grey) are pasted on lead-antimony grids. Positive and negative plate groups are interleaved; there is one more negative plate in each cell.
- **Separators:** porous insulating sheets (rubber/PVC/glass mat) between plates prevent short circuit but allow electrolyte to pass.
- **Electrolyte:** dilute sulphuric acid, specific gravity about 1.26–1.28 when fully charged.
- **Cell connectors, terminals, cover and vent plugs:** cells are connected in series by lead connectors; + and – terminal posts are provided; vent plugs allow gases to escape.

Chemical reaction: $\text{PbO}_2 + \text{Pb} + 2\text{H}_2\text{SO}_4 \rightleftharpoons 2\text{PbSO}_4 + 2\text{H}_2\text{O}$ (discharge $\rightarrow$ / $\leftarrow$ charge).

(Sketch 2 M, construction 2 M)

e) Toe-in and king pin inclination.

4 M

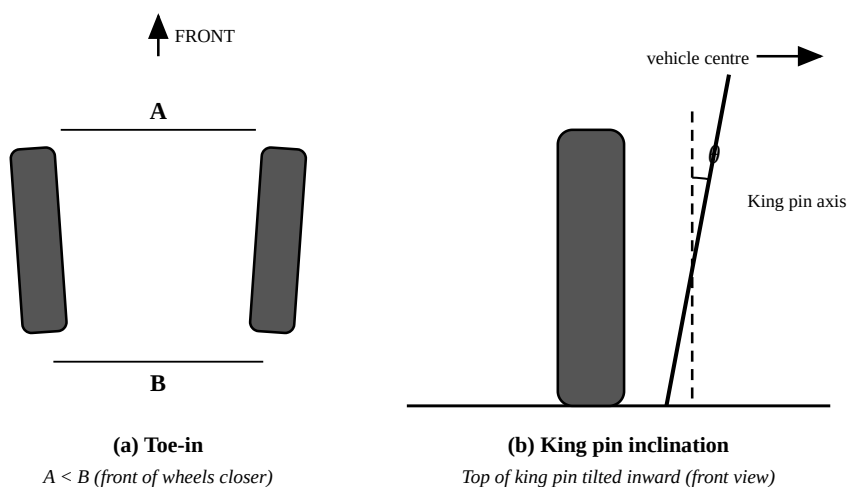


Fig. Toe-in and king pin inclination

i) Toe-in: When the front wheels are closer at the front than at the rear (seen from top), it is called toe-in. Toe-in = $B - A$, generally 3 to 5 mm. It compensates for the tendency of positively cambered wheels to roll outward and prevents side slip and tyre wear.

ii) King pin inclination (KPI) / steering axis inclination: The angle between the king pin centre line and the vertical, seen from the front, with the top of the king pin tilted inward, is called KPI (about 7° to 8°). It reduces the scrub radius, makes steering light, and gives self-centering (directional stability).

(Each definition 1 M, each sketch 1 M)

Q.5

a) Differential — construction and working.

6 M

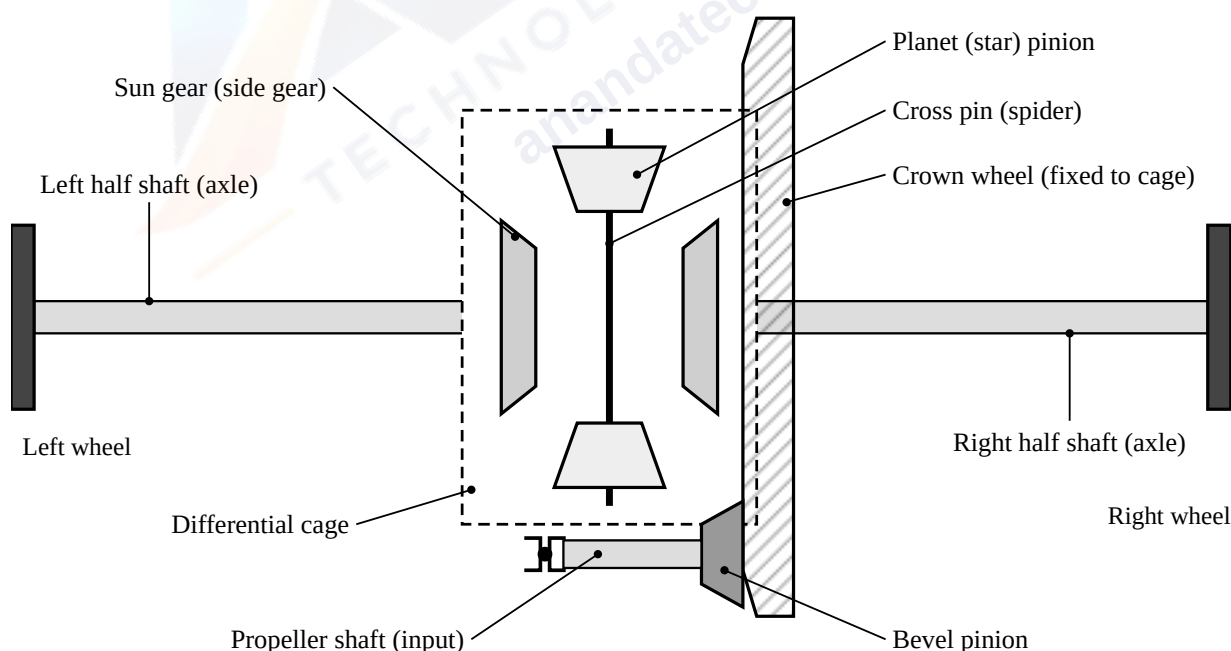


Fig. Conventional differential — plan view (schematic)

Necessity: On a turn, the outer wheel travels a longer distance than the inner wheel. If both wheels were on one solid axle, one wheel would slip, causing tyre wear and difficult steering. The differential allows the two rear wheels to rotate at different speeds while transmitting power to both.

Construction: The propeller shaft drives a bevel pinion which meshes with the crown wheel. The crown wheel is bolted to the differential cage. The cage carries a cross pin (spider) on which two (or four) planet (star) pinions are free to rotate. The planet pinions mesh with two sun (side) gears which are splined to the left and right half shafts (axles).

Working:

- **Straight road:** Both wheels have equal resistance. The cage, planet pinions and sun gears rotate as one unit; planet pinions do not rotate on their pin. Both half shafts turn at the speed of the crown wheel.
- **On a turn:** The inner wheel offers more resistance and slows down. The planet pinions now rotate on their own pin as well as revolve with the cage, so the outer sun gear speeds up by the same amount by which the inner one slows down. Speed of inner wheel + speed of outer wheel = $2 \times$ speed of crown wheel (cage).

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

b) Telescopic shock absorber.

6 M

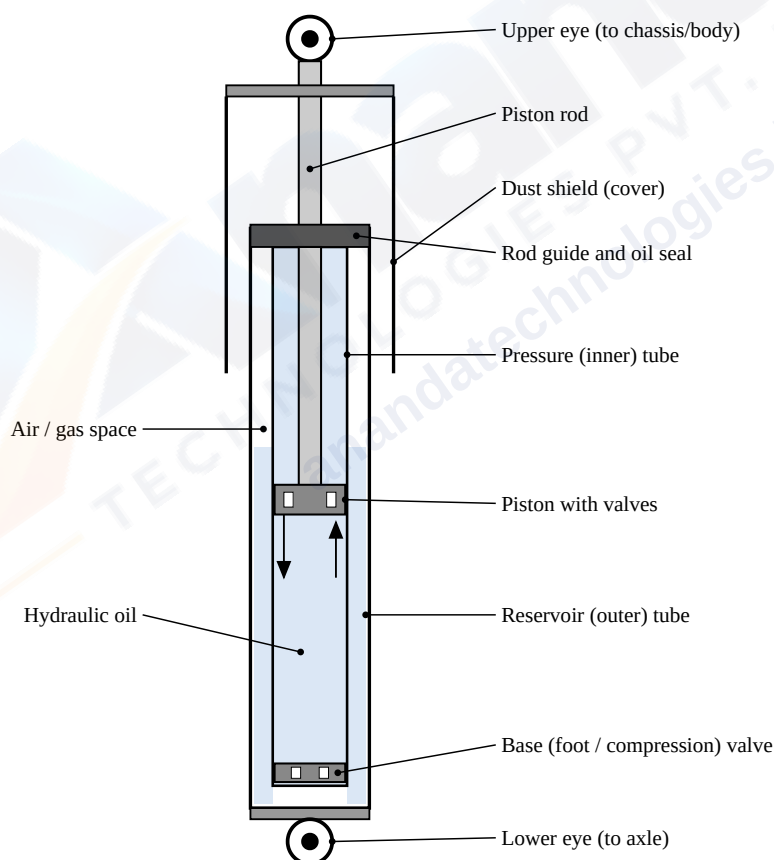


Fig. Telescopic (hydraulic, twin-tube) shock absorber

Construction: It consists of two concentric tubes — inner pressure tube and outer reservoir tube — filled with hydraulic oil. A piston with small valve holes is attached to the piston rod, whose

upper eye is fixed to the chassis (body). The lower eye of the outer tube is fixed to the axle. A base (foot) valve is fitted at the bottom of the pressure tube. A rod guide with oil seal at the top and a dust shield protect the unit.

Working:

- **Compression (bump) stroke:** When the wheel hits a bump, the tubes move up and the piston moves down relative to the pressure tube. Oil below the piston flows through the piston valves to the upper side; the extra oil (equal to volume of rod entering) flows through the base valve into the reservoir. The resistance to flow through small holes damps the motion.
- **Rebound stroke:** When the spring extends, the piston moves up. Oil above the piston is forced through the rebound valves to the lower side and oil is drawn back from the reservoir through the base valve. Rebound valves give greater resistance so that spring oscillations die out quickly.

Thus the kinetic energy of spring oscillation is converted into heat in the oil — giving comfortable ride and good road holding.

(Sketch 3 M, construction and working 3 M)

c) Battery ignition system (4-cylinder).

6 M

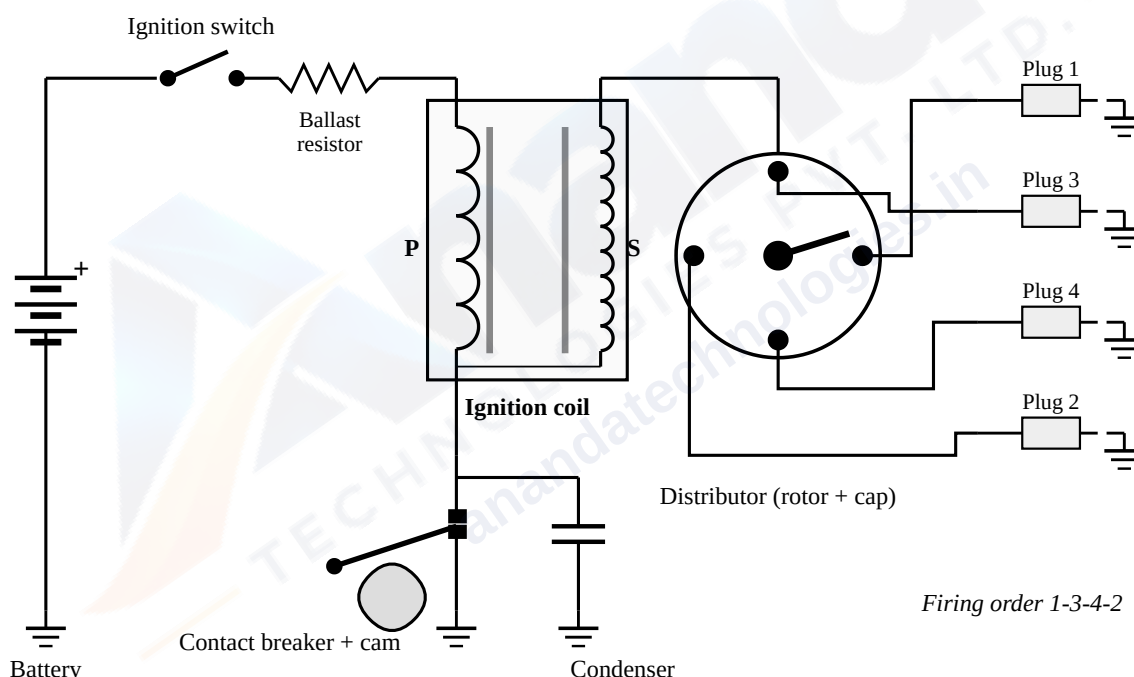


Fig. Battery (coil) ignition system for a four-cylinder engine

Components: battery (12 V), ignition switch, ballast resistor, ignition coil (primary 200–300 turns of thick wire, secondary about 20000 turns of fine wire on a soft iron core), contact breaker (CB) operated by a cam, condenser connected across the CB, distributor (rotor and cap) and four spark plugs.

Working:

- When the ignition switch is ON and CB points are closed, current flows from battery → switch → ballast resistor → primary winding → CB points → earth. A magnetic field builds up in the

coil core.

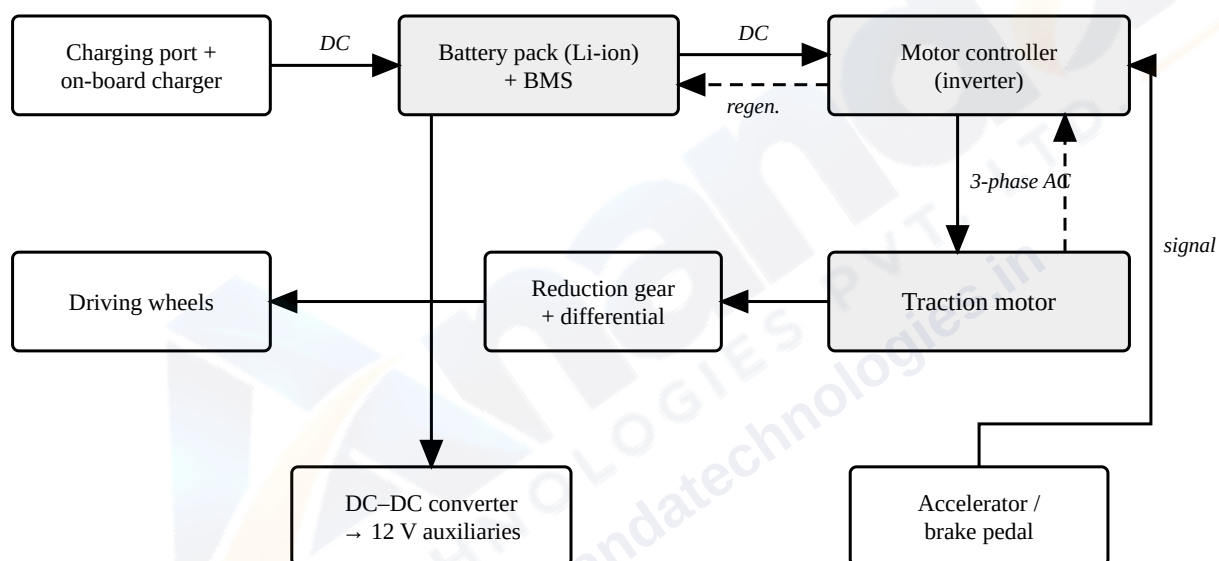
- When the cam opens the CB points, primary current stops suddenly and the magnetic field collapses rapidly. This induces a very high voltage (15 000–30 000 V) in the secondary winding by mutual induction.
- The condenser absorbs the self-induced current and prevents arcing at the CB points; it also helps faster collapse of the field.
- The high voltage goes to the centre of the distributor; the rotor distributes it to the spark plugs in firing order (1-3-4-2). A spark jumps across the plug gap and ignites the air–fuel mixture.
- The cam has four lobes (four-cylinder engine) and rotates at half the crankshaft speed, so each cylinder gets one spark per cycle.

(Sketch 3 M, working 3 M)

Q.6

a) Battery electric vehicle — layout, components, advantages, disadvantages.

6 M



Dashed arrows: regenerative braking — motor works as generator and charges the battery

Fig. Layout (block diagram) of a battery electric vehicle

Functions of main components:

- **Battery pack (Li-ion) with BMS:** stores electrical energy; the battery management system monitors cell voltage, temperature and state of charge.
- **Charging port and on-board charger:** converts AC mains supply into DC to charge the battery (DC fast chargers feed the battery directly).
- **Motor controller / inverter:** converts DC from battery to variable-frequency AC and controls speed and torque of the motor according to accelerator pedal signal.
- **Traction motor:** (PMSM / induction / BLDC) converts electrical energy into mechanical energy; acts as generator during regenerative braking.

- **Reduction gear and differential:** single-speed transmission that reduces speed, increases torque and drives the wheels.
- **DC-DC converter:** supplies 12 V for lights, wipers, ECU etc.

Advantages	Disadvantages
Zero tail-pipe emission; less pollution and noise.	High initial cost, mainly due to battery.
High efficiency; low running and maintenance cost (fewer moving parts).	Limited driving range per charge.
Full torque from zero speed — smooth and quick pick-up; no gear shifting.	Long charging time; charging stations not available everywhere.
Regenerative braking recovers energy.	Battery life is limited, replacement is costly; disposal problem.

(Layout 2 M, functions 2 M, advantages 1 M, disadvantages 1 M)

b) Semi-floating and fully floating rear axles.

6 M

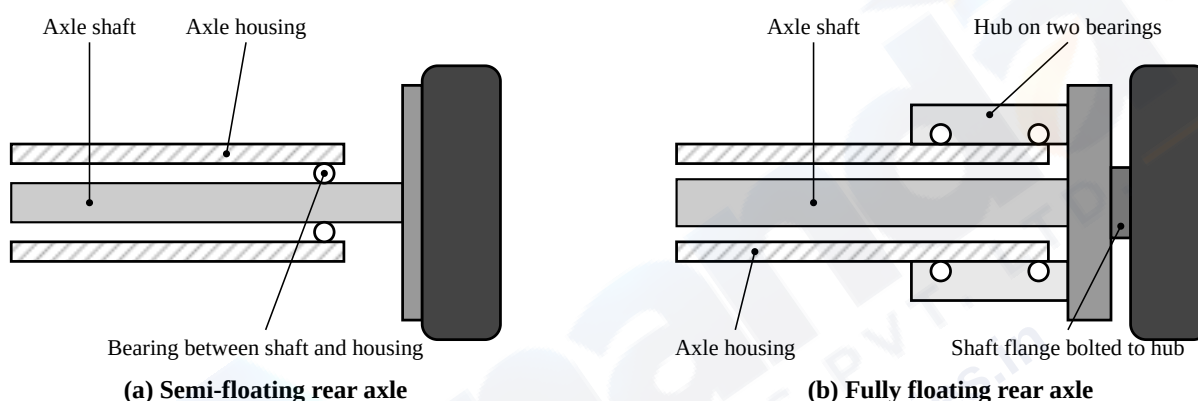


Fig. Types of rear axle (half sections at wheel end)

Semi-floating axle: The wheel hub is fixed directly on the outer end of the axle shaft. A single bearing is placed between the axle shaft and the axle housing. The axle shaft transmits driving torque and also carries the whole vertical load (weight) of the vehicle, side thrust and braking torque — so it is subjected to bending and shear and must be thicker. Simple and cheap; used in cars and light vehicles.

Fully floating axle: The wheel hub is mounted on two taper roller bearings on the outside of the axle housing. The axle shaft is bolted to the hub flange only to transmit torque. All vertical load, side thrust and braking loads are taken by the housing. The shaft can be removed without removing the wheel, and the vehicle can stand on its wheels even if the shaft breaks. Used in trucks and heavy vehicles.

Point	Semi-floating	Fully floating
Loads on axle shaft	Torque + vertical load + side thrust + braking load	Only driving torque
Bearings	One bearing, between shaft and housing	Two bearings, between hub and housing

Removal of shaft	Wheel must be removed	Shaft removed without removing wheel
Shaft breakage	Wheel may come off	Wheel stays on housing
Application	Cars, light vehicles	Trucks, buses, heavy vehicles

(Sketches 2 M, explanation 2 M, comparison 2 M)

c) Hydraulic brake system and master cylinder.

6 M

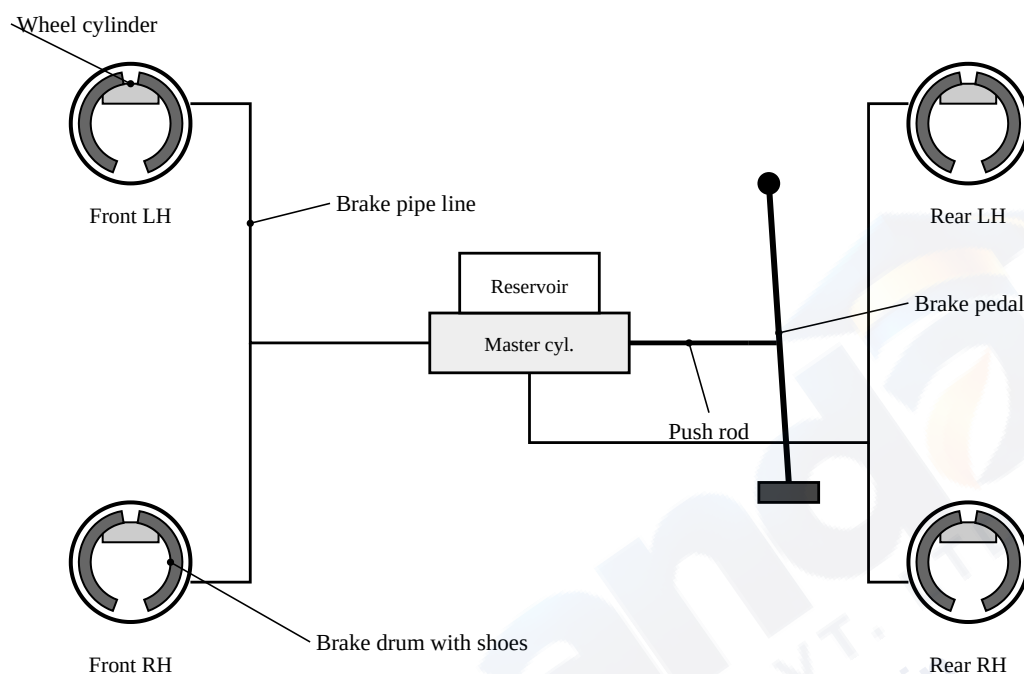


Fig. Hydraulic brake system — layout

Principle: Pascal's law — pressure applied to a confined liquid is transmitted equally in all directions.

Working: When the brake pedal is pressed, the push rod moves the master cylinder piston and pressurises the brake fluid. The pressure is transmitted equally through pipe lines to all wheel cylinders (or caliper pistons). The wheel cylinder pistons move outward and press the brake shoes against the drums (or pads against discs) — braking takes place. When the pedal is released, retractor springs return the shoes and fluid flows back to the master cylinder.

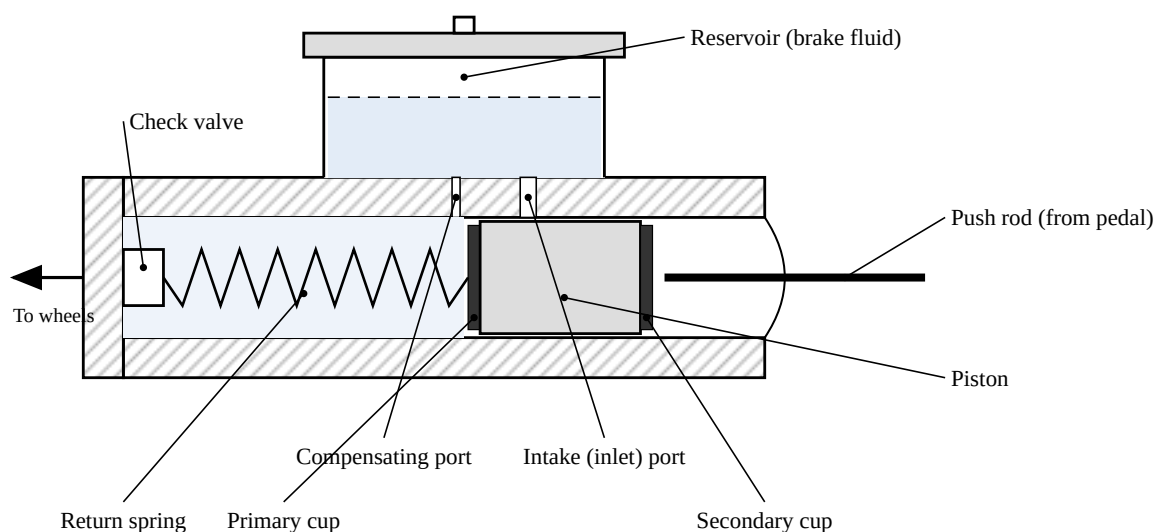


Fig. Master cylinder (single type) — section

Master cylinder: It has a reservoir and a cylinder bore containing a piston with primary cup and secondary cup, a return spring and a check valve at the outlet. The **compensating port** (just in front of the primary cup) allows fluid to expand/contract with temperature and to return after braking; the **intake port** (behind the primary cup) keeps the space behind the piston filled. When the pedal is pressed the primary cup closes the compensating port and fluid ahead is pressurised and sent through the check valve to the lines. The check valve keeps a small residual pressure in the lines to prevent air entry.

(Layout 2 M, working 1 M, master cylinder sketch 2 M, explanation 1 M)

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