ANNAMACHARYA INSTITUTE OF TECHNOLOGY AND SCIENCES:: RAJAMPET
(An Autonomous Institution)

DEPARTMENT OF MECHANICAL ENGINEERING

LECTURE NOTES

AUTOMOBILE ENGINEERING
[23A035BT]

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(An Autonomous Institution)
Department of Mechanical Engineering

Title of the Course:	AUTOMOBILE ENGINEERING	
Category:	PE	
Couse Code:	23A035BT	
Branch/es:	Mechanical Engineering	
Year & Semester:	III&I	

Lecture Hours	Tutorial Hours	Practice Hours	Credits
3	0	0	3

Course Objectives: The objectives of the course are to
1 Impart the knowledge on I C Engine, Automobile chasis and Body. 2 Familiarize different fuel systems and types of ignitions systems. 3 Gain knowledge on Principles of Steering system and Suspension system. 4 Provide awareness about on wheels, Tyres and Braking system. 5 Provide insight on Automobile electrical system.

Course Outcomes:
At the end of the course, the student will be able to
1. Summarize the components of automobile systems.
2. Summarize the engine sub systems.
3. Summarize the steering & suspension systems.
4. Summarize the wheels, types & braking systems.
5. Summarize automobile electrical systems & its advancements.

Unit 1	**Introduction to vehicle structure and engine components**	**10**
Vehicle construction -Chassis and body - Specifications - Engine - Types - Construction - Location of engine - Cylinder arrangement - Construction details - Cylinder block - Cylinder head - Cylinder liners - Piston – piston rings - Piston pin - Connecting rod - Crankshaft - Valves. Lubrication system - Types - Oil pumps - Filters. Crankcase ventilation.		

Unit 2	**Ignition and fuel supply systems**	**9**
Ignition system -Coil and Magneto - Spark plug - Distributor – Electronic ignition system - Fuel system - Carburetor - Fuel pumps - Fuel injection systems - Mono point and Multi point – Unit Injector – Nozzle types - Electronic Fuel Injection system (EFI) – GDI, MPFI, DTSI.		

Unit 3	**Steering and suspension system**	**9**
Principle of steering **-**Steering Geometry and wheel alignment - Steering linkages – Steering gearboxes - Power steering - front axle - Suspension system - Independent and Solid axle – coil, leaf spring and air suspensions - torsion bar - shock absorbers.		

Unit 4	**Wheels, Tyres and Braking System**	**9**
Wheels and Tyres - Construction - Type and specification - Tyre wear and causes - Brakes - Needs – Classification –Drum and Disc Mechanical - Hydraulic and pneumatic - Vacuum assist – Retarders – Anti-lock Braking System (ABS).		

Unit 5	Automobile electrical systems and advances in automobile engineering	9
Battery-General electrical circuits- Active Suspension System (ASS) - Electronic Brake Distribution (EBD) – Electronic Stability Program (ESP), Traction Control System (TCS) - Global Positioning System (GPS), Hybrid vehicle, Fuel Cell.		

Prescribed Textbooks:

1. William.H. Crouse, Automotive Mechanics, 10/e, McGraw-Hill, 2006.
2. Kirpal Singh, Automobile Engineering, Vol.1&2, Standard Publications, 13/e, 2020.
3. David A. Corolla, Automotive Engineering: Powertrain, Chassis System and Vehicle Body, Butterworth-Heinemann Publishing Ltd, 2009.

Reference Books:

1. Bosch, Automotive Hand Book, 6/e, SAE Publications, 2007.
2. K. Newton and W. Steeds, The motor vehicle, 13/e, Butterworth-Heinemann Publishing Ltd, 1989.
3. Joseph Heitner, Automotive Mechanics Principles and Practices, 2/e, CBS publishing 2004.
4. Richard Stone, Jeffrey K. Ball, Automotive Engineering Fundamentals" SAE International, 2004.

Online Learning Resources:

- https://nptel.ac.in/courses/107106088
- https://nptel.ac.in/courses/107106080
- https://hindustanuniv.ac.in/assets/pdf/ug/CBCS/cbcs-automobile-2018.pdf
- https://ed.iitm.ac.in/~shankarram/Course_Files/ED5160/ED5160.htm
- https://dbatu.ac.in/wp-content/uploads/2020/07/B-Tech-Automobile_Final-Yr_22.06.2020-pdf
- https://www.youtube.com/channel/UCGLlbmSTaLNUPhDwsMe-SgQ

Evaluation Criteria: (If any) Please delete if there is no special evaluation criteria

CO-PO Mapping:

Course Outcomes	Engineering Knowledge	Problem Analysis	Design/Development of solutions	Conduct investigations of complex problems	Modern tool usage	The engineer and society	Environment and sustainability	Ethics	Individual and team work	Communication	Project management and finance	Life-long learning	**PSO1**	**PSO2**
COURSE CODE.1	2	2	2	2	-	-	-	1	-	1	-	1	2	1
COURSE CODE.2	2	2	2	2	-	-	-	1	-	1	-	1	2	1
COURSE CODE.3	2	2	2	2	-	-	-	1	-	1	-	1	2	1
COURSE CODE.4	2	2	2	2	-	-	-	1	-	1	-	1	2	1
COURSE CODE.5	2	2	2	2	-	-	-	1	-	1	-	1	2	1

Unit 1
Introduction to vehicle structure and engine components

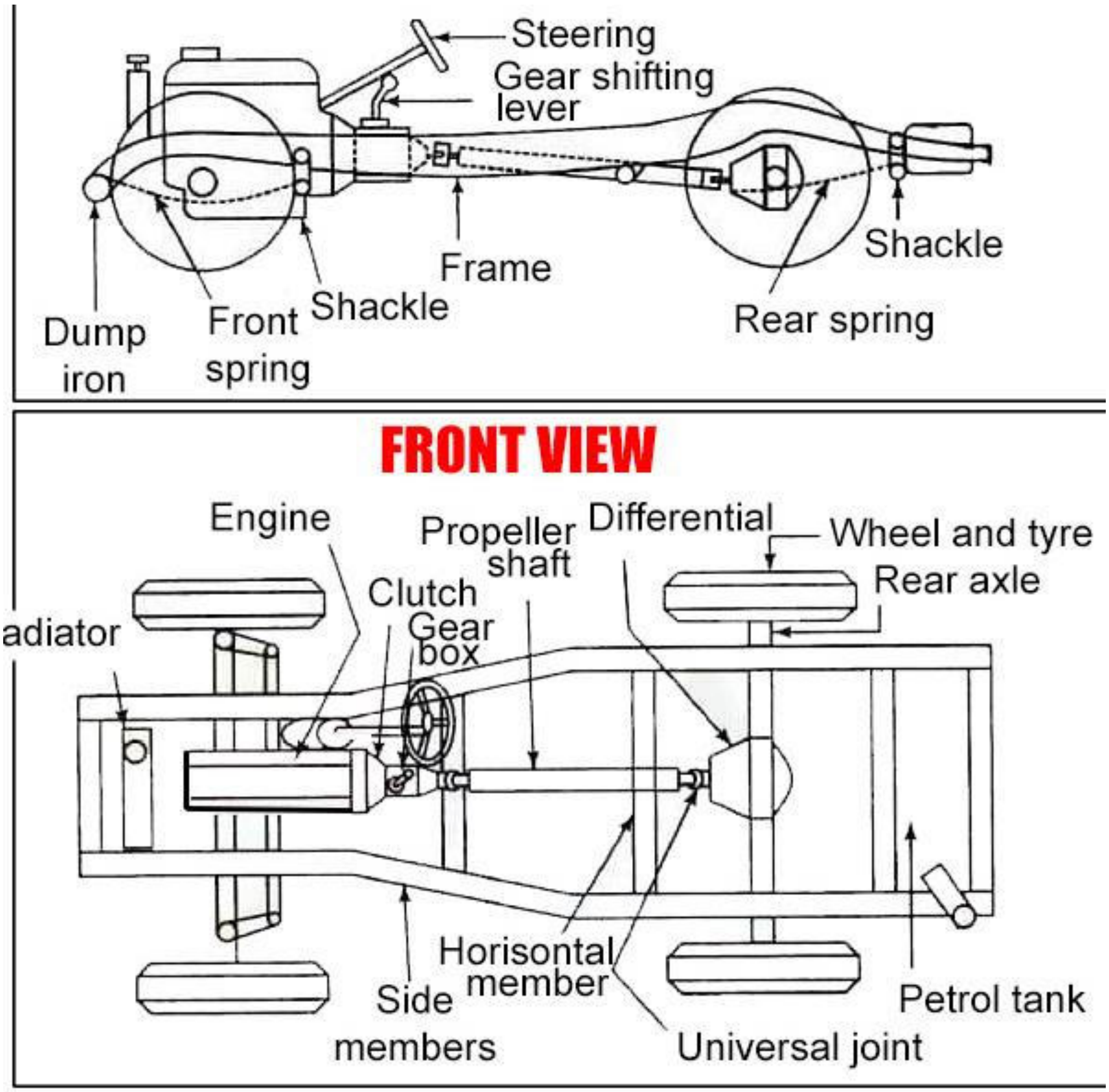
Vehicle construction is the process of assembling a vehicle from its many interconnected mechanical and electrical systems, involving a frame or chassis, body, and powertrain. It defines how the different parts of a car, such as the engine, suspension, and body panels, are integrated to create a functional vehicle. The two main types of construction are body-over-frame, where the body is built separately and then mounted, and unibody, where the body and frame are a single, integrated structure.

Key components and concepts

- **Chassis:** The vehicle's foundational structure, often compared to a skeleton. It houses and supports major components like the engine, transmission, and suspension.
- **Frame:** The basic frame is the skeleton of the chassis. It can be a conventional frame, or a chassis can be built into a single unit with the body (unibody).
- **Body:** The outer shell that includes the passenger and cargo compartments. It provides protection, styling, and contains elements like doors, windows, and a roof.
- **Unibody construction:** In this design, the body and chassis are a single structure, which can make the vehicle lighter and more rigid.
- **Body-over-frame construction:** This is a traditional method where a separate frame is built and then the body is bolted onto it.
- **Systems integration:** Vehicle construction involves the complex integration of multiple systems, including steering, brakes, suspension, powertrain, and electrical systems, to ensure they work together correctly.
- **Materials:** Common materials used in construction include steel, aluminum, and plastics.

Chassis frame is the basic frame work of the automobile. It supports all the parts of the automobile attached to it. It is made of drop forged steel. All the parts related to automobiles are attached to it only. All the systems related to automobile like powerplant,transmission, steering, suspension, braking system etc are attached to and supported by it only.

"Chassis" a French termwhich means the complete Automobiles without Body and it includes all the systems like power plant, transmission, steering, suspension , wheels tyres , auto electric system etc. without body. If Body is also attached to it them it is known as the particular vehicle as per the shape and design of the body.



The chassis is the vehicle's structural framework, a load-bearing foundation that supports the engine, drivetrain, and body. The body is the exterior shell of the vehicle, which is either mounted onto a separate chassis (body-on-frame) or integrated into the chassis itself in a single structure known as a unibody. Think of the chassis as the skeleton and the body as the skin and shell, where in modern cars, the skeleton and skin are often fused together.

Chassis

- **Function**: Provides the foundational structure for all other vehicle components and supports the weight of the vehicle, its passengers, and cargo. It absorbs the forces from driving, braking, and uneven road surfaces.

- **Components**: Includes the main structural elements like the frame, suspension, wheels, and steering system.
- **Types**:
  - **Body-on-frame**: A traditional, separate frame (often like a ladder) that the body is mounted on, common in trucks and SUVs for its strength and durability,
  - **Unibody:** The body and chassis are a single, integrated structure. This is the most common type in modern passenger cars, providing a lighter weight and rigid construction,
  - **Monocoque:** A type of unibody where the outer skin is a load-bearing part of the structure, Body
- **Function**: To enclose the passenger and cargo compartments and to house the chassis components,
- **Components**: Made of sheet metal or composite plastics, it includes all the outer panels, doors, roof, and interior parts.
- **Relationship with Chassis**:
  - In body-on-frame construction, the body is built separately and then attached to the frame.
  - In unibody construction, the body shell is reinforced and acts as the chassis's structural element, making the two inseparable.

CHASSIS

The chassis is the vehicle's skeleton, providing a strong foundation that supports the body and all components while withstanding stress from driving, and the body is the exterior shell that houses passengers and cargo and protects them from the elements. The chassis's primary functions include bearing the vehicle's weight, absorbing shock from uneven roads, and providing mounting points for the engine, suspension, and drivetrain. The body's main roles are to offer a comfortable and safe space for occupants, contribute to the vehicle's aerodynamics, and provide its overall aesthetic.

Chassis (the skeleton)

- **Structural support**: The chassis acts as the primary framework, supporting the weight of the entire vehicle, including the body, engine, passengers, and cargo.
- **Component mounting**: It provides a mounting platform for all other mechanical components, such as the engine, transmission, suspension, steering system, and wheels.
- **Stress absorption**: It absorbs stresses and forces from road conditions, like bumps and uneven surfaces, as well as those from accelerating, braking, and cornering.
- **Vehicle integrity**: It is designed to withstand torsional (twisting) and bending forces to maintain the vehicle's structural integrity and control vibration.

Body (the shell)

- **Occupant accommodation**: The body is the main structure that contains and encloses the driver, passengers, and cargo.

- **Environmental protection**: It protects occupants from external elements like weather, dust, and debris.
- **Structural contribution**: In a unibody construction, the body itself is a structural part of the frame. In traditional body-on-frame construction, it provides rigidity and is often bolted to the chassis.
- **Aerodynamics and aesthetics**: The body's shape is designed to improve aerodynamic efficiency and gives the vehicle its distinct appearance.
- **Safety**: It plays a crucial role in the vehicle's safety by absorbing impact forces in a collision and protecting the occupants.

Engine Specification	Value
Engine type	E2876E302
Cylinder number	In-line 4, 4-stroke cy
Cylinder bore	128 mm
Motor length	2650 mm
Motor width	1000 mm
Motor height	1500 mm
Stroke	166 mm
Firing order	1-3-4-2
Speed	1000 rpm
Compression ratio	12:1
n electrical power at ISO condition	130 kW
Weight	1850 kg
Molar air-fuel ratio	1.5
Intake type	Naturally aspiratec
Rated voltage	220 V
Rated current	18 A
Starting mode	24VDC electric starting :
Frequency	50 HZ/60 HZ

Engine-Construction

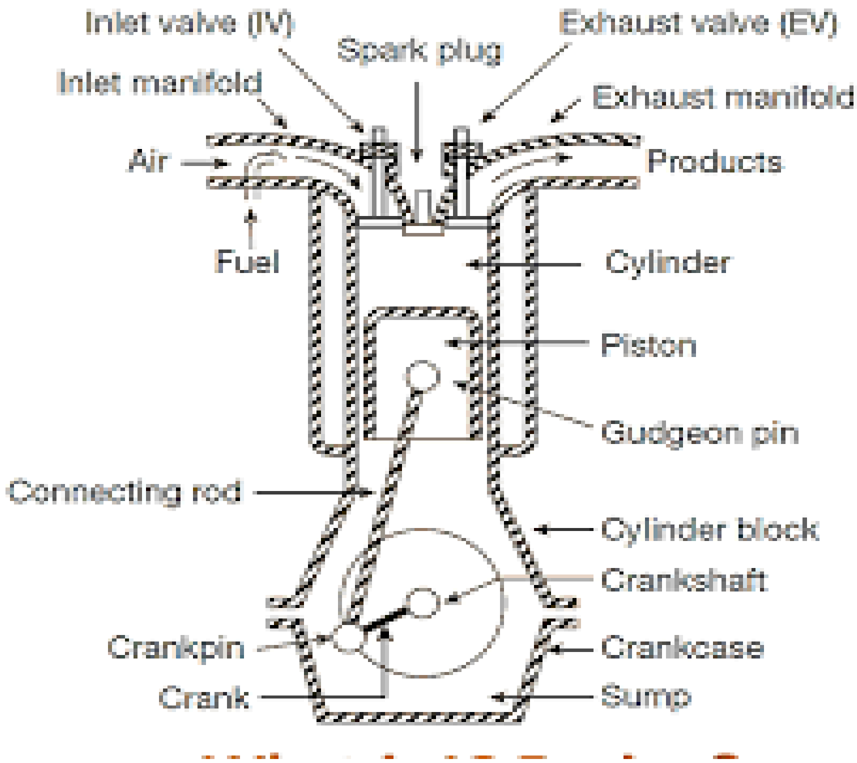
Automobile engines can be categorized by type (gasoline, diesel, hybrid, electric), with a primary construction being the internal combustion engine, which uses a cylinder block and head to house various parts. The location of the engine varies (e.g., front-mounted), and cylinder arrangements include inline, V-shape, or W-shape. Key components like the cylinder block, cylinder head, piston, piston rings, piston pin, connecting rod, crankshaft, and valves work together to convert fuel into mechanical power.

Types and location

- **Types**: Gasoline, diesel, hybrid, and electric engines are common. A gasoline or diesel engine is a type of internal combustion engine.
- **Location**: The engine is typically located at the front of a vehicle, though other configurations exist.
- **Cylinder arrangement**: Cylinders are arranged in different configurations, such as inline, V-shaped, or W-shaped, depending on the engine's design.

Construction details

- **Cylinder Block**: The main body of the engine, typically made of cast iron or aluminum. It contains the cylinders, coolant passages, and oil galleries.
- **Cylinder Head**: Sits on top of the cylinder block and contains the valves, spark plugs, and camshafts in some designs.
- **Cylinder Liners**: A cylinder liner is a sleeve inside the cylinder block that the piston slides in.
- **Piston**: A cylindrical component that moves up and down inside the cylinder. It seals the cylinder with rings and is connected to the connecting rod.
- **Piston Rings**: These are fitted on the piston to create a tight seal between the piston and cylinder wall.
- **Piston Pin (or Gudgeon Pin)**: A pin that connects the piston to the connecting rod.
- **Connecting Rod**: Connects the piston to the crankshaft, converting the piston's reciprocating motion into the crankshaft's rotary motion.
- **Crankshaft**: A rotating shaft that receives power from the connecting rods and converts the linear motion of the pistons into a rotational motion that drives the vehicle.
- **Valves**: These control the flow of air/fuel mixture into the cylinder (intake valves) and the exhaust gases out of the cylinder (exhaust valves). The camshaft, driven by the crankshaft, operates the valves.



Classifications

IC engines in automobiles are classified primarily by **ignition type** (spark ignition vs. compression ignition), **fuel type** (petrol, diesel, gas, biofuel), **cycle type** (two-stroke vs. four-stroke), and **cylinder arrangement** (e.g., inline, V-shape). The most common types found in modern cars are four-stroke spark ignition (petrol) and four-stroke compression ignition (diesel) engines.

By ignition type

- **Spark Ignition (SI) Engines:** Use a spark plug to ignite a fuel-air mixture. These are commonly gasoline/petrol engines.
- **Compression Ignition (CI) Engines:** Use the heat generated by high compression to ignite the fuel. These are commonly diesel engines.

By fuel type

- **Petrol Engines:** Run on petrol, a highly volatile fuel that is ignited by a spark plug.
- **Diesel Engines:** Run on diesel fuel and are a type of compression ignition engine.
- **Gas Engines:** Use gaseous fuels like compressed natural gas (CNG), liquid petroleum gas (LPG), or biogas.
- **Biofuel Engines:** Can be multi-fuel engines that can run on a combination of gasoline or diesel and an alternative fuel like CNG, LPG, or hydrogen.

By stroke cycle

- **Two-Stroke Engines:** Complete a power cycle in two strokes of the piston. Less common in modern cars, but found in some motorcycles and smaller equipment.
- **Four-Stroke Engines:** Complete a power cycle in four strokes of the piston (intake, compression, combustion/power, exhaust). This is the standard in most modern automobiles.

By cylinder arrangement

- **Inline:** Cylinders are arranged in a single straight line.
- **V-type:** Cylinders are arranged in two banks, forming a "V" shape.
- **Radial:** Cylinders are arranged in a circle around the crankshaft. This is less common in modern cars and more associated with older aircraft engines.

Lubrication System

An automobile's lubrication system provides oil to the engine's moving parts to reduce friction, which also helps cool, clean, and seal the engine. It works by using an oil pump to send filtered oil through passageways to components like the crankshaft and bearings, creating a thin film to prevent wear. The oil then drains back to the sump, where it is filtered and recirculated.

Functions of the lubrication system

- Reduces friction
- Cools the engine
- Cleans the engine
- Seals surfaces
- Cushions parts

Common components

- **Oil pump:** Draws oil from the sump and pressurizes it to send it through the system.
- **Oil filter:** Removes contaminants from the oil before it circulates to the engine parts.
- **Oil pan/Sump:** The reservoir that holds the engine oil.
- **Oil passages:** Channels within the engine block and cylinder head that direct oil to various components.
- **Bearings:** The components that are lubricated by the oil film.
- **Oil jets:** Direct jets of oil to lubricate and cool specific parts, like the underside of pistons.

Types of lubrication systems

- **Wet sump:**
  The oil is stored in a sump (pan) at the bottom of the engine and is pumped up to the engine's parts. This is the most common type for cars.
- **Dry sump:**
  Uses an external oil tank and a scavenge pump to pull oil from the engine, which is useful for high-performance vehicles or those with a low profile.
- **Splash:**
  Relies on parts like the crankshaft to splash oil onto other components; it is a simpler system often used in smaller engines.
- **Pressure feed:**
  Uses a pump to force oil under pressure to all moving parts, ensuring they receive enough lubrication.
- **Petroil:**
  Oil is mixed with the fuel; this is a simpler system common in older or two-stroke engines, but it can cause smoke and deposits.

Wet Type Lubrication System

A wet sump lubrication system stores oil in an oil pan (sump) at the bottom of the engine, from which a single pump circulates it to lubricate moving parts. The oil then drains back to the sump by gravity for recirculation. This system is common in most cars due to its simplicity, low cost, and compact design, though the oil can be exposed to high engine temperatures, which may lead to faster contamination.

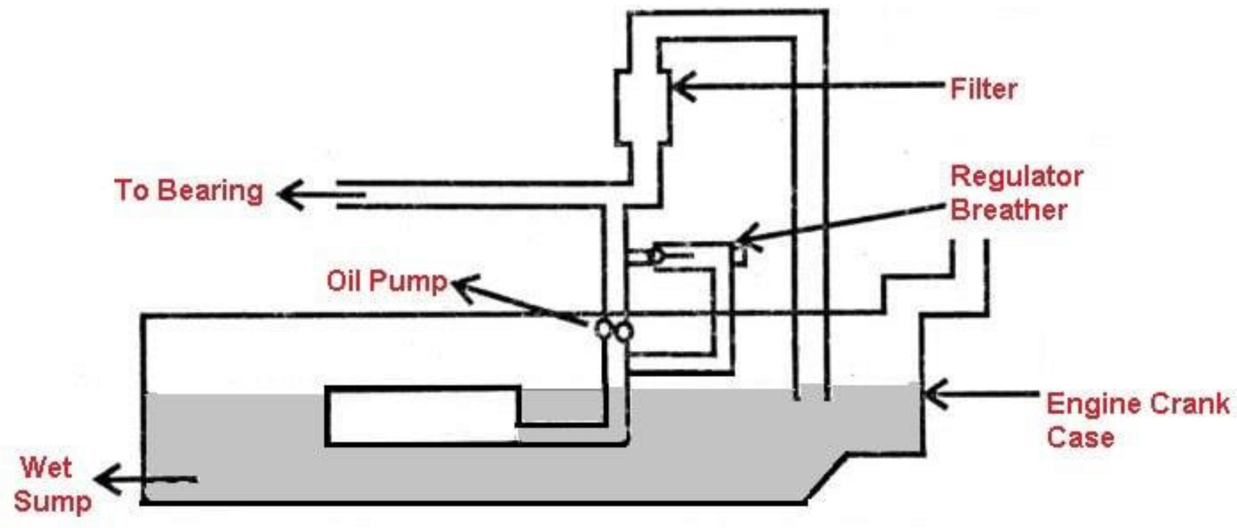
How it works

- **Oil storage**: Engine oil is stored in the oil pan, or sump, located at the bottom of the engine block.
- **Oil circulation**: A single oil pump draws oil from the sump through a pickup tube and strainer, pressurizes it, and sends it through an oil filter to remove contaminants.
- **Lubrication**: The pressurized oil is distributed to various engine components through oil galleries.
- **Return to sump**: After lubricating the parts, the oil drips back into the sump, where it is picked up by the pump again for continuous circulation.

Key components

- **Oil Pan (Sump)**: Holds the oil reservoir at the bottom of the engine.
- **Oil Pump**: Draws oil from the sump and pressurizes it for circulation.
- **Oil Filter**: Cleans the oil by removing contaminants before it is sent back to the engine.

- **Oil Galleries**: Passageways within the engine block and cylinder head that carry oil to the parts that need lubrication.
- **Relief Valve**: Prevents system damage from excess pressure by diverting oil back to the pump or sump.



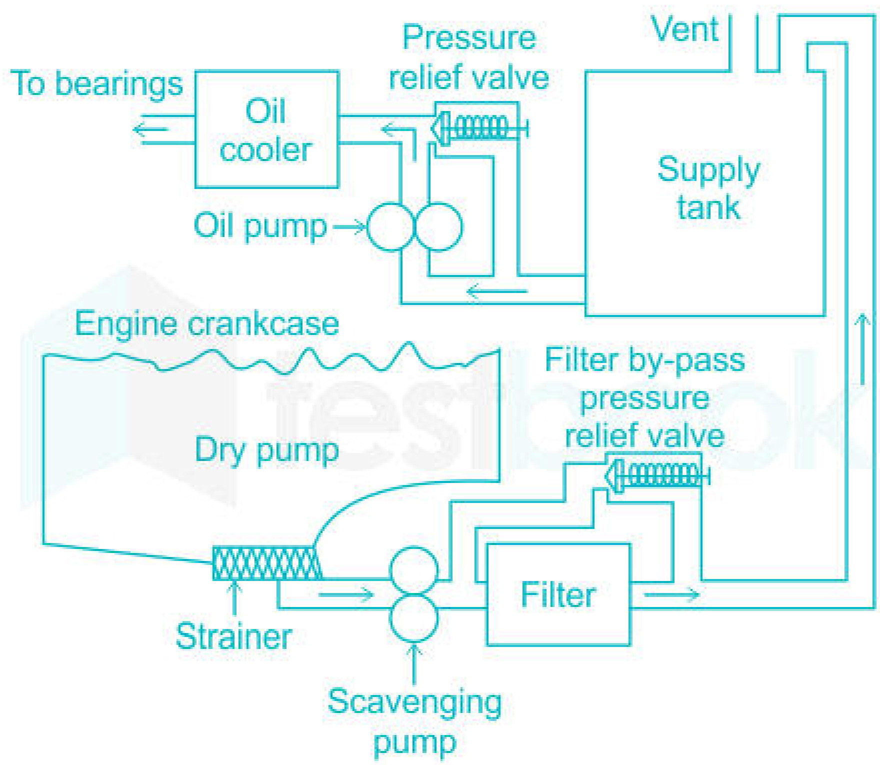
Dry Type Lubrication System

A dry type sump lubrication system is a high-performance system that stores oil in a separate external tank rather than the engine's oil pan. It uses two pumps: a **scavenge pump** to draw excess oil from the sump into the external tank, and a **pressure pump** to send fresh oil from the tank to lubricate engine parts. This setup keeps the sump mostly empty, which reduces drag from the crankshaft and allows for a lower engine placement, making it ideal for racing and high-performance vehicles.

How it works

- **Oil is pumped from the sump:** A scavenge pump pulls oil from the engine's crankcase (sump) and sends it to an external storage tank.
- **Sump is kept dry:** This continuous pumping action keeps the sump clear of oil, eliminating "windage" (resistance from the crankshaft hitting the oil) and allowing the engine to produce more power.
- **Oil is supplied under pressure:** A separate pressure pump draws oil from the external tank and forces it under pressure to the engine's bearings and other moving parts.
- **Oil is cooled:** The system includes an oil cooler to help manage the temperature of the oil before it's sent back into the engine.

- **Filter and bypass valve:** A filter removes contaminants from the oil. A pressure relief valve allows oil to bypass the filter if it becomes clogged, sending it directly back to the supply tank and preventing system failure.



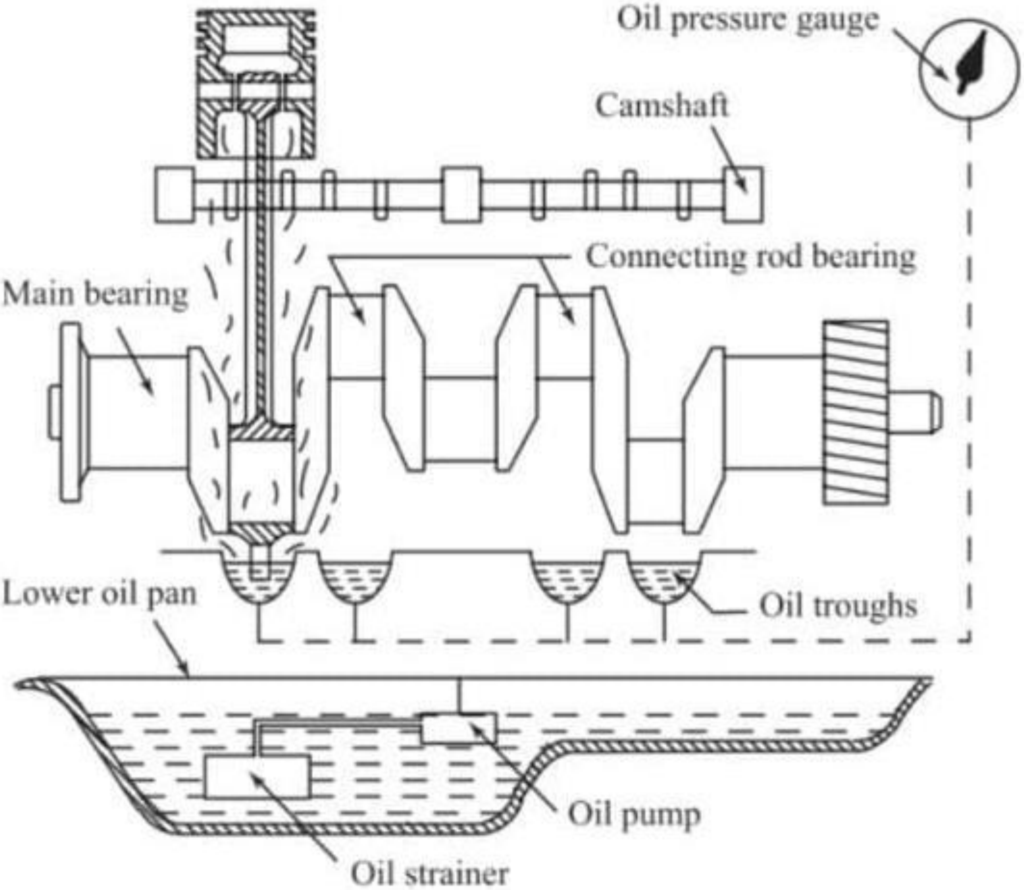
Splash Type Sump Lubrication System

A splash type sump lubrication system is a simple, cost-effective method for lubricating internal combustion engines by using a "dipper" or "splasher" on a connecting rod to splash oil from a sump onto engine components. As the crankshaft rotates, the dipper dips into oil troughs and splashes it over the crankcase interior, lubricating the cylinder walls, pistons, and other exposed parts, and is often used in small, slow-speed engines.

How it works

- **Oil reservoir:** The lubricating oil is stored in the engine's oil sump at the bottom of the crankcase.
- **Oil delivery:** A low-pressure oil pump draws oil from the sump and sends it to oil troughs or channels under the connecting rods.
- **Dipper mechanism:** Each connecting rod has a scoop or "dipper" attached to its cap.
- **Splashing:** As the crankshaft rotates, the dipper dips into the oil in the troughs and splashes oil onto the cylinder walls, pistons, and other parts of the engine.

- **Lubrication:** The splashed oil lubricates the components as it runs down, and any excess oil collects back in the sump to be recirculated.
- **Component lubrication:** Some oil also passes through holes in the crankshaft and connecting rods to lubricate the bearings.



Oil Pumps

An automobile's oil pump is a critical component that circulates engine oil under pressure to lubricate the engine's moving parts, prevent overheating, and prolong its life. It pulls oil from the sump (oil pan), forces it through oilways to the crankshaft, bearings, and camshaft, and returns it to the sump to be recirculated.

How it works

- **Pulls oil:** The pump draws oil from the engine's oil pan, often through a filter to remove contaminants.
- **Pressurizes oil:** It then forces the oil into the engine's lubrication channels at high pressure.

- **Lubricates and cools:** This pressurized oil flows to all moving parts like the camshaft, bearings, and pistons, providing a lubricating film that reduces friction and heat.
- **Regulates pressure:** A relief valve prevents the oil pressure from becoming too high, protecting the engine from damage.
- **Recirculates oil:** After lubricating and cooling the parts, the hot oil drains back into the oil pan to be pumped again.

Why it's essential

- **Prevents engine failure:** Without a functioning oil pump, the engine's components would quickly overheat and fail due to lack of lubrication.
- **Reduces wear:** By providing a constant supply of oil, the pump significantly reduces wear and tear on engine parts.
- **Improves performance:** It plays a key role in maintaining proper engine temperature and efficiency.

Common types

- **Gear pump:** The most common type, using two meshing gears to draw and push oil.
- **Rotor pump:** Uses two intermeshing rotors to move oil; often found in high-performance engines.
- **Crescent pump:** Another type, often located at the crankshaft end.

Gear Pump

A gear oil pump in an automobile is a positive displacement pump that uses two intermeshing gears to circulate engine oil. As the gears rotate, they create a vacuum that draws oil from the oil pan into the pump, then they trap and force the oil through the pump's outlet and into the engine's lubrication system under pressure. This process lubricates moving parts, reduces friction, and helps cool the engine.

How it works

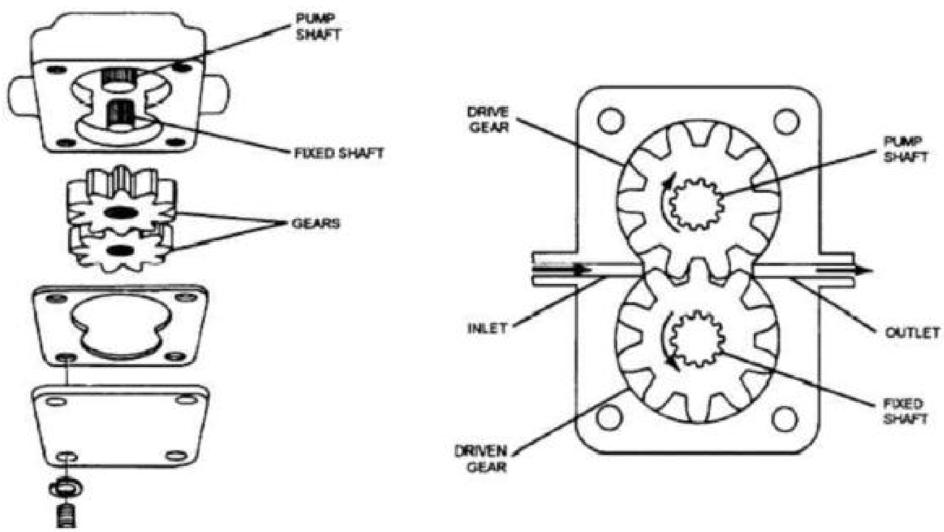
- **Intake:** When the engine is running, the gears rotate. As the teeth of the gears separate on the inlet side, they create a void that pulls oil from the pickup tube and into the pump.
- **Transfer:** The oil is trapped in the spaces between the gear teeth and the pump housing.
- **Discharge:** As the gears continue to rotate, they mesh together on the outlet side, reducing the volume and forcing the trapped oil out under pressure.
- **Pressure generation:** The pump continuously forces a fixed volume of oil into the engine's oil passages, which increases the pressure to a level sufficient to lubricate all parts.

Key functions

- **Lubrication:** It provides a continuous flow of oil to lubricate engine components like bearings and pistons.
- **Cooling:** The oil circulation helps to dissipate heat from the engine.
- **Cleaning:** The pressurized oil also flows through an oil filter, removing dirt and debris from the system.
- **Hydraulic power:** In some modern engines, the pressurized oil is also used as a hydraulic fluid to power systems like variable valve timing or hydraulic tappets.

Types of gear pumps in engines

- **External gear pump:** This is the most common type, featuring two identical gears that mesh together.
- **Internal gear pump (Gerotor pump):** This design uses an inner gear rotating inside an outer rotor.
- **Crescent pump:** Similar to an internal gear pump, this type is often mounted on the crankshaft and is designed for space-saving and high pressure at low speeds.

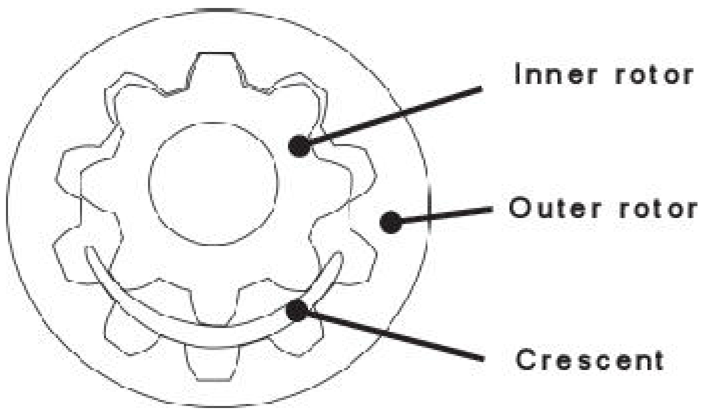


Crescent Pump

A crescent oil pump in an automobile is a type of internal gear pump that uses two rotating gears with a crescent-shaped separator to move oil from the intake to the outlet. This design creates pockets of oil that decrease in volume as they pass around the crescent, forcing the oil out under pressure to lubricate engine components.

How it works

- **Internal gears:** The pump has two meshing gears: an outer gear with internal teeth and an inner gear with external teeth.
- **Crescent separator:** A crescent-shaped piece sits between the gears, separating the inlet and outlet sides.
- **Oil flow:** As the inner and outer gears rotate, they trap oil in the spaces between their teeth on the inlet side.
- **Increased pressure:** As the gears move toward the outlet side, the trapped oil is forced into a smaller volume as the teeth mesh, and it is pushed out through the outlet port.



Filters

An automobile's oil filter is a vital component that cleans engine oil by removing contaminants like dirt and metal particles, ensuring the oil can properly lubricate and protect the engine. A clogged filter can lead to a buildup of debris, causing the oil to become more viscous and potentially damaging engine parts. The filter is typically a cylindrical metal canister, and it is essential to replace it regularly according to the vehicle's maintenance schedule to maintain engine health and longevity.

Function

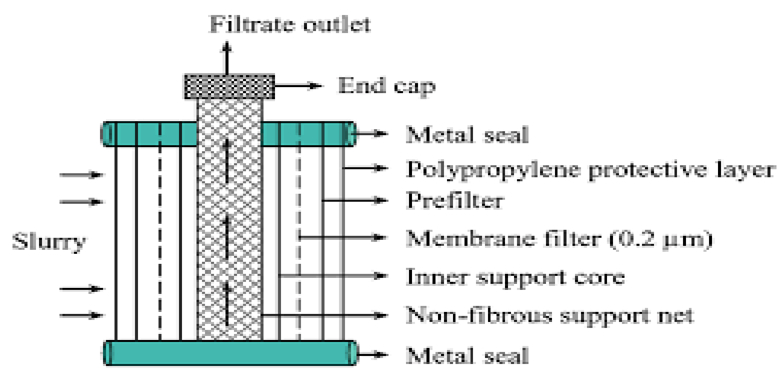
- **Removes contaminants:** The primary job of the oil filter is to trap impurities like dirt, carbon residue, and metal shavings that accumulate in the engine oil.
- **Ensures clean oil circulation:** By filtering the oil, it ensures that only clean oil is circulating, which provides better lubrication and helps to reduce friction and heat buildup inside the engine.
- **Protects engine components:** By removing harmful particles, the oil filter prevents them from damaging critical engine parts like bearings and cylinders, which extends the life of the engine.

Catridge oil filter

A cartridge oil filter works by channeling engine oil through a pleated filter media that traps contaminants, allowing only clean oil to pass back into the engine. The oil enters the housing from the outer ports, is pushed through the media, and exits through a central hole to continue lubricating the engine's moving parts. A pressure-activated bypass valve prevents oil starvation if the filter becomes clogged.

Working Principle

- **Oil intake:** The engine's oil pump sends pressurized, dirty oil into the filter housing through a series of small inlet holes around the perimeter of the base.
- **Filtration process:** The oil is forced to flow through a pleated filter element, which can be made of paper, cellulose, or synthetic material. The pleats increase the surface area for more effective filtration.
- **Contaminant removal:** As the oil passes through the filter media, particles like dirt, metal shavings, and sludge are trapped and held within the filter.
- **Clean oil exit:** The clean, filtered oil then exits the cartridge through a large hole in the center and returns to the engine to lubricate its components.
- **Bypass valve:** A spring-loaded bypass valve is built into the filter housing. If the filter media gets clogged, or the oil is too thick (especially in cold weather), this valve will open to allow unfiltered oil to flow to the engine, preventing it from being starved of oil.

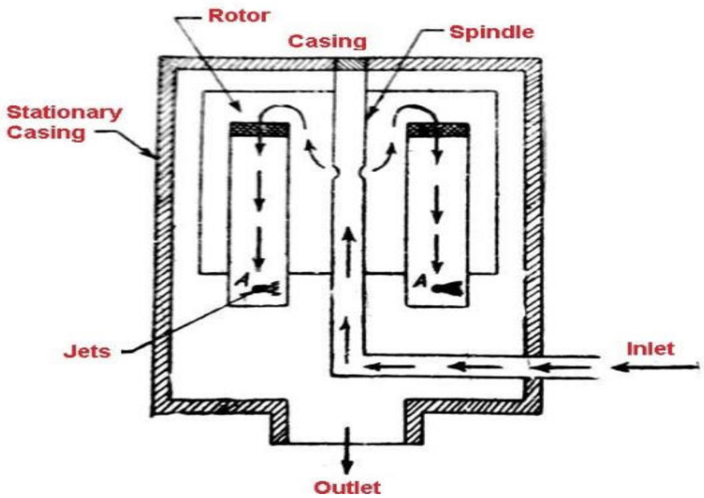


Centrifugal

A centrifugal oil filter works by using centrifugal force to separate contaminants from the engine oil. It is a bypass system where pressurized oil enters a spinning rotor, and the oil's exit through high-speed jets causes it to spin at up to 8,000 RPM. The high rotational speed forces heavier particles like dirt and sludge to the inner wall of the rotor, where they form a cake, while the clean oil is returned to the engine.

Working Principle

- **Oil enters the rotor:** Engine oil enters the filter's hollow shaft under pressure and flows into the rotor.
- **Rotor spins:** As the oil exits through small, high-speed jets, the force creates a reaction that spins the rotor assembly to speeds of 3,000 to 8,000 RPM.
- **Contaminants are separated:** The extreme centrifugal force throws heavier particles and contaminants outward, pressing them against the inner wall of the rotor in a dense cake.
- **Clean oil returns:** The now-cleaner oil is forced up through the center and flows back to the engine's oil system.
- **Manual cleaning:** The collected sludge cake is periodically removed by manually cleaning the rotor assembly with a tool like a wooden spatula.



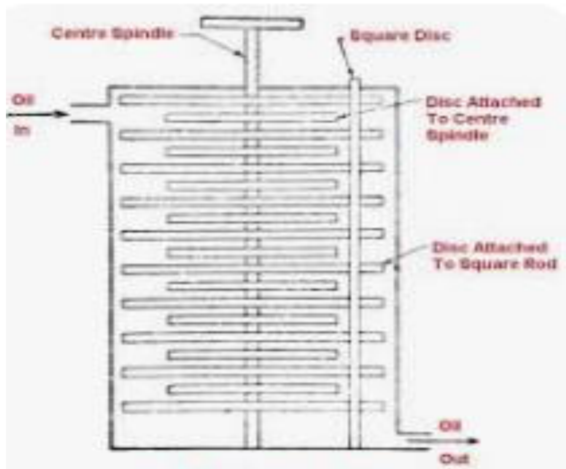
Edge Type Filter

An edge-type oil filter works by drawing dirty oil in through small holes on its outer base, forcing it through a filtering media (like paper or synthetic fibers) to capture contaminants, and then returning the clean oil through a large center hole back to the engine. An anti-drain-back valve prevents oil from draining out when the engine is off, ensuring immediate lubrication upon startup.

Working Principle

- **Dirty oil intake:** When the engine is running, oil is pumped under pressure and enters the filter housing through a series of small holes around the outer perimeter of the base plate.
- **Filtration:** The dirty oil is forced to flow outwards through the filter media. The media, often a pleated paper or synthetic material, traps harmful particles such as dirt, carbon deposits, and metal wear debris.

- **Clean oil return:** The clean, filtered oil then travels through the large center hole in the base plate and is sent back to the engine's lubrication system to lubricate and protect moving parts.
- **Anti-drain-back valve:** Many filters include a rubber membrane or a similar component that acts as a one-way valve at the intake holes. This valve opens to let oil in when the engine is running but closes when it shuts off. This keeps the filter full of oil, preventing a "dry start" where the engine runs for a few seconds without lubrication.



Edge Type Oil Filter

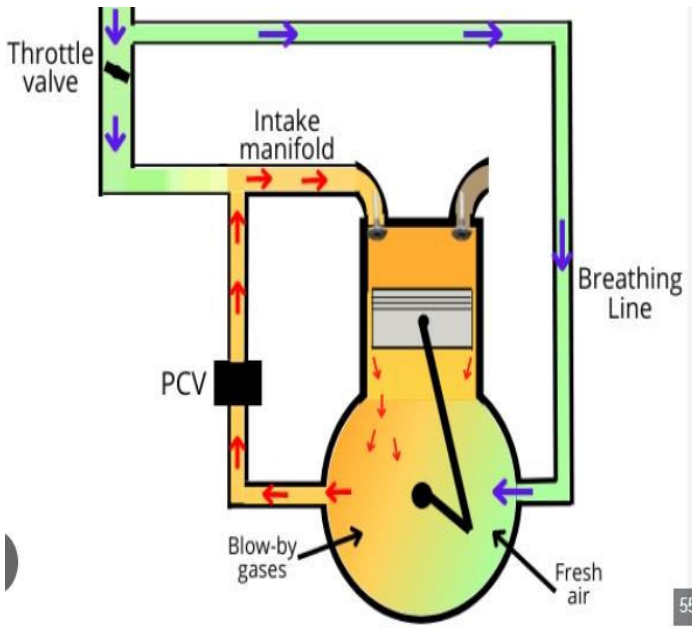
Crankcase Ventilation

A crankcase ventilation system (often called a Positive Crankcase Ventilation or PCV system) works by using engine vacuum to pull "blow-by" gases from the crankcase back into the intake manifold. This process prevents pressure buildup in the crankcase and reduces harmful emissions by rerouting these gases to be burned in the engine. In modern systems, the gases pass through a PCV valve, which adjusts the flow rate based on engine speed, and a filter or baffle to remove oil mist before re-entering the intake system.

Working Principle

1. **Blow-by gas generation:** During engine operation, some combustion gases leak past the piston rings into the crankcase, a phenomenon known as "blow-by".
2. **Pressure buildup:** Without a ventilation system, these gases can build up pressure, which can cause oil leaks and dilute the engine oil, leading to sludge formation.
3. **Fresh air intake:** A PCV system supplies fresh, filtered air to the crankcase, often through the air intake hose.
4. **Gas mixture:** This fresh air mixes with the blow-by gases inside the crankcase.

5. **Gas evacuation:** The engine's intake manifold vacuum draws the mixed gases from the crankcase through a PCV valve.
6. **Oil separation:** Before reaching the intake manifold, the gases often pass through a baffle or filter designed to separate oil mist from the gases. The oil drips back down to the crankcase, while the gases continue to the intake.
7. **Re-combustion:** The evacuated gases are then sent into the intake manifold to be re-combusted in the engine cylinders.
8. **Valve regulation:** The PCV valve automatically adjusts the amount of gas it allows through based on engine conditions, allowing more flow at high speeds and less at idle.
9. **Emissions control:** By routing these gases back for re-combustion, the PCV system prevents them from being released into the atmosphere, which reduces air pollution.



UNIT 2

IGNITION AND FUEL SUPPLY SYSTEMS

An automobile ignition system uses the car's low-voltage battery to produce a high-voltage spark at the spark plugs to ignite the air-fuel mixture in the engine's combustion chambers. It converts the low voltage into a high-voltage pulse, delivered at precisely the right moment, which creates a spark to burn the mixture, generating power to drive the vehicle.

Function

Ignite Air-Fuel Mixture:

The primary function is to create a powerful electric spark that ignites the compressed air-fuel mixture in the engine's cylinders.

Timing:

The system precisely times the spark to ensure optimal and efficient combustion for smooth engine operation.

Power Generation:

The resulting combustion of the fuel-air mixture drives the engine's pistons, which ultimately turn the vehicle's wheels.

Key Components and How They Work

1. **Battery:**
   The system starts with the car's 6-12 volt battery, which provides the initial electrical power.
2. **Ignition Switch:**
   This controls whether the ignition system is on or off.
3. **Ignition Coil:**
   This is a transformer that steps up the battery's low voltage (around 12V) to a much higher voltage (thousands of volts).
4. **Distributor (in older systems):**
   In conventional systems, a distributor distributes the high-voltage current from the coil to the correct spark plug at the right time.
5. **Spark Plugs:**
   Located in the combustion chambers, the spark plugs create the actual spark by creating a gap that the high-voltage current jumps across, igniting the fuel.

- **Conventional Breaker-Point Systems:**
  Early systems used mechanical breaker points to interrupt the flow of current to the coil, creating the necessary magnetic field collapse to induce high voltage.
- **Electronic Ignition (EI) Systems:**
  Introduced in the early 1970s, these systems use transistors and sensors to control the coil's operation electronically, leading to more reliable and efficient ignition and improved fuel economy.
- **Distributorless Ignition Systems (DIS):**
  Becoming popular in the mid-1980s, these systems eliminate the distributor, using multiple coils or coil packs to deliver the spark directly to each spark plug.

Ignition System: The ignition system is a system used to generate a very high voltage from the car battery and to send it to each sparkplug in turn thereby igniting the fuel-air mixture in the combustion chamber of the engine.

Battery Coil Ignition System

A battery coil ignition system works by converting low-voltage current from the battery into a high-voltage spark to ignite the air-fuel mixture in an engine. It uses an ignition coil to step up the voltage, a distributor to time and direct the spark to the correct cylinder, and a contact breaker to open and close the primary circuit at the right moment. When the contact breaker points open, the magnetic field in the coil collapses, inducing a high-voltage current that jumps the spark plug gap.

Components and their roles

Battery: Supplies the initial low-voltage electrical energy.

Ignition Switch: Controls the flow of current, allowing the system to be turned on or off.

Ignition Coil: A transformer that steps up the low voltage (e.g., 12V) to a high voltage (20,000 to 30,000 volts) needed for the spark.

Contact Breaker (or Points): A mechanical switch that opens and closes the primary circuit to the coil at precise intervals.

Capacitor (or Condenser): Works with the contact breaker to absorb electrical energy, preventing arcing across the breaker points and helping the magnetic field collapse quickly.

Distributor: A rotating component that directs the high-voltage current from the coil to the correct spark plug in the engine's firing order.

Spark Plug: Located in the cylinder, it creates the spark across its gap to ignite the compressed air-fuel mixture.

Ballast Resistor: Controls the current to the primary winding and helps regulate the temperature of the ignition coil, especially during prolonged operation.

How it works

When the ignition switch is turned on, the battery provides low voltage to the primary circuit.

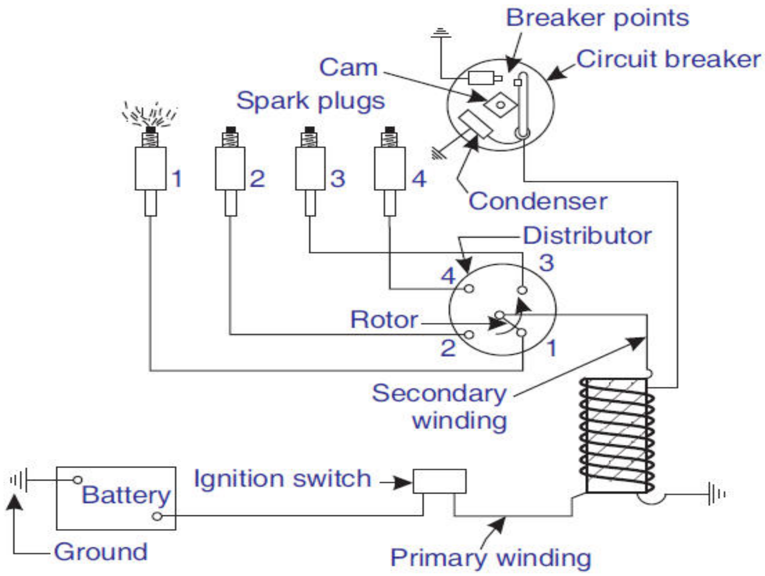
As the engine turns, the contact breaker points are closed, allowing current to flow through the coil's primary winding. This builds a magnetic field around the coil.

At the correct time for combustion, the contact breaker points open. This sudden break in the circuit causes the magnetic field to rapidly collapse.

The collapsing magnetic field induces a very high voltage in the secondary winding of the ignition coil.

This high-voltage current is sent to the distributor, which routes it to the spark plug of the cylinder that is ready to fire.

The high voltage jumps the gap on the spark plug, creating a spark that ignites the air-fuel mixture, and the process repeats.

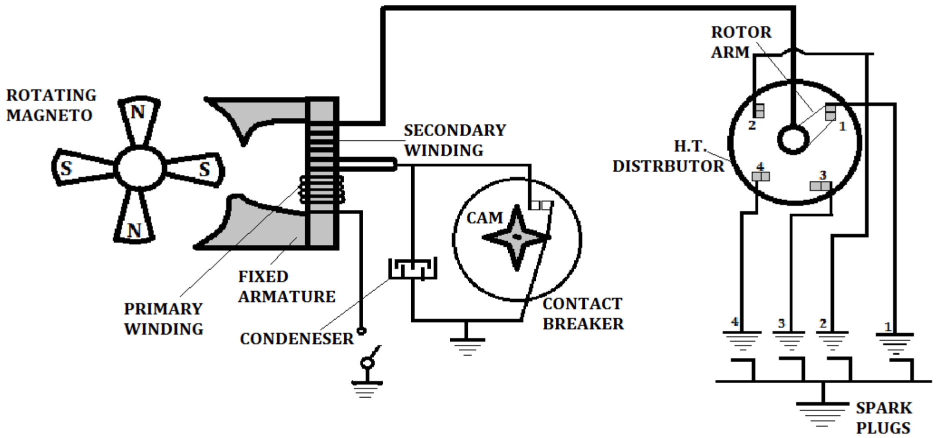


Magneto Ignition System

A magneto ignition system generates its own high-voltage spark without a battery, using a rotating magnet and coil to induce an electrical current. The engine's rotation turns the magneto, creating a changing magnetic field that generates low-voltage current in a primary coil. When the contact breaker opens, the magnetic field collapses, inducing a very high voltage in a secondary coil that is then sent to a spark plug to ignite the fuel-air mixture.

Working principle

- **Energy generation:**
  As the engine rotates, it turns the magneto, which is a generator. This generates a low-voltage current in the primary coil.
- **Magnetic field and current build-up:**
  The current flows through the primary coil and a contact breaker, which is a switch opened and closed by a cam driven by the engine. This build-up of current creates a magnetic field.
- **Magnetic field collapse:**
  When the cam opens the contact breaker, the primary circuit is broken, causing the magnetic field to suddenly collapse.
- **High voltage induction:**
  The collapsing magnetic field cuts across the secondary coil, which has many more turns than the primary coil. This induces a very high voltage, typically around 30,000 volts.
- **Spark delivery:**
  The high-voltage surge from the secondary coil is sent through a distributor to the correct spark plug. The voltage is so high that it jumps the gap between the spark plug's electrodes, creating a spark that ignites the fuel-air mixture in the cylinder.

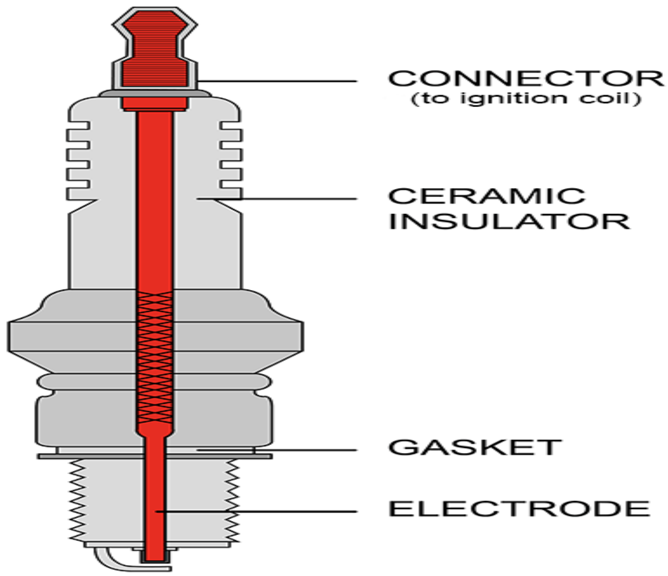


spark plug

A spark plug works by creating a high-voltage spark to ignite the air-fuel mixture in an internal combustion engine. High voltage from the ignition system travels through the central electrode, and when the voltage becomes high enough, it ionizes the air in the gap between the central and ground electrodes. This ionized gas becomes conductive, allowing the current to jump the gap as a spark, which ignites the mixture and drives the engine's piston.

How it works

1. **High voltage supply**:
   The engine's ignition system generates a high-voltage current (often between 20,000 and 40,000 volts).
2. **Current flow**:
   This current travels through the central electrode inside the spark plug.
3. **Ionization**:
   The high voltage creates an electrical pressure that strips electrons from the gas molecules in the air gap between the central and ground electrodes, turning the gas into a plasma conductor.
4. **Spark creation**:
   Once the gas is ionized, the current can jump the gap, creating a high-temperature spark.
5. **Ignition**:
   The spark ignites the compressed air-fuel mixture inside the engine's cylinder.
6. **Explosion and power**:
   The rapid expansion of this ignited mixture creates a small explosion that pushes the piston down, generating power for the engine.

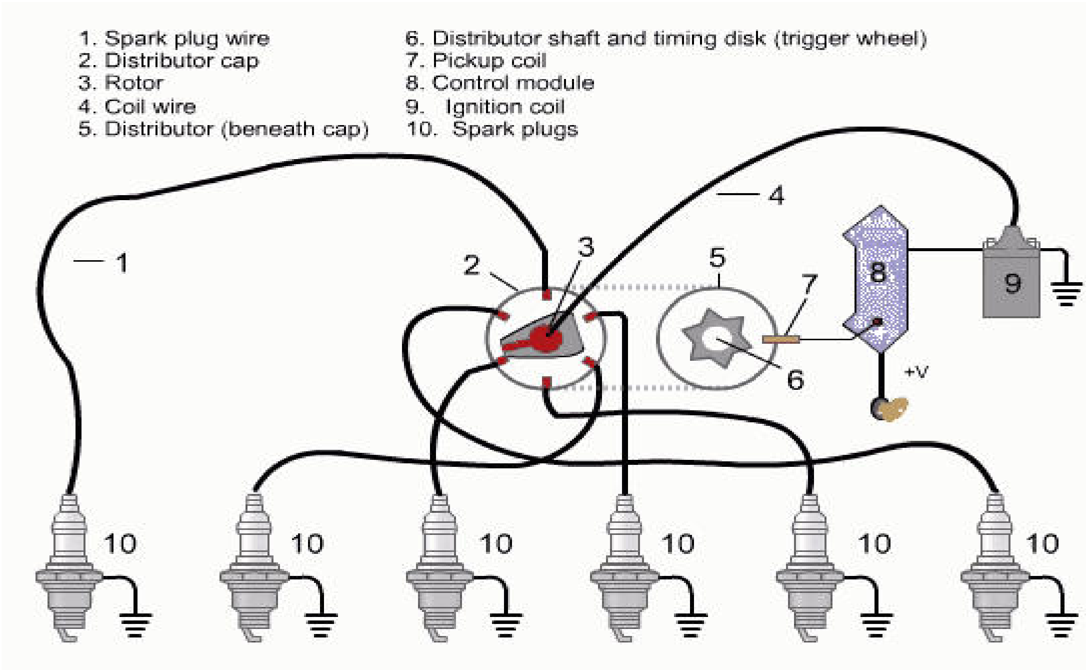


Distributor

A distributor is an electromechanical device that distributes high-voltage electricity from an ignition coil to the correct spark plug in an internal combustion engine at the right time. It works by using a rotating rotor inside a distributor cap to direct the spark to each cylinder's terminal, which is connected to a spark plug via a wire. The rotor's rotation is synchronized with the engine's camshaft, ensuring the spark occurs at the correct point in the engine's firing order.

Working principle

1. High-voltage generation: The ignition coil converts low voltage from the battery into a high voltage.
2. Rotor rotation: The distributor shaft, driven by the engine's camshaft, spins a rotor inside the distributor cap.
3. High-voltage delivery: As the rotor spins, its tip comes close to each terminal in the distributor cap.
4. Spark distribution: When the rotor aligns with a terminal, a high-voltage spark jumps the gap and travels through the corresponding spark plug wire to ignite the air-fuel mixture in the engine's cylinder.
5. Timing and advance: The timing of this process is crucial for smooth operation. Older systems used a mechanical contact breaker that was opened by a rotating cam, while modern systems use electronic sensors. A spark advance mechanism adjusts the timing based on engine speed to ensure maximum power.

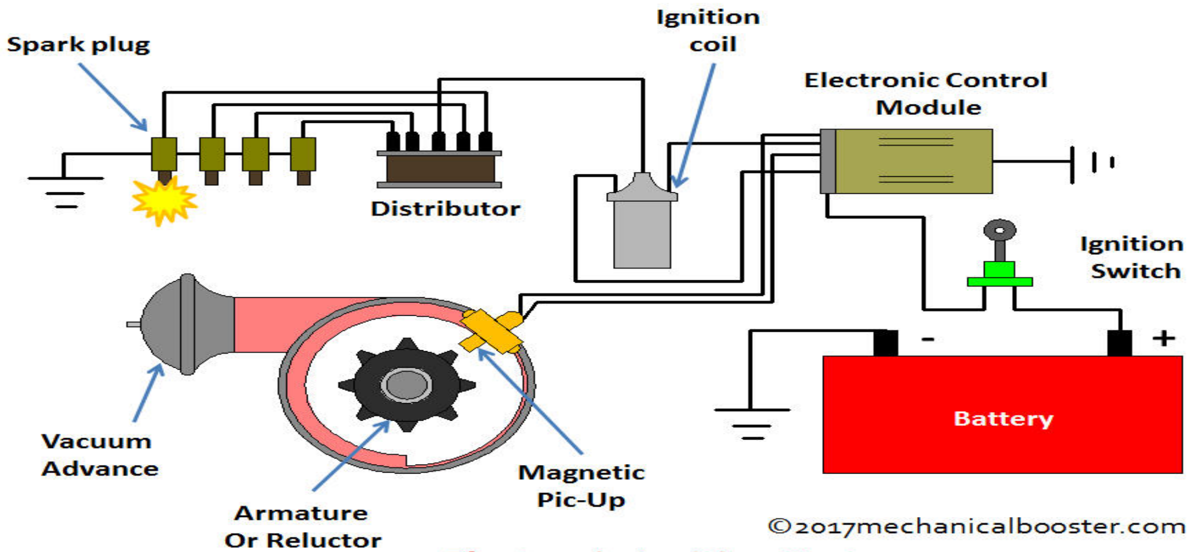


Electronic Ignition System

An electronic ignition system works by precisely controlling the timing of a spark using sensors and an engine control unit (ECU), which signals an ignition module to interrupt the flow of current to the primary coil. This rapid interruption causes a high-voltage spark to be induced in the secondary coil, which is then delivered to the spark plug to ignite the air-fuel mixture. Unlike older mechanical systems, electronic systems use solid-state components for greater reliability and efficiency.

How it works:

- **Current flows to the coil**: Power from the battery flows through the ignition switch and into the primary winding of the ignition coil.
- **Sensor detects position**: As the engine runs, sensors (like a Hall effect sensor or a pulse generator) detect the position of the engine's rotating parts.
- **ECU signals the module**: The sensor sends a signal to the electronic control module (ECM), which is part of the ECU.
- **Coil current is interrupted**: The ECM tells the ignition module, which contains a transistor, to instantly switch off the current to the primary coil.
- **High voltage is induced**: The sudden collapse of the magnetic field in the primary coil induces a very high voltage in the secondary coil.
- **Spark is distributed**: This high-voltage current travels to the spark plug, creating a spark that ignites the fuel.
- **Current resumes**: The ECM then signals the module to turn the current back on, allowing the magnetic field to build up again for the next cycle.



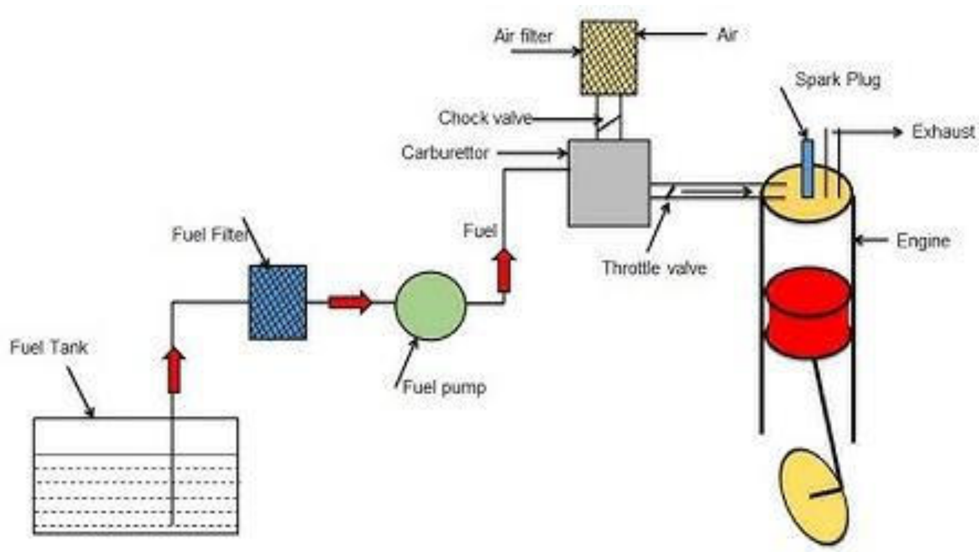
Electronic Ignition System

Fuel System

A fuel system's working principle is to deliver fuel from the tank to the engine's combustion chamber, where it is mixed with air and ignited to generate power. This involves a low-pressure pump moving fuel to a filter for cleaning, a high-pressure pump or injection system pressurizing it, and injectors spraying the pressurized fuel into the cylinders at the correct time.

Step-by-step breakdown of a typical fuel system

- **Fuel storage**: The fuel tank holds a reserve of fuel.
- **Low-pressure transfer**: A low-pressure fuel pump draws fuel from the tank and pushes it through fuel lines.
- **Filtration**: The fuel passes through a filter to remove any impurities or water before it reaches the high-pressure components.
- **Pressurization**: A high-pressure pump (or a combined injection pump in some systems) pressurizes the fuel to very high levels.
- **Distribution**: The pressurized fuel is sent to the injectors, often via a common rail which holds fuel at a constant high pressure.
- **Injection**: The injectors, controlled by the engine's control unit (ECU), precisely spray the pressurized fuel into the engine's combustion chambers.
- **Combustion**: The injected fuel combines with compressed air and is ignited by a spark plug, creating a powerful explosion that drives the piston and generates power.

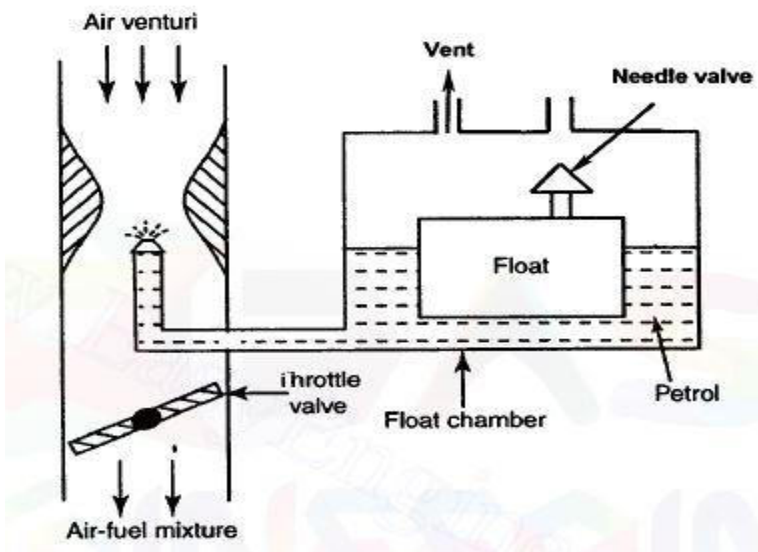


Carburetor

A simple carburetor works on the principle of Bernoulli's principle, using the venturi effect to mix fuel and air. Air is drawn through a narrow passage (the venturi), which increases its velocity and decreases its pressure. This low pressure sucks fuel from a float chamber into the airflow, creating a combustible vapor mixture that is sent to the engine. The engine's throttle valve controls how much of this mixture enters the engine.

Key steps of a simple carburetor's operation:

- **Airflow and pressure drop:**
  As the engine creates a vacuum, air is pulled into the carburetor and through a venturi tube.
- **Venturi effect:**
  The venturi tube is narrow in the middle, which forces the air to speed up as it passes through.
- **Fuel suction:**
  According to Bernoulli's principle, the increased velocity of the air in the venturi creates a low-pressure area.
- **Fuel mixing:**
  This low pressure pulls fuel from the float chamber through a small nozzle into the venturi, where it mixes with the air.
- **Throttle control:**
  The throttle valve, controlled by the accelerator, regulates the amount of this air-fuel mixture that is drawn into the engine. Opening the throttle increases power, while closing it reduces power.
- **Vaporization:**
  The mixture of air and fine fuel droplets then moves to the engine's intake manifold, where heat fully vaporizes the fuel before it enters the cylinder for combustion.



Fuel Pump

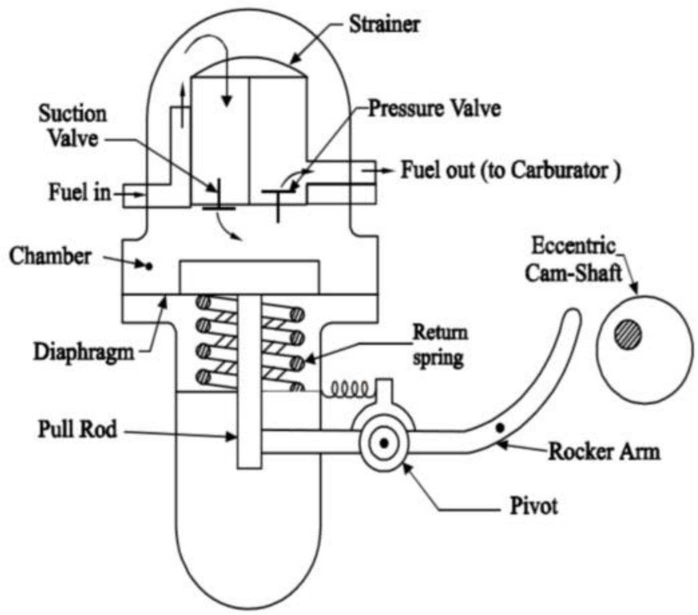
A fuel pump delivers fuel from the tank to the engine by creating pressure to push the fuel through the lines. This is achieved by different mechanisms depending on the type: **mechanical pumps**, driven by the engine's camshaft or crankshaft, use a diaphragm or plunger to create suction and pressure. **Electric pumps**, found in most modern vehicles, use an electric motor and a pump (often a roller-cell or impeller type) to move the fuel.

Mechanical Pump

A mechanical fuel pump works by using a diaphragm or plunger, driven by the engine's camshaft or crankshaft, to create suction and pressure. As the cam lobe rotates, it moves a rocker arm or push rod, which pulls a diaphragm down to draw fuel from the tank into a chamber through an inlet valve. When the diaphragm is pushed back up, it forces the fuel out through an outlet valve and towards the engine's carburetor.

Detailed steps

- **Cam action:** An eccentric lobe on the engine's camshaft rotates and pushes on a rocker arm or push rod connected to the pump.
- **Intake stroke:** As the cam lobe moves away from the rod, the diaphragm is pulled downward. This creates a vacuum, which draws fuel from the fuel tank into the pump's chamber through a one-way inlet valve.
- **Discharge stroke:** As the cam rotates, the lobe pushes the rod, which forces the diaphragm upward. This pressurizes the fuel inside the chamber.
- **Fuel delivery:** The pressure from the diaphragm closes the inlet valve and opens the outlet valve, forcing the fuel to be pumped to the carburetor.
- **Constant flow:** The process repeats with every rotation of the camshaft, providing a continuous supply of fuel to the engine.

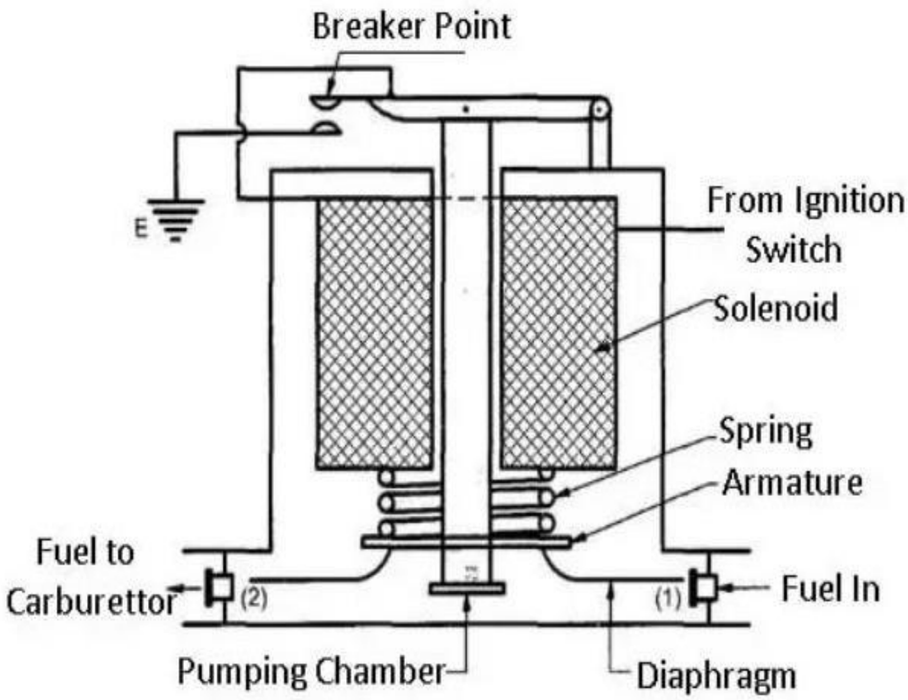


Electrical Fuel Pump

An electrical fuel pump works by using an electric motor to spin a pump impeller, which creates suction to pull fuel from the tank and push it out at high pressure to the engine. The motor is powered by the vehicle's electrical system, and its rotation is transferred to the impeller via a shaft, generating a vacuum at the inlet. This vacuum draws in filtered fuel, and the impeller then forces the fuel out through an outlet, providing a steady, pressurized supply for the engine's fuel injectors.

Detailed breakdown of the working principle

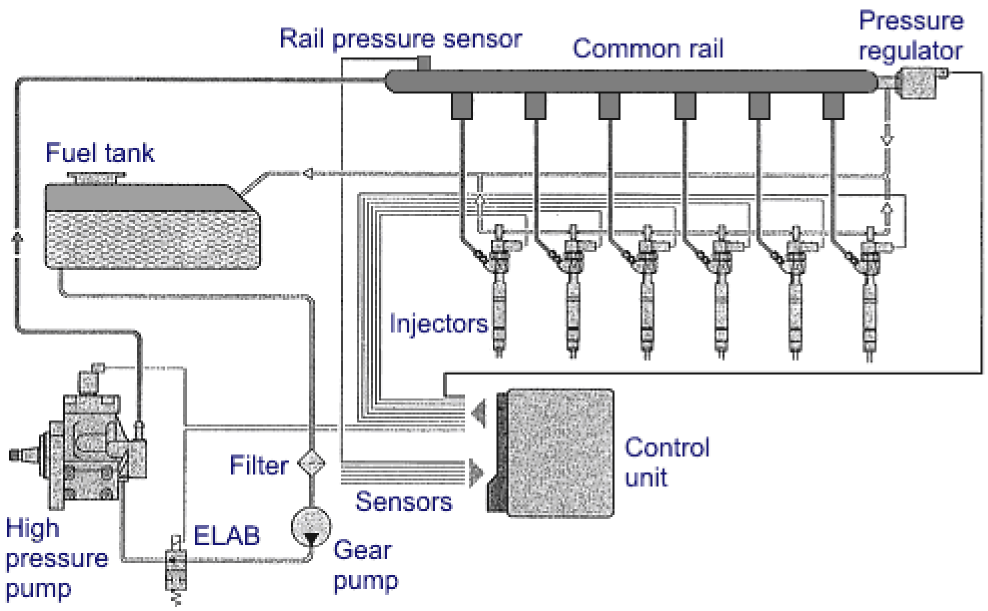
- **Electric motor activation**: When the ignition is turned on, the electrical system sends power to the fuel pump's small DC motor.
- **Motor and impeller rotation**: The electric motor's armature rotates, which in turn spins the pump's impeller at high speed.
- **Fuel suction**: The high-speed rotation of the impeller creates a vacuum in the inlet area, drawing fuel from the tank up through a fuel line.
- **Fuel pressurization**: As the impeller spins, it forces the fuel into the pump housing and then out through the outlet at a high pressure.
- **Fuel delivery**: This pressurized fuel is sent through the fuel lines to the engine's injectors, which spray it into the combustion chamber.
- **Cooling and lubrication**: In most modern vehicles, the fuel pump is located inside the fuel tank. The fuel surrounding the pump helps to cool and lubricate the electric motor, preventing it from overheating.



Fuel Injection Systems

A fuel injection pump works by first pressurizing fuel using a high-pressure pump, which sends it to an accumulator or fuel rail. The Engine Control Unit (ECU) then signals the pump to control the injection timing and quantity of fuel, which is injected into the engine's cylinders through injectors.

- **Pressurization:** Fuel is drawn from the tank and is pressurized by a fuel pump, which can be a high-pressure pump that delivers fuel to an accumulator (like in a common rail system) or directly to the engine's cylinders.
- **Control**: The Engine Control Unit (ECU) receives data from sensors about the engine's condition and requirements. It then determines the precise amount and timing of fuel needed for optimal combustion, power output, and emissions.
- **Injection**: The ECU sends signals to the injectors to open and inject the pressurized fuel into the engine cylinders.
- **Fuel metering**: Some systems, like the helix fuel pump, use a plunger with a helical groove. As the plunger rotates, it changes the point at which a spill port is uncovered, controlling the amount of fuel delivered.
- **Regulation**: A pressure regulator maintains the correct fuel pressure throughout the system, while relief valves manage any excess pressure.



Mono point Fuel System

Mono-point (or single-point) injection combines air and fuel in a single throttle-body unit before it is distributed to all cylinders, while multi-point injection uses a separate injector for each cylinder to spray fuel directly into the intake port, leading to more precise control, better performance, and improved efficiency. The multi-point system's main advantage is that it precisely delivers the correct amount of fuel to each cylinder individually, overcoming the inaccuracies of a single-point system.

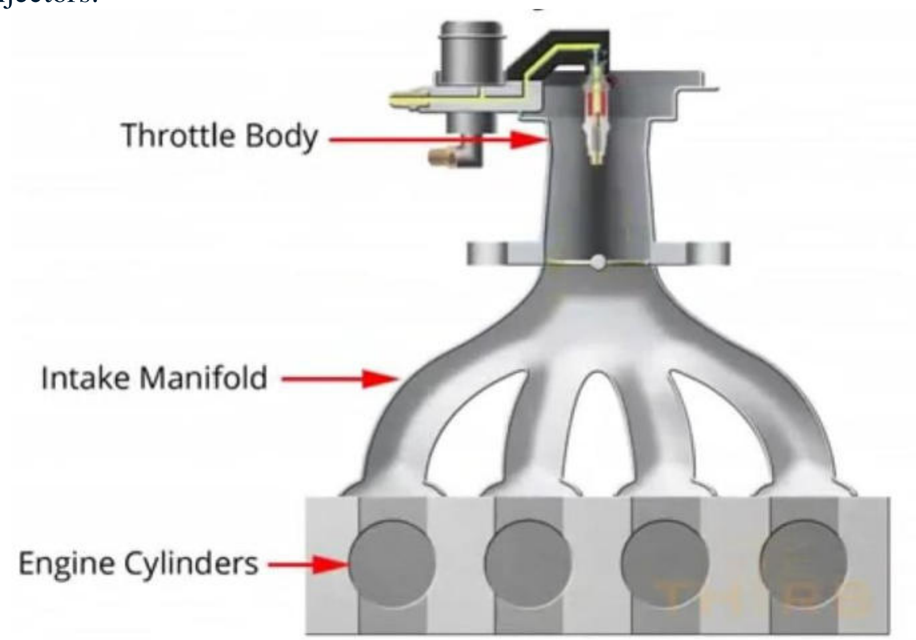
Mono-point injection (Single-Point Fuel Injection - SPFI)

- **Working principle:** It's similar to a high-tech carburetor. A single injector is mounted in the intake manifold, often near the throttle body, which sprays fuel into the incoming air.
- **Fuel delivery:** The mixture of air and fuel then travels through the intake manifold to each cylinder.
- **Pros:** Simpler and less expensive to manufacture.
- **Cons:** Less precise fuel distribution to each cylinder, which can lead to poorer fuel economy and higher emissions.

Multi-point injection (Multi-Point Fuel Injection - MPFI)

- **Working principle:** Each cylinder has its own individual fuel injector located in the intake manifold, just before the intake valve.
- **Fuel delivery:** The engine control unit (ECU) precisely controls each injector to spray fuel directly into its respective cylinder's intake port.
- **Pros:**
  - Allows for much more precise fuel delivery to each cylinder, leading to better performance, fuel efficiency, and lower emissions.

- Improved engine response and smoother operation.
- **Cons:** More complex and expensive than mono-point systems, requiring regular maintenance of individual injectors.

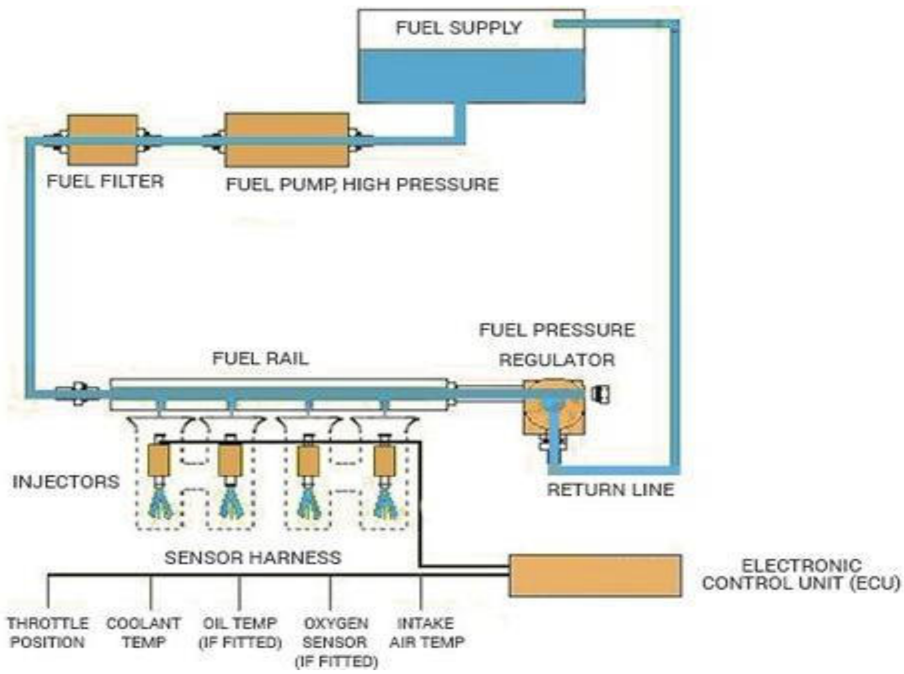


Multi Point Fuel System

A multi-point fuel injection (MPFI) system works by using an electronic control unit (ECU) to precisely control a fuel injector for each cylinder. The system uses sensors to monitor engine conditions and then commands the injectors to spray the correct amount of fuel into the intake port just before each intake valve opens, resulting in better atomization, improved fuel efficiency, lower emissions, and smoother performance.

Working principle of an MPFI system:

- **Fuel delivery:** A fuel pump draws fuel from the tank and sends it under pressure to a fuel rail, which supplies all the injectors. A pressure regulator maintains the correct pressure in the fuel rail.
- **Sensor monitoring:** A network of sensors continuously collects data on engine parameters like engine speed (RPM), vehicle speed, throttle position, and air temperature.
- **ECU calculation:** The Engine Control Unit (ECU) receives data from all the sensors and calculates the optimal amount of fuel needed for the current engine conditions.
- **Precise injection:** Based on the ECU's calculations, the individual fuel injectors are activated to spray a precise amount of fuel into the intake port of their respective cylinder.
- **Combustion:** The injected fuel is mixed with air, and the mixture is drawn into the cylinder for combustion. In modern sequential systems, the fuel is injected just as the intake valve opens for each cylinder, leading to a more complete and efficient burn.



Unit Injector

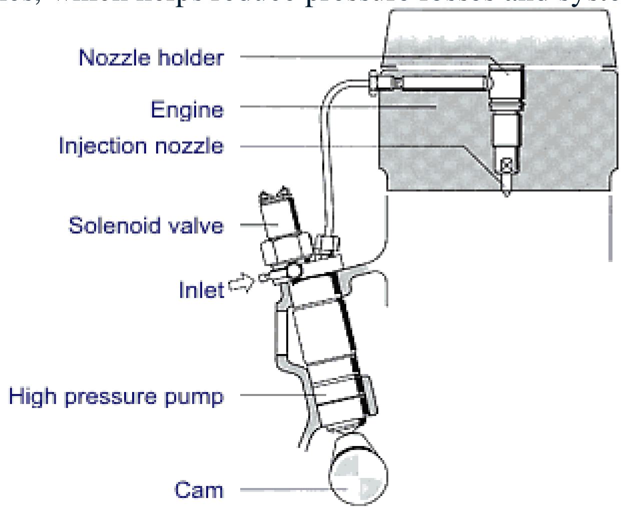
A unit injector combines a high-pressure pump and an injector nozzle into a single component mounted in the cylinder head of an engine. It works by receiving low-pressure fuel from a supply pump. When a solenoid valve is energized by the Electronic Control Unit (ECU), it closes, trapping the fuel and allowing the mechanically-driven plunger to build high pressure and inject the fuel directly into the combustion chamber. The ECU controls the injection's start and duration by controlling the solenoid's timing, which dictates the amount of fuel injected and the start time.

Working principle

1. **Fuel supply**: A low-pressure fuel pump supplies fuel to the injector through a passage in the cylinder head.
2. **Plunger filling**: During the upward stroke, the plunger is pulled up by the engine's camshaft via a rocker arm. In this phase, a spill valve is open, allowing fuel to flow into the pump chamber below the plunger and then back to the low-pressure system.
3. **Injection start**: When the ECU sends an electrical signal to the injector's solenoid, the spill valve closes. This traps the fuel in the chamber.
4. **Pressure buildup**: As the plunger continues its downward motion, the trapped fuel's pressure rapidly increases.
5. **Fuel injection**: When the pressure is high enough to overcome the nozzle's opening pressure, the fuel is injected in a fine spray into the combustion chamber.
6. **Injection end**: The ECU de-energizes the solenoid, causing the spill valve to open again. This releases the pressure, the nozzle closes, and the injection stops.

Key features

- **Direct injection**: Fuel is injected directly into the combustion chamber under very high pressure, which promotes more complete combustion.
- **Electronic control**: The ECU precisely controls the timing and duration of the injection by managing the solenoid valve, allowing for optimized performance, fuel efficiency, and reduced emissions.
- **Integrated design**: The combination of the pump and injector in a single unit eliminates the need for high-pressure fuel lines, which helps reduce pressure losses and system complexity.



Nozzle

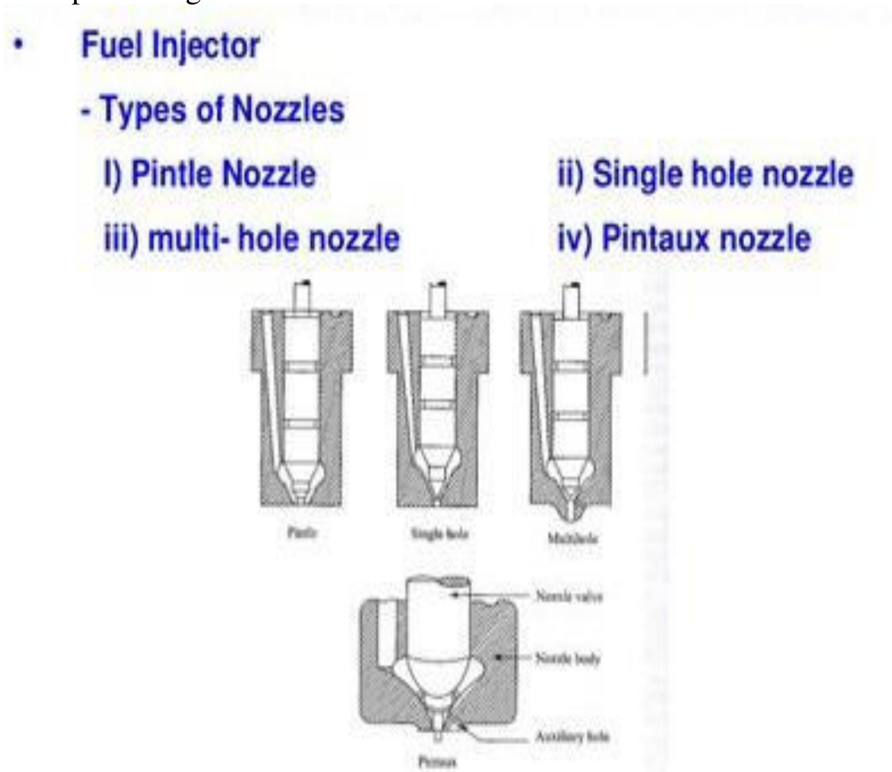
In automobiles, a nozzle's primary function is to atomize liquid fuel into a fine spray for efficient mixing with air, which is crucial for combustion. It does this by converting the fuel's pressure energy into kinetic energy, forcing it through small holes or orifices at high velocity. Key types of nozzles include pintle, single-hole, and multi-hole nozzles, each with different spray patterns and effects on fuel delivery and mixing.

Working principle

- **Pressure to kinetic energy conversion**: The fundamental principle is to convert the high-pressure fuel's potential energy into a high-speed kinetic energy stream.
- **Atomization**: This high-velocity spray breaks the fuel into tiny droplets, a process called atomization.
- **Proper mixing**: Atomized fuel mixes more easily and thoroughly with air in the combustion chamber, ensuring a more complete and efficient combustion event.
- **Direction and distribution**: The nozzle's design directs the fuel spray to specific areas within the combustion chamber for optimal distribution and prevents fuel from hitting cylinder walls.

Types of nozzles

- **Pintle nozzle**: This type has a pin or pintle that protrudes into the spray hole, creating a specific spray pattern and reducing fuel penetration.
- **Single-hole nozzle**: A simple design with a single hole, often used in older systems. It provides a basic spray, but may not offer the same level of atomization as multi-hole designs.
- **Multi-hole nozzle**: This nozzle has multiple small holes (from 4 up to 18 or more) to create a more dispersed and uniform fuel spray.
  - **Advantages**: Multi-hole designs offer better fuel distribution and more efficient air-fuel mixing, even in chambers with lower air motion.
  - **Regulation**: The size of the holes is carefully controlled to meet emission standards, with modern nozzles capable of producing holes as small as 20 microns in diameter.

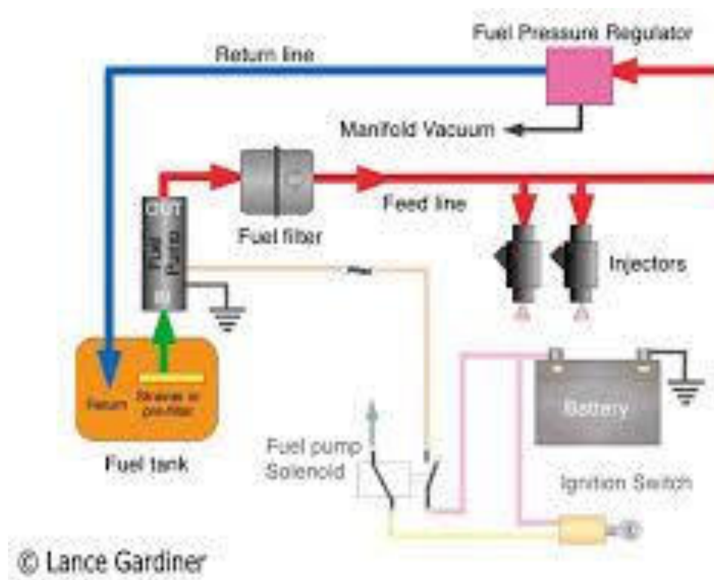


Electronic Fuel Injection System (EFI)

An Electronic Fuel Injection (EFI) system works by using sensors to monitor engine conditions, which the Engine Control Unit (ECU) uses to calculate the precise amount of fuel needed. The ECU sends electrical signals to fuel injectors, which spray atomized fuel into the intake manifold or directly into the cylinder. This system maintains an optimal air-fuel ratio for efficient combustion, leading to better performance and fuel economy compared to older carburetor systems.

Step-by-step breakdown of the working principle:

- **Sensing and data collection:** Various sensors (like the air flow meter, manifold absolute pressure sensor, and coolant temperature sensor) constantly send data about engine speed, load, temperature, and air intake to the ECU.
- **ECU calculation:** The ECU processes the data from these sensors to determine the exact amount of fuel needed for optimal combustion under the current conditions.
- **Fuel delivery:** A fuel pump pressurizes fuel from the tank and sends it to the fuel rail. A pressure regulator maintains this pressure, ensuring a consistent supply to the injectors.
- **Fuel injection:** Based on the ECU's calculation, the injectors are pulsed on and off electronically. This opens the injectors for a specific duration, spraying a fine mist of fuel into the engine.
- **Air-fuel mixture:** The injected fuel mixes with the incoming air in the intake manifold (or cylinder) to create a combustible mixture. The ECU adjusts the fuel delivery to maintain the ideal air-to-fuel ratio, which is approximately 14.7:1by weight, for efficient combustion.
- **Combustion:** This air-fuel mixture is then ignited by the spark plug, generating power.



Gasoline Direct Injection (GDI)

Gasoline Direct Injection (GDI) works by injecting fuel directly into the combustion chamber at high pressure, rather than mixing it in the intake manifold first. This direct injection allows for more precise control over the air-fuel mixture, resulting in higher efficiency, greater power, and lower fuel consumption.

Working principle

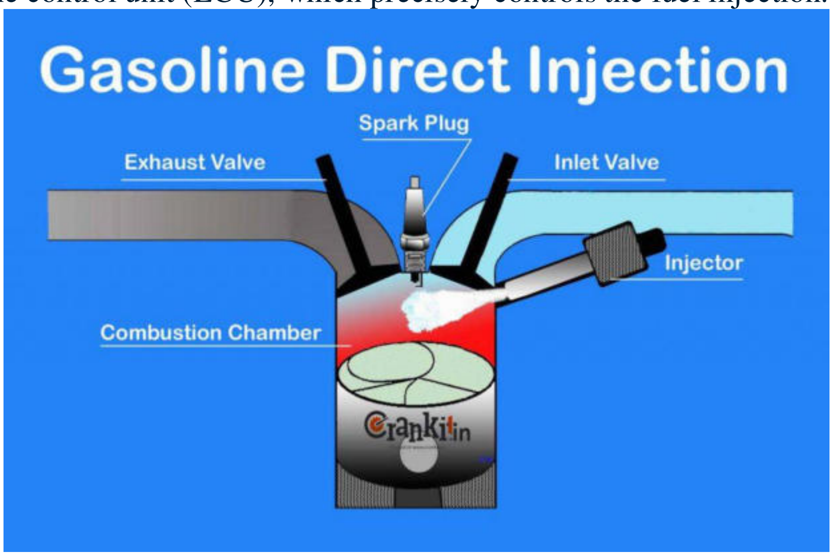
1. **Air intake**: Air flows into the cylinder through the intake valve during the intake stroke.
2. **High-pressure fuel injection**: The engine's high-pressure fuel pump sends gasoline to the injectors, which are mounted directly in the cylinder head. The injectors spray the fuel into the cylinder with high pressure, which atomizes it into a fine mist.
3. **Mixture preparation**: The fuel mixes with the air directly inside the combustion chamber, allowing for precise timing and control.
4. **Combustion**: The spark plug ignites the compressed air-fuel mixture, creating an explosion that drives the piston down to produce power.

Benefits

- **Improved efficiency**: More precise control over the air-fuel mixture means less fuel is wasted and can lead to better fuel mileage.
- **Higher power**: By directly spraying fuel into the cylinder, the system improves combustion cooling, which allows for higher engine compression ratios and increased torque.
- **Lower emissions**: The precise mixture preparation can lead to more stable and complete combustion, reducing emissions.

Key components

- **High-pressure pump**: Delivers fuel at pressures up to 350 bar or higher.
- **High-pressure injectors**: Spray fuel directly into the combustion chamber with high precision.
- **Fuel rail**: Stores and distributes the high-pressure fuel to the injectors.
- **Sensors and ECU**: A network of sensors (like crankshaft position and oxygen sensors) provides data to the engine control unit (ECU), which precisely controls the fuel injection.



DTSI (Digital Twin Spark Ignition)

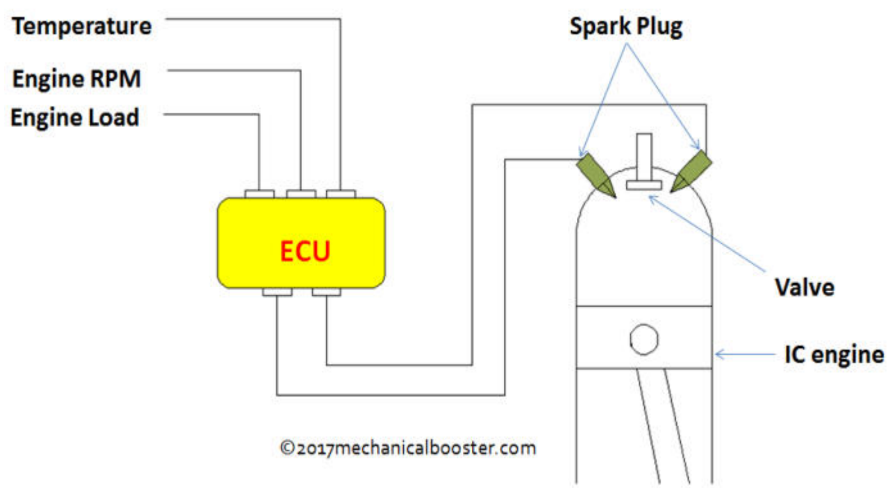
DTSI (Digital Twin Spark Ignition) is an automobile engine technology that uses two spark plugs per cylinder to ignite the air-fuel mixture simultaneously, leading to more efficient and complete combustion. The dual ignition creates faster, more even burning from two points within the combustion chamber, which results in increased power, better fuel economy, and reduced emissions compared to a single-spark system.

How DTS-i works

- **Two spark plugs:** Each engine cylinder has two spark plugs, positioned at opposite ends of the combustion chamber.
- **Simultaneous ignition:** At the optimal moment in the compression stroke, both spark plugs fire at the same time.
- **Dual flame fronts:** This dual ignition creates two flame fronts that spread rapidly and evenly across the air-fuel mixture.
- **Faster, complete combustion:** The converging flames lead to faster and more thorough combustion, which generates more power.
- **Digital control:** An electronic control unit (ECU) manages the timing of the sparks and fuel injection for optimal performance across different conditions.

Benefits of DTS-i technology

- **Increased power:** The dual-spark ignition produces more power from the same engine size.
- **Improved fuel efficiency:** Faster and more complete combustion means less fuel is wasted.
- **Reduced emissions:** More efficient burning leads to lower emissions of harmful gases.
- **Smoother ride:** DTS-i engines are often quieter and provide a smoother riding experience.
- **Durability:** Since the system is electronic, there are fewer moving parts and less wear and tear, leading to a longer lifespan for engine components.



UNIT-3

STEERING AND SUSPENSION SYSTEM

The principle of a car's steering system is to convert the rotary motion of the steering wheel into the angular turning of the front wheels**.** Modern systems, like the rack and pinion, achieve this by using the steering wheel to turn a pinion gear, which moves a rack back and forth linearly

How it works:

- **Steering Wheel to Pinion:** When you turn the steering wheel, it rotates a steering column. At the base of the column, a pinion gear is attached.
- **Pinion to Rack:** This rotating pinion gear meshes with a toothed rack, which is a long bar that can only move side to side (linearly).
- **Rack to Wheels:** The rack is connected to the wheels via tie rods and steering arms.
  - As the rack moves left or right, it pushes or pulls on the tie rods, which in turn pivot the steering arms.
  - This causes the front wheels to turn in the direction you are steering.
- **Amplifying force:** The system is designed so that a small force on the steering wheel results in a large steering movement of the wheels. Power steering systems (hydraulic or electric) further amplify this force, making it easier to turn the wheels, especially at low speeds.

STEERING GEOMETRY

Steering geometry aligns the wheels and suspension components to ensure a vehicle turns smoothly and predictably, with the core principle being that the inner and outer wheels of a turn must travel different-radius paths. The Ackermann steering system is the most common mechanism for this, arranging steering linkages so the inner wheel turns at a greater angle than the outer one to prevent tire slippage and ensure all wheels' turning axes intersect at a common point on the line extending from the rear axle. This geometry is crucial for vehicle handling, stability, and minimizing tire wear.

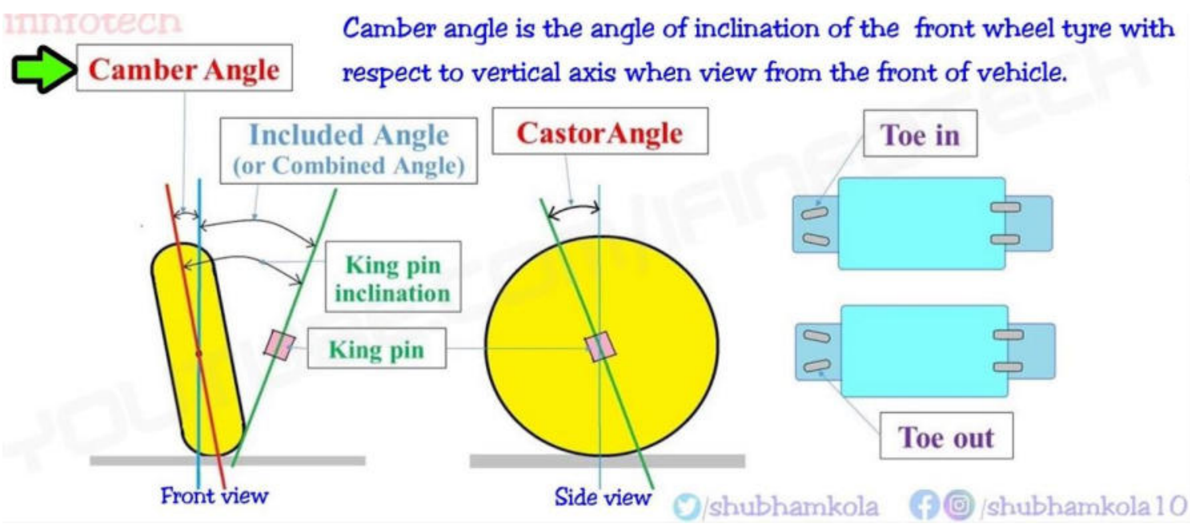
Working Principle

- Input: When the driver turns the steering wheel, the motion is converted by the steering column and rack-and-pinion system into a linear movement of the tie rods.
- Mechanical Linkage: The steering linkages (tie rods) are connected to the steering arms on the front wheel knuckles, which are attached to the wheels.

- The Ackermann effect: The steering linkage is designed in a trapezoidal shape. This specific linkage geometry ensures that as the tie rods move, the inner wheel (which is turning in a tighter circle) is steered to a greater angle than the outer wheel, as described in Scribd and Scribd.
- Common Center Point: This difference in angle allows both front wheels to follow paths that are arcs of circles with a single, common center point.
- Result: By following arcs with a common center, the wheels do not slip sideways, leading to smooth turns, predictable handling, and reduced tire wear, notes Wikipedia and Medium.

Other geometry aspects

- Caster angle: A pivot point for the wheel that is ahead of the wheel's contact patch helps the steering self-center.
- Camber angle: The angle of the wheel in its vertical plane, which influences steering dynamics.
- Kingpin inclination: The angle of the steering axis when viewed from the front, which helps with stability and reduces steering effort, according to Slideshare.



Wheel Alignment

Wheel alignment works by adjusting the angles of the vehicle's wheels to meet manufacturer specifications, which ensures they are parallel to each other and perpendicular to the road for safe and stable driving. A modern alignment process involves placing the vehicle on a lift, attaching sensors to each wheel, and then using a computerized machine to measure the current angles of the wheels (camber, caster, and toe). Adjustments are made to the suspension components until the readings match the vehicle's specifications, correcting problems like the car pulling to one side or the steering wheel being off-center.

Key concepts and process

- **The goal:** The primary goal is to get the wheel angles right so that the tires make solid contact with the road and the vehicle travels straight and true.

- **Key angles:** Technicians adjust the three main angles:
  - **Camber:** The tilt of the wheel when viewed from the front. It is the angle between the vertical axis of the wheel and the vertical axis of the vehicle.
  - **Caster:** The angle of the steering axis, which is like the angle of a shopping cart's caster wheel. It affects steering stability and the self-centering effect of the steering wheel.
  - **Toe:** The angle of the wheel's rotation relative to the vehicle's centerline, viewed from above. It can be set to be "toeing in" or "toeing out".

The process:

- The vehicle is placed on a lift and a machine with sensors or cameras is used.
- Alignment heads or cameras are attached to the wheels.
- The machine measures the current camber, caster, and toe angles.
- A technician makes adjustments to the vehicle's suspension components to correct the angles.
- The machine verifies that all angles are within the manufacturer's specifications.

STEERING LINKAGES

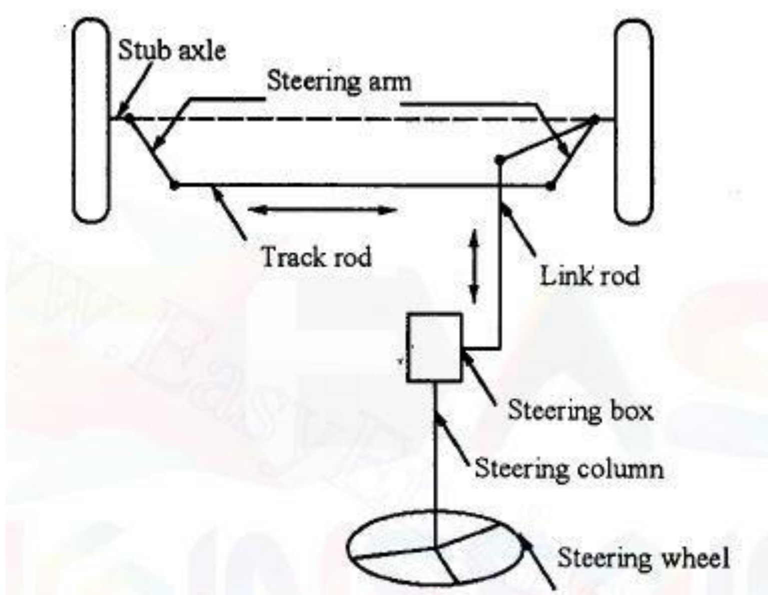
Steering linkages transfer the rotational motion from the steering wheel to the wheels, converting it into the linear motion needed to turn the vehicle. When the driver turns the steering wheel, this motion goes through the steering column to the steering gear, which is either a rack and pinion or a steering box. The steering gear then pushes or pulls the tie rods, which are connected to the steering arms on the wheels, causing them to pivot and turn. This system is designed using Ackermann geometry to ensure the inner wheel turns at a sharper angle than the outer wheel for better handling.

Mechanical steering linkage (e.g., rack and pinion)

- **Steering wheel:** The driver turns the steering wheel, which rotates the steering column.
- **Steering gear:** The rotation is transmitted to the steering gear. In a rack and pinion system, this is a pinion gear that meshes with a toothed rack. As the pinion rotates, it moves the rack linearly from side to side.
- **Tie rods:** The ends of the rack are connected to tie rods. The linear motion of the rack pushes or pulls the tie rods.
- **Steering knuckles/arms:** The tie rods are connected to the steering arms on the steering knuckles, which the wheels are mounted on.
- **Wheels:** As the tie rods move, they cause the steering arms and, therefore, the wheels to pivot left or right.

Power steering linkage

- **Hydraulic or electric assist:** Power steering systems add assistance to reduce the effort needed to turn the wheels.
- **Hydraulic:** A pump sends hydraulic fluid under pressure to a valve. When the steering wheel is turned, the valve directs the fluid to one side of a cylinder, pushing a piston to move the steering linkage and assist the steering.
- **Electric:** An electric motor provides assistance. Sensors detect the steering input, and the motor applies torque to either the steering column or the steering rack to help turn the wheels.



A steering gearbox translates the driver's rotational steering input into linear motion to turn the wheels. The main types are rack and pinion and recirculating ball (also known as worm and nut), each with a different working principle. Rack and pinion uses a pinion gear that meshes with a toothed rack to convert rotation to linear movement, while recirculating ball uses a worm gear to drive a nut-like component with ball bearings to move a lever connected to the steering linkage.

Rack and pinion

- Principle: The steering wheel's rotation spins a small gear (pinion) at the end of the steering shaft. The teeth of the pinion mesh with a toothed bar (rack).
- How it works: As the pinion rotates, it pushes the rack to move left or right. This linear movement is transmitted through tie rods to the steering arms on the wheels, turning them.
- Application: This is the most common system in modern cars and SUVs due to its direct, responsive, and compact design.

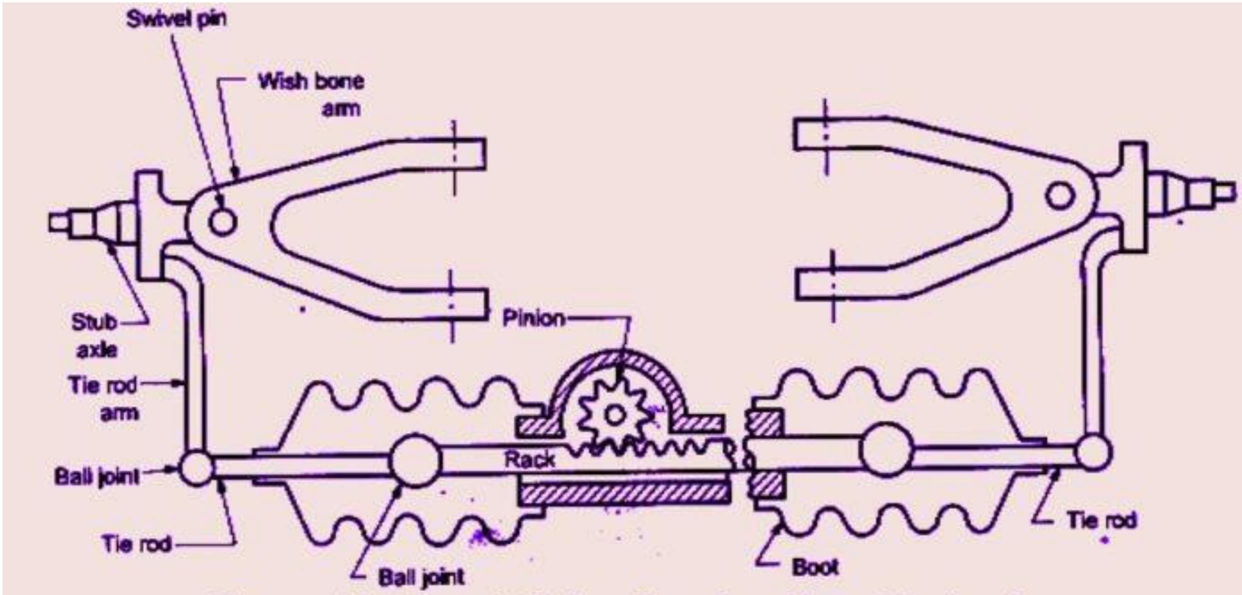
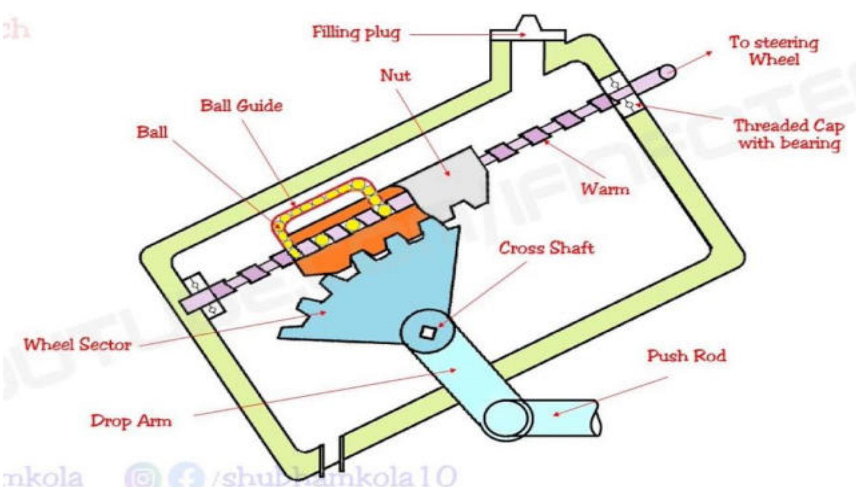


Figure: Rack and Pinion Steering Gear Mechanism.

Recirculating ball (Worm and nut)

- Principle: The steering wheel rotates a worm gear, which is a large screw-like component.
- How it works: A nut with internal threading is mounted on the worm gear. As the worm gear turns, the nut moves along the screw. Ball bearings are placed between the worm and nut to reduce friction. The nut is connected to a sector shaft or lever, which is linked to the steering linkage to turn the wheels.
- Application: Found in larger vehicles like trucks and sometimes in older or heavy-duty passenger vehicles.

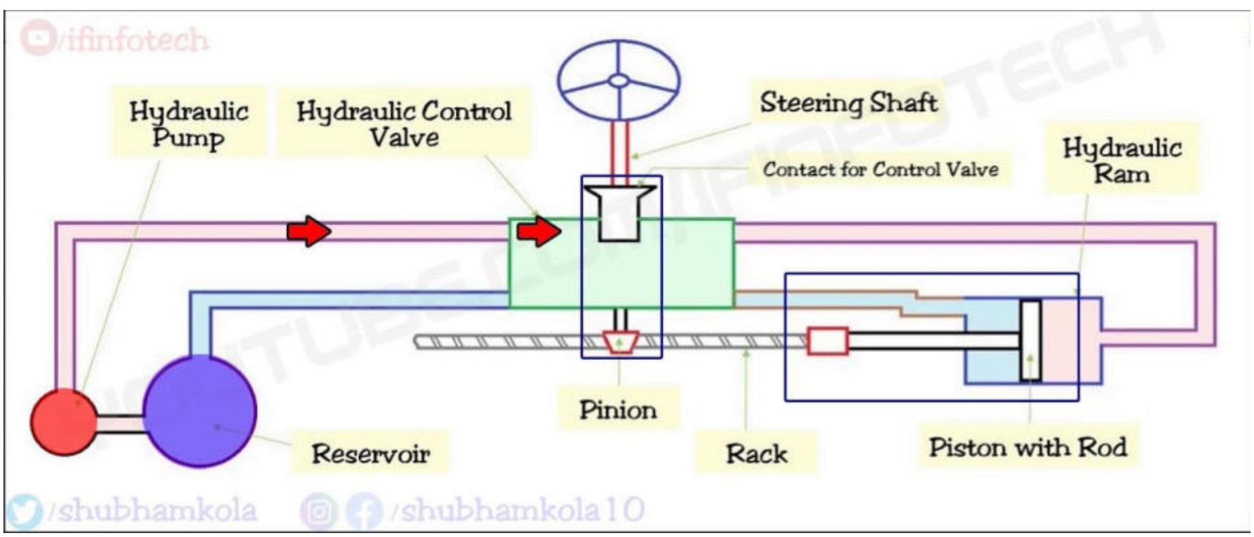


POWER STEERING

Power steering uses a hydraulic pump or electric motor to assist the driver's effort in turning the wheels. In hydraulic systems, a pump driven by the engine pressurizes fluid, which is then directed to a cylinder to apply force to the steering linkage. In electric systems, an electric motor connected to the steering column, controlled by a computer, provides the assistance. The steering system translates the driver's input from the steering wheel into a turning motion of the wheels via a rack and pinion or other gear mechanism.

How it works

- **Driver input:** The driver turns the steering wheel, which rotates the steering column.
- **System activation:**
  - **Hydraulic:** The rotation activates a valve that directs pressurized fluid from the hydraulic pump to one side of a piston in a steering gear.
  - **Electric:** Sensors on the steering column detect the driver's input and send signals to an electronic control unit (ECU).
- **Assistance:**
  - **Hydraulic:** The fluid pressure pushes the piston, which moves the steering linkage (like a rack) to turn the wheels. The pump provides more pressure at low speeds for easier parking and less assistance at high speeds for better control.
  - **Electric:** The ECU sends a signal to an electric motor, which then provides torque to the steering column or rack to assist the steering.
- **Steering output:** The movement of the steering linkage, whether from hydraulic pressure or the electric motor, turns the wheels in the desired direction.



Front Axle

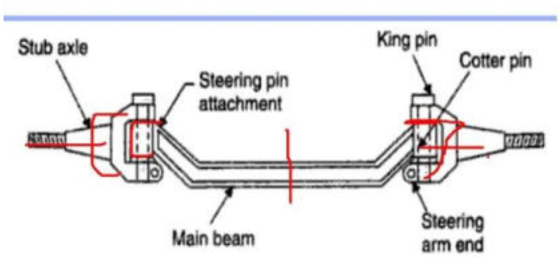
The front axle's working principle involves a dual role of supporting the vehicle's front weight and enabling steering. It transmits the front's weight from the springs to the wheels and allows the wheels to turn left or right as directed by the steering system. In front-wheel-drive or all-wheel-drive vehicles, a "live" front axle also transmits engine power to the wheels to propel the vehicle.

Components and functions

- **Axle beam**: The main structural component that carries the vehicle's weight and is often a drop-forged steel I-beam in the center for strength.
- **Stub axles**: These are the short axle sections at each end, connected to the main beam by a kingpin/swivel pin assembly.
- **Kingpin/Swivel pin**: A pivot that allows the stub axle to swivel, which is the fundamental movement for steering.
- **Steering linkage**: Components like the track rod connect the stub axles, translating the steering wheel's rotation into the turning motion of the wheels.
- **Constant Velocity (CV) joints**: In live axles, these are crucial for transmitting power to the wheels even as they turn and the suspension moves, allowing for steering without interrupting power flow.

Types of front axles

- **Live front axle**: Contains a differential and shafts that transmit engine power to the front wheels.
- **Dead front axle**: Does not transmit power; it primarily serves as a structural and steering component.



1. It carries weight of front end of the vehicle.
2. It provides mountings for stub axle, king pin and steering arm by which vehicle can be steered.
3. It transmits power to front wheels in case for front wheel drive vehicle.
4. It carries front wheels.

Suspension System

A car's suspension system works by using springs and shock absorbers (dampers) to dissipate forces, converting impact energy into heat. Springs absorb and store the energy from bumps, while the dampers slow down the spring's oscillations, preventing excessive bouncing and keeping the tires in contact with the road. This ensures a smoother ride, provides stability, and maintains tire-to-road friction for better handling.

Key components and their functions

- **Springs:** These are the primary energy absorbers. When a wheel hits a bump, the spring compresses to store the force. Common types include coil springs, leaf springs, and torsion bars.
- **Dampers (Shock Absorbers):** These control the rapid compression and extension of the springs. They contain a piston moving through hydraulic fluid; as the piston moves, it forces the fluid through small holes, converting the spring's kinetic energy into heat that dissipates into the atmosphere.
- **Control Arms:** These are links that connect the wheel to the vehicle's frame, controlling its position.
- **Ball Joints:** These connect the control arms to the steering knuckle, allowing the wheel to move up and down while also turning with the steering wheel.
- **Anti-sway Bars:** These are used to reduce the body roll of the vehicle when cornering.

Independent Suspension System

The fundamental working principle of an independent suspension system is to allow each wheel on the same axle to move vertically and independently of the others. This contrasts with a dependent suspension system, where wheels are linked by a single rigid axle, so the movement of one wheel directly affects the other.

The independent movement of each wheel provides several key advantages for a vehicle's handling, ride comfort, and stability.

Key working principles

- **Isolation of movement:** When one wheel hits a bump, the suspension components—like springs and shock absorbers—absorb the impact for that single wheel. This prevents the shock and vibration from being transferred across the axle to the other wheel and the rest of the vehicle.
- **Improved handling and traction:** Since each wheel can adjust to the road surface individually, the tires maintain more consistent contact with the ground. This improves traction, especially during cornering or when navigating uneven terrain. It also significantly reduces body roll (the vehicle's tilting motion) during turns.

- **Enhanced ride comfort:** By absorbing and isolating bumps, an independent suspension system provides a much smoother and more comfortable ride for the vehicle's occupants compared to a rigid axle setup.
- **Controlled motion:** A series of linkages, known as control arms, guide the motion of the wheels. Along with springs and shock absorbers, these parts work together to precisely control the wheel's position and orientation relative to the vehicle's chassis.

Core components

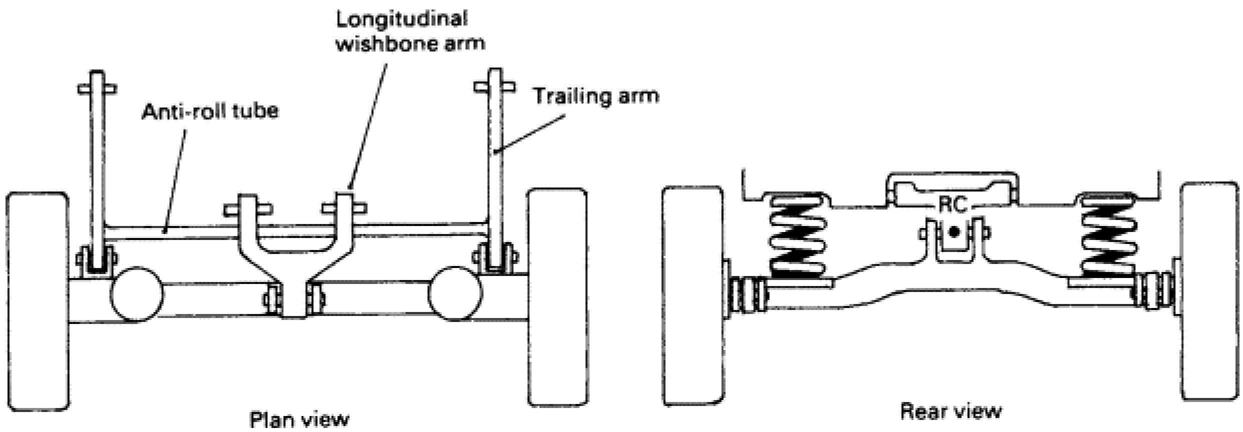
Though the specific design varies by type, the system generally consists of the following components:

- **Springs:** Absorb the energy from road irregularities, compressing and expanding to cushion the ride.
- **Shock absorbers (dampers):** Control the spring's motion by dissipating the energy absorbed by the springs, preventing the vehicle from bouncing excessively after hitting a bump.
- **Control arms (or linkages):** Connect the wheel hub to the vehicle's frame, guiding the wheel's motion and maintaining proper alignment.
- **Ball joints:** Allow for the rotational movement necessary for steering and for the wheels to move up and down.
- **Anti-roll bar (or stabilizer bar):** A torsion bar that links the suspension on opposite sides of the vehicle to minimize body roll when cornering.

Common types of independent suspension

Several common designs are used to achieve the independent working principle:

- **MacPherson Strut:** A compact and simple design where a single strut unit combines the spring and shock absorber. It is widely used in front-wheel-drive cars.
- **Double Wishbone:** This setup uses two wishbone-shaped control arms (an upper and a lower) to connect the wheel hub to the chassis. It offers superior wheel control and is common in sports and luxury cars.
- **Multi-link:** An advanced design that uses three or more lateral and longitudinal arms to provide precise control over the wheel's position and movement. It is often found in high-end luxury and performance vehicles.
- **Trailing and Semi-trailing Arm:** A design often used for rear suspensions, where the wheel hub is connected to the chassis by a horizontal arm.



Solid Axle Suspension System

A solid axle works by connecting both wheels on an axle with a single, rigid beam, causing them to move in tandem. When one wheel encounters a bump, the opposite wheel is also affected, though some systems use links and dampers to manage this. This design, also known as a non-independent suspension, is known for its durability, simplicity, and cost-effectiveness, making it common in heavy-duty trucks, SUVs, and some performance vehicles.

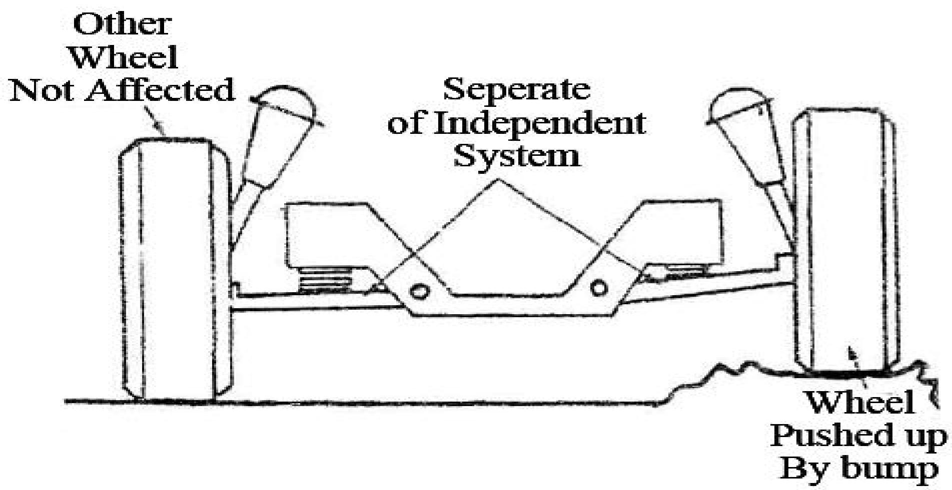
How it works

- **Wheel connection:** The right and left wheels are rigidly connected to a single axle. A single beam connects them, sometimes with a differential in the middle for driven axles.
- **Suspension movement:** Since the wheels are linked, a force on one wheel directly affects the other. For example, if one wheel hits a bump, its upward movement causes the axle to tilt slightly, which affects the position and angle of the other wheel.
- **Support and dampening:** The axle is mounted to the vehicle's chassis using springs (such as leaf or coil springs) and dampers (shock absorbers).
  - **Springs:** Absorb and support the vehicle's weight.
  - **Dampers:** Control the motion of the springs by converting the kinetic energy of the suspension movement into heat energy, preventing uncontrolled bouncing.
- **Steering:** In some designs, like the front axle of a commercial vehicle, the axle is a rigid beam that is steered, with each wheel attached to the axle at a pivot point. This is a simpler approach compared to independent suspension systems.

Key characteristics

- **Durability and simplicity:** The design is robust and requires less maintenance due to fewer complex parts.
- **Cost-effectiveness:** It is a more economical system to manufacture and repair compared to independent suspensions.

- **Strength:** It is well-suited for applications that require high strength, such as heavy-duty commercial vehicles and drag racing, where stability and power transfer are critical.
- **Handling on uneven surfaces:** While strong and durable, the coupled nature of the suspension means that imperfections on the road will affect both wheels, potentially reducing traction and handling comfort on rough roads.

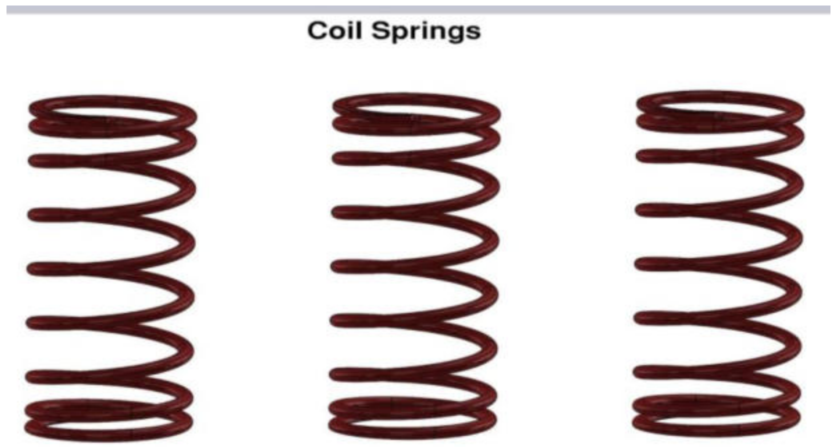


Coil Spring

Coil springs work by storing and releasing mechanical energy to absorb shocks and vibrations. When a vehicle encounters a bump, the compression spring compresses, storing energy, and then expands to return to its original shape, releasing the stored energy. This process allows the suspension to absorb impacts, providing a smoother ride by minimizing the transfer of road forces to the vehicle's body and passengers.

Key principles of coil spring operation

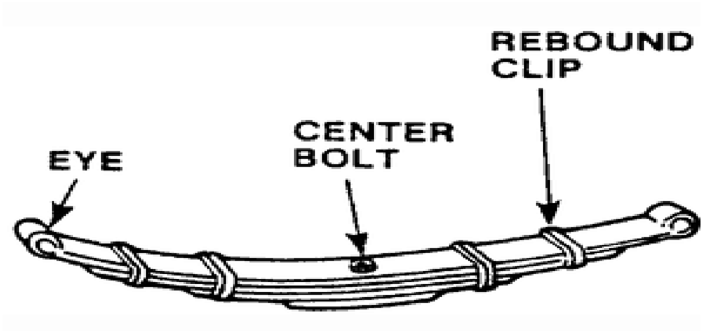
- **Energy absorption:** The spring's helical shape allows it to deform (compress or extend) under load, converting kinetic energy from bumps into stored potential energy.
- **Energy release:** Once the force is removed, the spring expands back to its original, uncompressed shape, releasing the stored energy.
- **Shock absorption:** By repeatedly compressing and expanding, the spring acts as a damper, absorbing the shock from road imperfections and isolating the car's body from harsh impacts.
- **Support and ride height:** Coil springs also provide the primary support for the vehicle's weight, determining its ride height and stability.
- **Dampening:** In most suspension systems, a shock absorber is paired with the coil spring to control and dampen the spring's movement, preventing the car from bouncing excessively after a bump.
- **Versatility:** The size, material, and configuration of coil springs can be tailored for different vehicles, from stiff springs for performance cars to heavy-duty springs for trucks and SUVs.



Leaf Spring

A leaf spring works by flexing and bending under load to absorb shocks, with its multiple stacked metal layers (leaves) absorbing energy when the vehicle encounters bumps. When a wheel hits an obstacle, the spring compresses, and the leaves slide against each other, which absorbs and dissipates the impact through friction and stored energy. A flexible connection called a shackle allows the spring to lengthen and contract smoothly as the suspension moves, preventing it from being too rigid.

- **Load absorption:** When a vehicle hits a bump, the wheel moves upward, compressing the leaf spring. The stacked, curved leaves are forced to bend further, acting like a simple beam that flexes under pressure.
- **Energy dissipation:** This flexing action stores energy in the spring. As the leaves slide against each other, friction occurs, which helps to dampen the shock and dissipate the energy, providing a smoother ride.
- **Flexibility:** One end of the spring is fixed, while the other is attached via a shackle, which is a hinged connection. This allows the length between the spring's mounting points to change as it flexes, preventing the spring from being overstressed.
- **Return to shape:** After the bump is passed, the stored energy is released as the spring returns to its original, slightly curved shape.
- **Structural connection:** In addition to providing suspension, the leaf spring also acts as a structural link, connecting the vehicle's frame directly to the axle. The axle is secured to the bottom of the spring with U-bolts.



Air Suspension

Air suspension works by using a compressor to pump air into flexible air springs (or airbags) to support the vehicle's weight and absorb shocks. Sensors monitor the vehicle's height, and a control unit adjusts the amount of compressed air in the springs to maintain a consistent ride height or to change the suspension stiffness for different driving conditions.

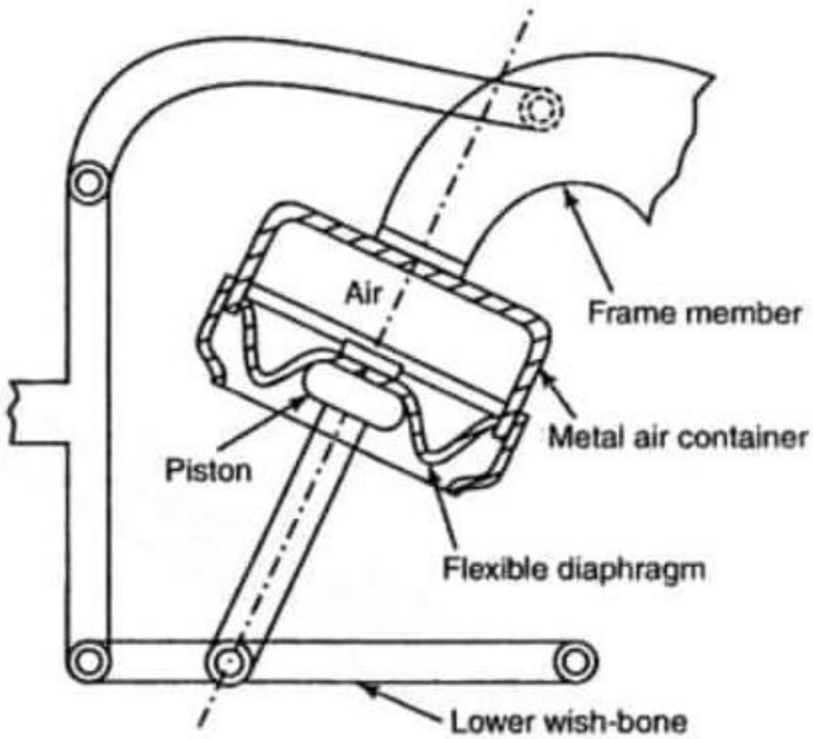
Key components and working process

- **Air compressor:** This is the heart of the system, drawing in atmospheric air and compressing it to a high pressure.
- **Air reservoir (accumulator):** A tank that stores the compressed air, providing a ready supply and reducing the need for the compressor to run constantly.
- **Air springs:** These are flexible, reinforced rubber bellows that replace traditional metal springs.
- **Height sensors and electronic control unit (ECU):** Sensors constantly measure the vehicle's height. The ECU uses this data to determine how much air to add or release from the air springs to maintain the desired ride height.
- **Lift control/leveling valves:** These valves direct the flow of compressed air from the reservoir to the air springs to inflate them, or release air from the springs back into the atmosphere to deflate them.

How the system operates

1. **Compression and storage:** The air compressor draws in air, filters it, and compresses it to a high pressure, storing it in the air reservoir.
2. **Height adjustment:**
1. When the vehicle's load increases, height sensors detect the drop. The ECU signals the valves to release compressed air from the reservoir into the air springs, which inflates them and lifts the vehicle back to its set height.
2. When the load is removed, the sensors detect the lift. The ECU signals the valves to release air from the springs, deflating them to lower the vehicle to the proper height.
3. **Shock absorption:** When the vehicle hits a bump, the compressed air inside the air springs absorbs and cushions the shock, providing a smoother ride than traditional springs.

4. **Stiffness control:** By adjusting the air pressure in the springs, the system can change the stiffness of the ride, from soft for comfort to firm for performance.



Torsion Bar

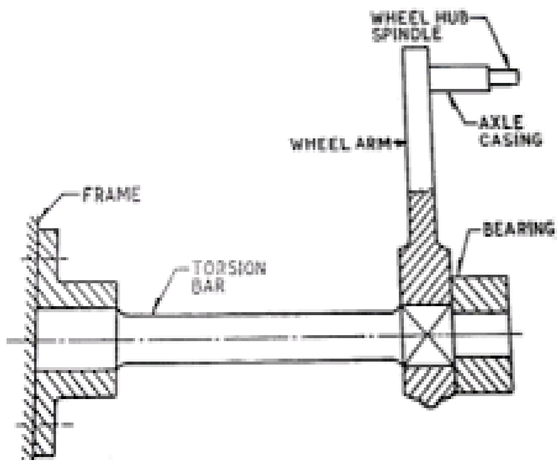
A torsion bar in an automobile acts as a spring, using a metal bar that twists to absorb shock. One end of the bar is fixed to the vehicle's chassis, while the other is connected to the suspension arm or axle via a lever. When a wheel hits a bump, the bar twists along its axis, and its resistance to this twisting motion provides the spring action to absorb the impact.

How it works

- **Anchored end**: One end of the torsion bar is rigidly attached to the vehicle's frame.
- **Lever arm**: The other end is connected to a lever (often called a torsion key) that is attached to the suspension arm or axle.
- **Twisting motion**: When the wheel moves up and down due to road irregularities, the suspension arm forces the lever to twist the bar along its length.
- **Spring force**: The bar's resistance to this twisting provides a spring force that absorbs the shock and returns the suspension to its original position.
- **Ride height adjustment**: The ride height of the vehicle can be adjusted by turning the torsion bar's lever, which changes the bar's preload.

Advantages of torsion bars

- Space efficiency
- Adjustability
- Durability
- Soft ride



Torsion Bar

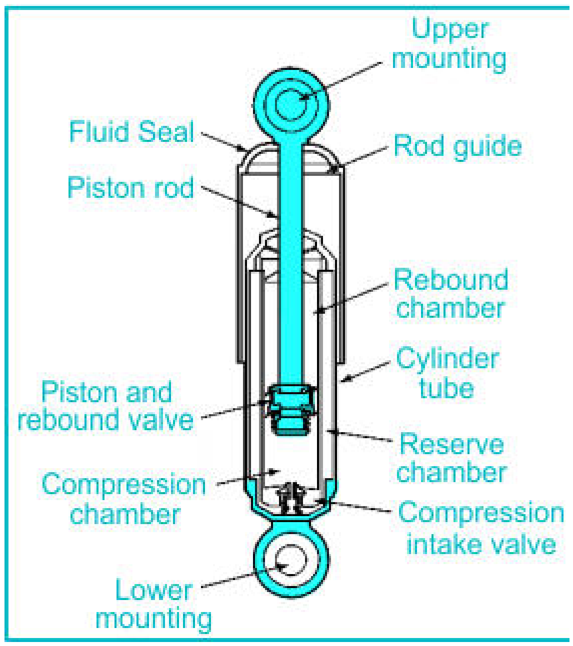
SHOCK ABSORBERS

Shock absorbers work by converting the kinetic energy of a vehicle's suspension into heat energy through hydraulic resistance. When a car hits a bump, the springs compress and then oscillate; the shock absorber, a hydraulic cylinder with a piston, resists this motion. The piston forces oil through small orifices (holes) in the piston, which creates a damping force that slows the oscillation and dissipates the energy as heat, ensuring the tires stay on the road for better control and a smoother ride.

Working principle

- **Energy conversion:** According to the principle of conservation of energy, shock absorbers convert the spring's kinetic energy (energy of motion) into heat energy.
- **Hydraulic resistance:** A shock absorber is an oil-filled cylinder containing a piston that moves up and down.
- **Damping action:** As the piston moves, it forces hydraulic fluid through small holes (orifices) in the piston. This flow resistance slows down the up-and-down movement of the suspension.
- **Heat dissipation:** The resistance from the fluid creates friction, which converts the mechanical energy into heat. This heat is then dissipated into the surrounding air.

- **Velocity-sensitive:** Shock absorbers are velocity-sensitive, meaning the faster the suspension moves (e.g., over a large bump), the more resistance the shock absorber provides, which ensures a more stable ride.



Unit 4
Wheels, Tyres and Braking System

Wheels consist of a metal rim and a hub, while tires are rubber components that fit onto the rim. The construction of a wheel provides the structural base, and the tire provides the necessary grip, cushioning, and contact with the road. The working principle is that the wheel converts the axle's rotary motion into the vehicle's linear motion, and the tire's properties allow for acceleration, braking, steering, and a comfortable ride by absorbing shocks and providing traction.

Construction

Wheel

- **Rim:** The outer circular part of the wheel that holds the tire.
- **Hub:** The central part of the wheel that is attached to the axle, which allows the wheel to rotate.
- **Materials:** Wheels are typically made of steel or aluminum alloys and can be made by casting or forging.

Tire

- **Bead:** A wire ring that provides a tight seal with the rim to keep the tire in place.
- **Carcass/Casing:** The main body of the tire, made of multiple layers of cord fabric (plies) bonded with rubber to provide strength and flexibility.
- **Sidewall:** The side of the tire that protects the carcass from damage and contains important information like size and load rating.
- **Tread:** The part of the tire that is in contact with the road, designed for grip and to resist wear.
- **Liner:** For tubeless tires, an inner liner is used to keep air inside the tire.

Working Principle

- **Support:** The wheel and tire assembly supports the vehicle's weight and keeps it in contact with the road.
- **Movement:** When the axle rotates, the wheel and tire rotate with it, and the friction between the tire's tread and the road surface converts the rotary motion into forward or backward motion for the vehicle.
- **Traction and Control:** The tire's tread provides the necessary friction for acceleration, braking, and steering. The steering system uses the wheel to change the vehicle's direction.
- **Cushioning:** The inflated tire acts as a shock absorber, flexing to absorb impacts from the road surface and providing a more comfortable ride.
- **Sealing:** For tubeless tires, a specially designed rim with a "hump" ensures that the tire's bead seals tightly against the rim to prevent air loss. A valve is used to inflate the tire.

Wheels and tyres work by converting rotational motion into linear motion, supporting the vehicle's weight, and providing grip for acceleration, braking, and steering. The tyres are flexible, air-filled cushions that absorb road shocks, creating a smoother ride, while the wheel, a rotating disc or spokes, translates the power from the axle into the vehicle's movement and allows for directional changes.

Function of tyres

- **Support:** Tyres bear the entire weight of the vehicle and its cargo.
- **Cushioning:** The air inside the tyre acts as a cushion to absorb shocks and vibrations from the road surface, providing a comfortable ride.
- **Traction:** The tread on the tyre provides the necessary friction to grip the road, allowing the vehicle to accelerate, brake, and turn without skidding.
- **Steering:** When the vehicle steers, the tyres generate the lateral forces needed for the vehicle to change direction.
- **Braking:** Tyres are essential for braking, as their contact with the road surface dissipates the vehicle's kinetic energy.

Function of wheels

- **Motion:** Wheels convert the rotational motion of the axle into the forward motion of the vehicle.
- **Support:** The wheel assembly supports the vehicle's weight and is the point of contact with the road.
- **Load transfer:** Wheels transmit the forces from braking and cornering to the rest of the vehicle.
- **Steering:** Front wheels are designed to pivot, allowing them to steer the vehicle.
- **Power transmission:** Rear wheels are used to transmit driving power from the engine to the road.

Key differences and interaction

- The **wheel** is a strong, rigid structure (typically made of steel or aluminum) that holds the tyre and rotates on an axle.
- The **tyre** is the flexible, rubber component mounted onto the wheel rim that is responsible for the direct contact with the road surface and provides crucial functions like cushioning and traction.

Types of Wheels

The main types of automobile wheels are steel, alloy, and forged, each with different characteristics for cost, durability, and performance. Steel wheels are strong, cheap, and durable, while alloy wheels are lighter, improving handling and fuel economy. Forged wheels are exceptionally strong and lightweight for high-performance applications, and chrome is a finish applied to other wheel types.

Steel wheels

- **Description:** Made from steel, they are a strong and heavy option often found on entry-level vehicles.
- **Pros:** Durable, cost-effective, and easy to repair.
- **Cons:** Heavy, which can impact fuel efficiency and performance.

Alloy wheels

- **Description:** Made from a mixture of metals like aluminum and magnesium. They are a very popular choice for their weight and design options.
- **Pros:** Lighter than steel, which can improve handling and fuel economy.
- **Cons:** Can be more prone to cracking or bending than steel wheels.

Types:

- **Cast alloy wheels:** Made by pouring molten alloy into a mold. They offer many design options at a lower cost.
- **Forged alloy wheels:** Made by applying high pressure to a solid block of alloy. They are stronger and lighter than cast wheels but are also more expensive.

Other types and finishes

- **Carbon fiber rims:** Extremely lightweight and strong, but very expensive and used in high-performance and racing applications.
- **Chrome wheels:** This is a shiny chrome plating finish applied over steel or alloy wheels, not a material itself.
- **Multi-piece wheels:** Consist of multiple separate pieces (often two or three) bolted together, allowing for custom widths, offsets, and designs.
- **Split rims:** Similar to multi-piece wheels, these are made of two or more pieces that are bolted together, making them easier to repair.

Tyres Types

Tyres work by using friction and air pressure to transmit the vehicle's forces to the road, while also acting as a shock absorber for a comfortable ride. They support the vehicle's load and convert the engine's power into motion, enabling acceleration, braking, and steering. Key functions include providing traction, cushioning impacts from the road, and maintaining contact with the ground to allow control.

Working principle

- **Load support:** The air inside the tyre is compressed, and the tire deforms to balance the vehicle's weight. This is why proper tyre pressure is crucial; incorrect pressure affects the vehicle's ability to carry its load.
- **Traction and friction:** The tread pattern creates friction with the road surface, which is what allows the tyres to transmit forces for acceleration, braking, and steering without skidding.
- **Cushioning:** Pneumatic tyres act as air-filled cushions, absorbing high-frequency vibrations and shocks from road irregularities to provide a smoother ride.
- **Steering:** When a car turns, the tyre tread deflects slightly, creating a "slip angle" that generates the lateral force needed to turn the vehicle.
- **Power transmission:** The tyre's rotation converts the engine's angular velocity into the car's linear travel speed, moving the vehicle forward.

Types of tyre construction

- **Radial tyres:** The most common type today, radial tyres have plies that run straight across from bead to bead, providing a stable and flexible footprint for better handling and durability.
- **Cross-ply tyres:** In this older design, plies run diagonally across the tyre and are layered at alternating angles, creating a less stable and more rigid tyre than a radial.

- **Tubeless tyres:** These tyres have an integrated air-retaining liner and a bead that creates a seal against the rim, eliminating the need for an inner tube. They are safer as they lose air more slowly in the event of a puncture.
- **Tube-type tyres:** These require a separate inner tube to hold the air, with a valve stem passing through the rim for inflation.
- **Run-flat tyres:** These are designed with reinforced sidewalls or internal support structures that allow the vehicle to be driven for a limited distance at a reduced speed after a complete loss of air pressure.

Specification

Wheel specifications in automobiles include **diameter, width, offset, bolt pattern (PCD), and load rating**. These factors determine how the wheel fits and performs, influencing handling, ride comfort, and safety. Key details like diameter and width are measured in inches, while offset and bolt circle diameter (PCD) are measured in millimeters.

Key wheel specifications

- **Diameter:** The overall size of the wheel, measured in inches from one outer edge to the opposite side.
- **Width:** The distance between the inner and outer rim edges, also measured in inches.
- **Offset:** The distance from the wheel's mounting surface to its centerline, measured in millimeters.
    - **Positive offset:** The mounting surface is closer to the outside of the wheel (inboard).
    - **Negative offset:** The mounting surface is closer to the inside of the wheel (outboard).
- **Bolt Pattern (PCD):** The number of bolts and the diameter of the imaginary circle passing through the center of the bolt holes. For example, a $5x114.3$ pattern means there are 5 bolts on a circle with a diameter of 114.3 mm.
- **Load Rating:** A numerical code that corresponds to the maximum weight the wheel can safely support, often found on the tire's sidewall.

Tyre Specifications

Automobile tyre specifications are a code of numbers and letters on the sidewall, such as **205/55 R16 91V**. This code indicates the tyre's **width** (205mm), **aspect ratio** (55%, which is the sidewall height as a percentage of the width), **construction type** (R for radial), **rim diameter** (16 inches), and a combination of **load index** (91) and **speed rating** (V).

How to read the code (e.g., 205/55 R16 91V)

- **205:** The width of the tyre in millimeters, from sidewall to sidewall.
- **55:** The aspect ratio, which is the sidewall height as a percentage of the tyre's width. A 55% aspect ratio means the sidewall is 55% of 205mm high.

- **R:** The construction type. 'R' stands for radial, the most common type for passenger cars.
- **16:** The diameter of the wheel rim that the tyre fits, in inches.
- **91:** The load index, which is a numerical code representing the maximum load the tyre can carry. For example, index 91 corresponds to a maximum load of 615 kg per tyre.
- **V:** The speed symbol, which indicates the maximum speed the tyre can handle. 'V' is a speed rating for a maximum speed of 240 km/h (149 mph).

TYRE WEAR AND CAUSES

Tyre wear in automobiles is caused by improper inflation, wheel misalignment, and suspension issues, as well as aggressive driving habits and a lack of maintenance. These factors can lead to uneven wear, such as wear on the center, edges, or shoulders of the tire, or general premature wear and tear.

Causes of Tyre Wear

- Improper inflation
  - Underinflation
  - Overinflation
- Wheel misalignment:
- Suspension issues:
- Driving habits:
- **Lack of maintenance:**
  - Tire rotation
  - Unbalanced wheels
- Other factors
  - Overloading
  - Road conditions
  - Age and environmental exposure

BRAKES

In automobiles, brakes are friction-based mechanical devices used to slow down or stop a moving vehicle by converting its kinetic energy into thermal energy. The heat generated during this process is then dissipated into the atmosphere. A wide range of braking systems exists, and they can be classified based on their operating mechanism, structural design, and function.

Classification by operating mechanism

This classification is based on how the braking force is transmitted from the brake pedal to the wheel.

- **Mechanical braking system:** An older, simpler system that uses physical linkages such as rods, levers, and cables to transfer the force from the brake pedal to the brakes at the wheels. Due to their lower efficiency, these are now primarily used for parking or emergency brakes.
- **Hydraulic braking system:** The most common system in modern cars and light trucks, based on Pascal's principle. When the driver presses the brake pedal, it pressurizes brake fluid in a master cylinder, and this fluid pressure is then transmitted through brake lines to activate the brake components at each wheel.
- **Pneumatic (air) braking system:** Used mainly in heavy vehicles like trucks and buses, this system uses compressed air to apply the brakes. When the pedal is pressed, it releases pressurized air from a reservoir into a brake chamber at each wheel to create the braking force.
- **Vacuum (servo) braking system:** This system uses a vacuum from the engine's intake manifold to amplify the force a driver applies to the brake pedal. This provides more powerful braking with less physical effort and is standard in most passenger cars.
- **Electromagnetic braking system:** Used in trains and some electric or hybrid vehicles, this system uses magnetic force to generate resistance and slow down a vehicle without contact or friction.
- **Electric braking system:** Found in electric and hybrid vehicles, this is also known as regenerative braking. The electric motor switches to generator mode during braking, converting the vehicle's kinetic energy back into electrical energy and storing it in the battery.

Classification by structural design

This classification is based on the type of friction-generating components installed at the wheels.

- **Disc brakes:** The most common type of brake on modern vehicles, often used on the front wheels for their superior stopping power and heat dissipation.
    - **Mechanism:** When the driver presses the brake pedal, a caliper squeezes brake pads against a flat, rotating disc (or rotor) connected to the wheel, causing friction.
- **Drum brakes:** An older and less expensive technology, still used on the rear wheels of many smaller cars.
    - **Mechanism:** When activated, a wheel cylinder forces two curved brake shoes outwards against the inner surface of a hollow rotating drum, creating friction.
- **Emergency or parking brakes:** Also known as the handbrake, this is a separate, mechanically operated system that is used to keep the vehicle stationary when parked. It typically works on the rear wheels through a cable mechanism.

Classification by application

This is a functional classification based on the brake's intended use.

- **Foot or service brakes:** These are the primary brakes used for normal, everyday driving and are operated by the brake pedal.
- **Hand or parking brakes:** A secondary, mechanical system used to hold the vehicle in place when parked.
- **Anti-lock braking system (ABS):** An advanced safety feature, ABS uses sensors to prevent the wheels from locking up during sudden or hard braking. By rapidly modulating brake pressure, it helps the driver maintain steering control and avoid skidding.

Needs and functions of automobile brakes

- **Stopping and slowing down:** The primary function is to safely slow down the vehicle or bring it to a complete stop. This is achieved through the hydraulic braking system, where pressing the brake pedal forces brake fluid through brake lines to the wheels.
- **Holding the vehicle stationary:** A separate parking (or emergency) brake is needed to keep the vehicle from rolling when parked, especially on inclines.
- **Safety:** Brakes are a critical safety feature, and a well-maintained system is essential for preventing accidents and protecting occupants.

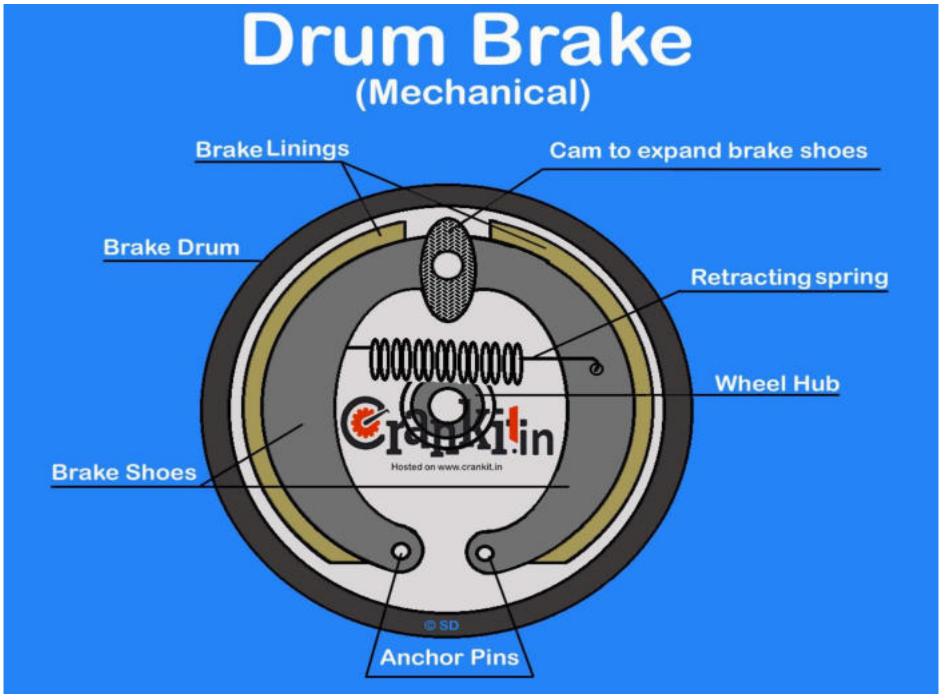
Drum Brake System

A mechanical drum brake works by using a cable or rod to expand brake shoes against the inside of a rotating drum when the brake pedal is pressed. This creates friction, which slows the wheel and ultimately the vehicle. When the pedal is released, return springs pull the shoes back, allowing the drum to spin freely again.

How it works

1. **Initial force**: When the brake pedal is pressed, it pulls a connected cable or linkage.
2. **Shoe expansion**: This linkage is connected to a cam or lever system that pushes the two semicircular brake shoes outward.
3. **Friction and slowing**: The brake shoes, which are lined with friction material, press against the inner surface of the rotating brake drum. This friction converts the wheel's kinetic energy into heat, slowing the wheel down.
4. **Releasing the brake**: When the brake pedal is released, the tension on the cable decreases.
5. **Return to normal**: Return springs pull the brake shoes back to their original position, away from the drum.

6. **Free rotation**: This creates a small gap between the shoes and the drum, and the wheel is free to spin again.



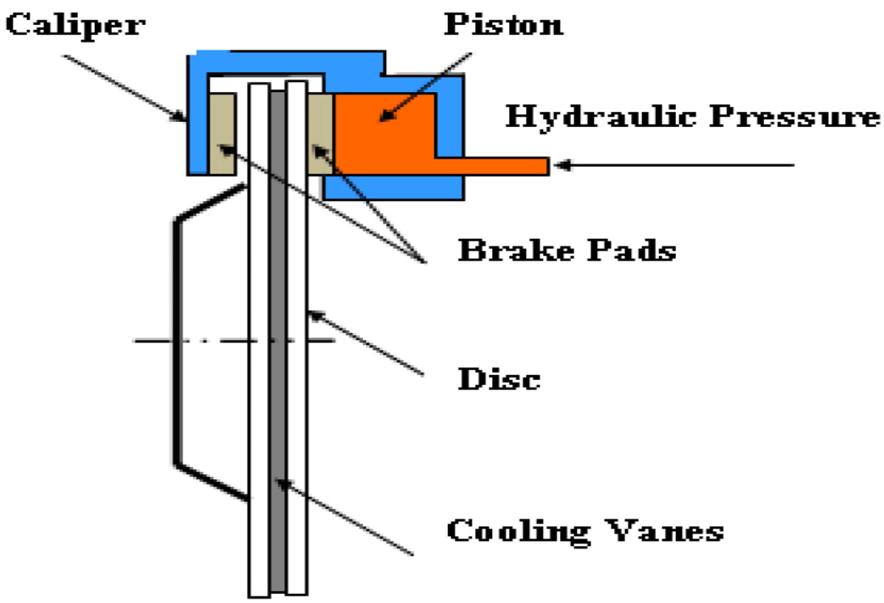
Disc Brake

A disc brake works by using a hydraulic system to press brake pads against a spinning disc (rotor) attached to the wheel, converting the vehicle's kinetic energy into heat through friction. When the brake pedal is pressed, hydraulic fluid forces pistons to clamp the pads against the rotor, slowing the wheel's rotation. When the pedal is released, the pistons retract, and the pads pull away, allowing the wheel to spin freely again.

The process of disc brake operation:

- **Brake pedal application:** The driver presses the brake pedal, which initiates the process by activating a master cylinder.
- **Hydraulic fluid pressure:** The master cylinder sends high-pressure brake fluid through brake lines to the brake caliper.
- **Caliper and piston action:** The hydraulic pressure forces one or more pistons inside the caliper to move.
- **Friction pad engagement:** These pistons push the brake pads firmly against both sides of the spinning rotor.
- **Energy conversion:** The friction generated between the brake pads and the rotor converts the wheel's kinetic energy into thermal energy (heat), which slows the vehicle down.

- **Brake pedal release:** When the driver releases the pedal, the hydraulic pressure is released. The pistons retract, the brake pads move away from the rotor, and the wheel is free to spin again.



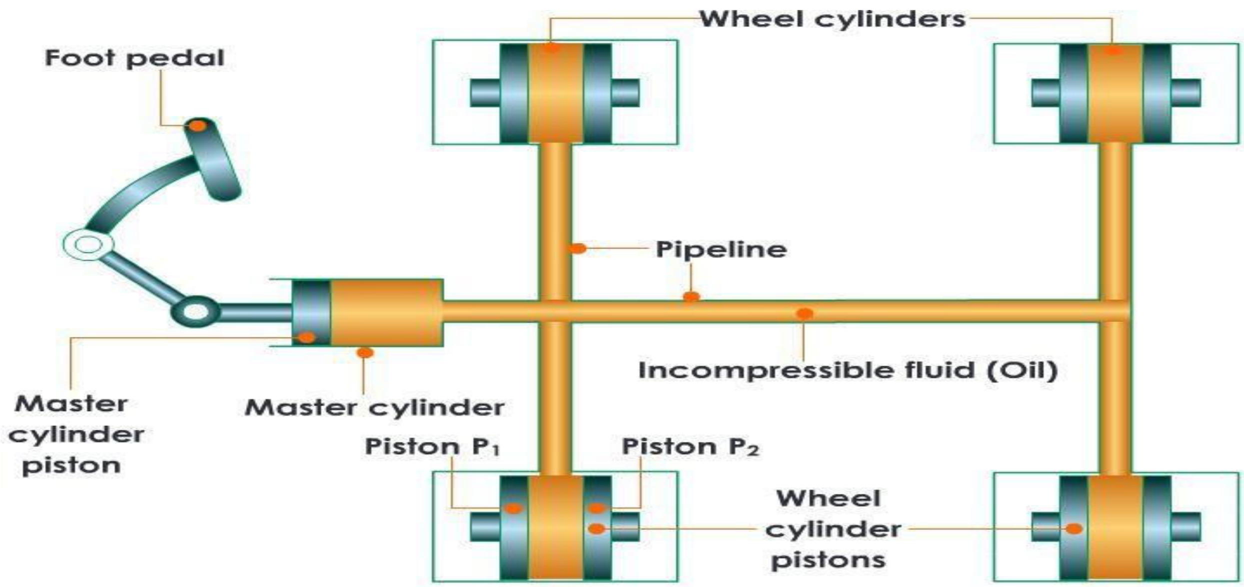
Hydraulic Brake System

Hydraulic brakes use an incompressible fluid to transfer force from the brake pedal to the wheels, converting the mechanical force of the driver's foot into hydraulic pressure, which then operates the brake pads or shoes against rotors or drums to slow the vehicle. This system works on Pascal's Law, which states that pressure applied to an enclosed fluid is transmitted equally in all directions. When the brake pedal is pressed, the master cylinder creates pressure in the brake lines, which forces pistons in the wheel cylinders or calipers to actuate the brake mechanisms, creating friction to stop the car.

How hydraulic brakes work:

- **Applying the brake pedal:** When the driver presses the brake pedal, it pushes a piston inside the master cylinder.
- **Creating hydraulic pressure:** The master cylinder, which is filled with brake fluid, creates hydraulic pressure. This pressure is then transmitted equally through the brake lines to the wheels, thanks to Pascal's Law.
- **Actuating the brakes:** The brake lines lead to the wheel cylinders or calipers, which contain pistons.
- **Generating friction:** This hydraulic pressure pushes the pistons in the wheel cylinders or calipers outward. These pistons then force the brake pads to clamp down on the rotating brake rotors or push the brake shoes against the brake drums.

- **Slowing the vehicle:** The friction created between the brake pads and rotors (or brake shoes and drums) converts the vehicle's kinetic energy into heat, slowing down the wheels and the vehicle.
- **Releasing the brake pedal:** When the pedal is released, the pressure is relieved, and springs return the master cylinder piston and the wheel/caliper pistons to their original positions, releasing the brake pads or shoes from the rotors or drums.



Pneumatic Brake System

Pneumatic brakes use compressed air to create friction for stopping a vehicle, and are common in heavy vehicles like trucks and buses. When the brake pedal is pressed, the driver's brake valve allows compressed air to flow from a reservoir to brake chambers at each wheel. This air pressure pushes pistons, which in turn activate brake pads against the brake drums, slowing the vehicle.

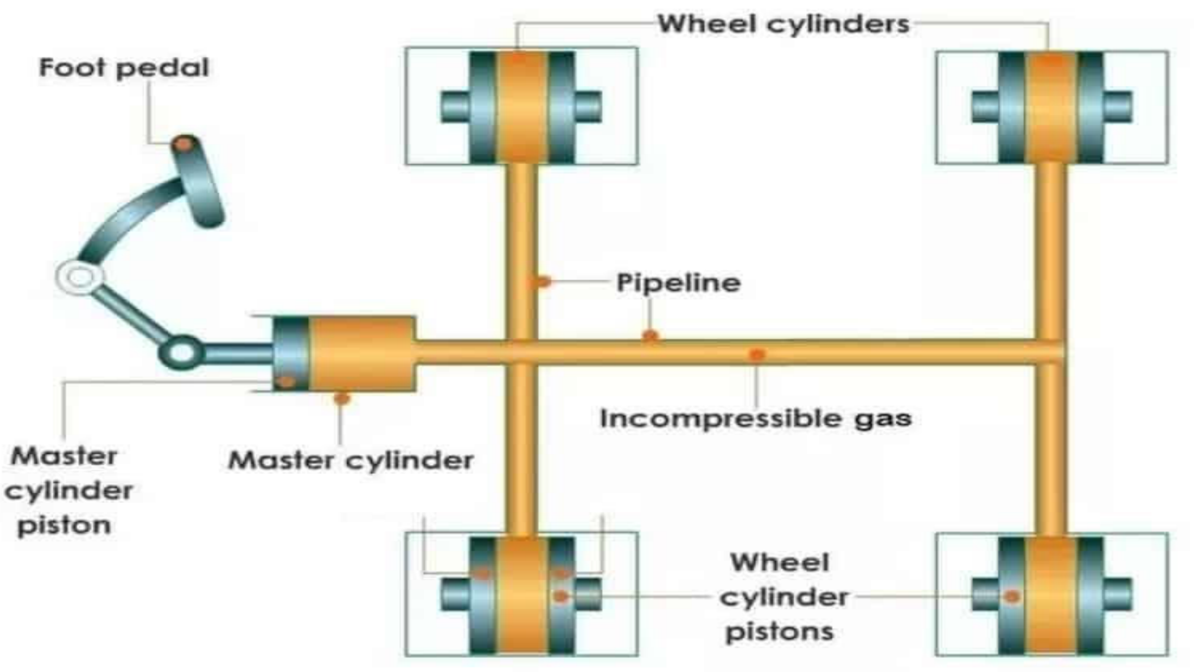
Working principle

1. **Air compression**: An engine-driven air compressor draws in atmospheric air, filters it, and compresses it to high pressure.
2. **Air storage**: The compressed air is stored in a high-pressure air reservoir, which is also used to supply other pneumatic systems on the vehicle.
3. **Brake pedal application**: When the driver presses the brake pedal, it operates a brake valve.
4. **Air release**: The brake valve opens a path for the stored compressed air to flow through brake lines to the brake chambers at each wheel.
5. **Braking action**: Inside the brake chamber, the air pressure pushes a piston and a pushrod, which activates the mechanical brake components (like brake shoes or pads) to press against the rotating wheel drums or discs.

6. **Friction and stopping**: The friction generated between the brake pads and the drums or discs slows the vehicle down.
7. **Brake release**: When the driver releases the brake pedal, the air pressure is released from the brake chambers. A return spring pushes the piston back, disengaging the brakes.

Key components

- **Air Compressor**: Compresses atmospheric air.
- **Air Reservoir**: Stores the compressed air.
- **Brake Valve**: Controlled by the driver's foot pedal to regulate air flow to the brakes.
- **Brake Chamber**: A cylinder at each wheel that converts air pressure into mechanical force.
- **Brake Drum/Disc**: The rotating part of the wheel assembly.
- **Brake Pads/Shoes**: The friction material that is pressed against the drum or disc.

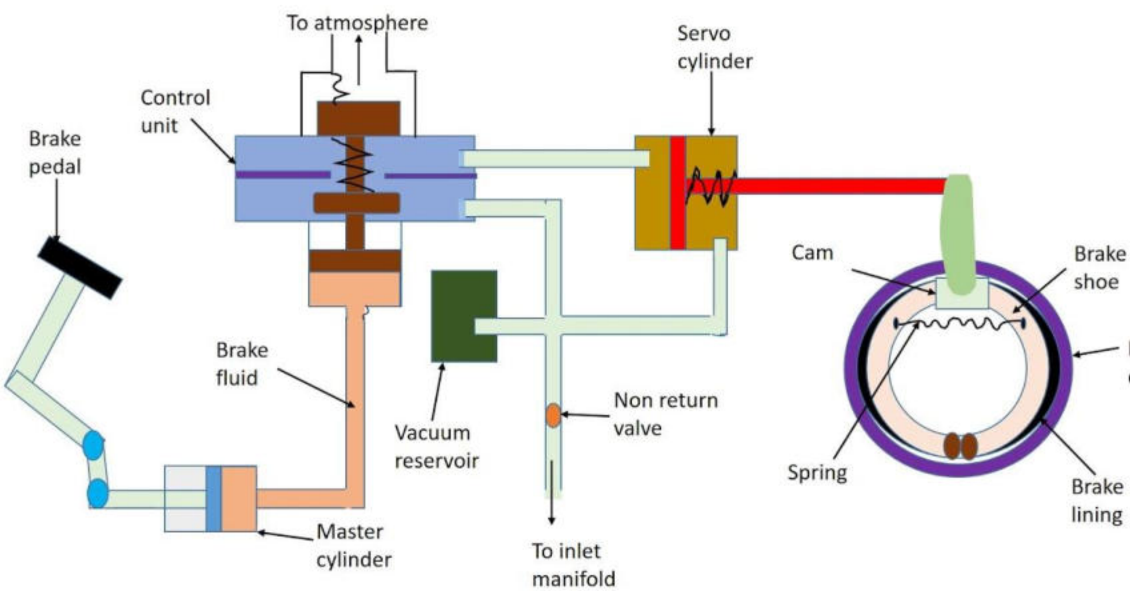


Vacuum Assist Brake System

A vacuum-assist brake system works by using engine vacuum to amplify the force the driver applies to the brake pedal. When the pedal is pushed, a valve opens to allow atmospheric air pressure to enter one side of a diaphragm, while a vacuum is maintained on the other side. This pressure difference pushes the diaphragm and a connected pushrod, multiplying the force that is transmitted to the master cylinder to engage the brakes.

How it works

- **Vacuum source:** The engine's intake manifold (in a gasoline engine) or a vacuum pump (in a diesel engine) provides a constant vacuum to one side of a brake booster chamber.
- **Booster chamber:** This chamber is separated by a large diaphragm into a vacuum chamber and a pressure chamber.
- **Brake pedal application:** When the driver presses the brake pedal, it opens a valve that closes the connection to the vacuum source and simultaneously lets atmospheric air into the pressure chamber on the other side of the diaphragm.
- **Force multiplication:** The pressure differential between the vacuum side and the atmospheric pressure side pushes the diaphragm, amplifying the force applied to the pushrod that is connected to the master cylinder.
- **Braking:** The amplified force from the pushrod activates the master cylinder, which then sends hydraulic pressure to the brake calipers or wheel cylinders to apply the brakes.
- **Brake release:** When the driver releases the pedal, the valve closes the air inlet, and vacuum re-establishes on both sides of the diaphragm, returning the system to its ready state.



Retarders

Retarders are auxiliary braking systems in vehicles that use mechanisms like hydraulic, electromagnetic, or engine compression to slow a vehicle down without using traditional friction brakes. They work by converting the vehicle's kinetic energy into heat or by creating resistance in the drivetrain, which helps prevent brake fade and reduces wear on the main braking system, especially on long descents.

How retarders work

- **Hydraulic retarders:** These are the most common type, integrated into the transmission. When activated, they use internal vanes and a fluid (like transmission fluid or a separate oil supply) to create resistance. As the fluid is forced to move through a chamber by the rotating vanes, it creates drag that slows the vehicle down. The kinetic energy is converted to heat, which is then typically dissipated through the vehicle's cooling system.
- **Electromagnetic retarders:** These work using electromagnetic induction. They have a rotor and a stator. When the stator is energized, it creates a magnetic field that induces eddy currents in the rotor. These currents generate a force that opposes the rotor's movement, slowing the vehicle. The braking energy is converted into heat that dissipates into the atmosphere.
- **Engine retarders:** Also known as "Jake brakes," these use the engine itself to create resistance. They work by modifying the engine's normal exhaust cycle to create back pressure. The engine, instead of burning fuel, acts as a large air compressor, using its own energy to slow the vehicle down.
- **Exhaust brakes:** These are another engine-based type that are often less powerful than Jake brakes. They use a valve in the exhaust system to create backpressure, which slows the engine down and thus the vehicle.

Benefits of using retarders

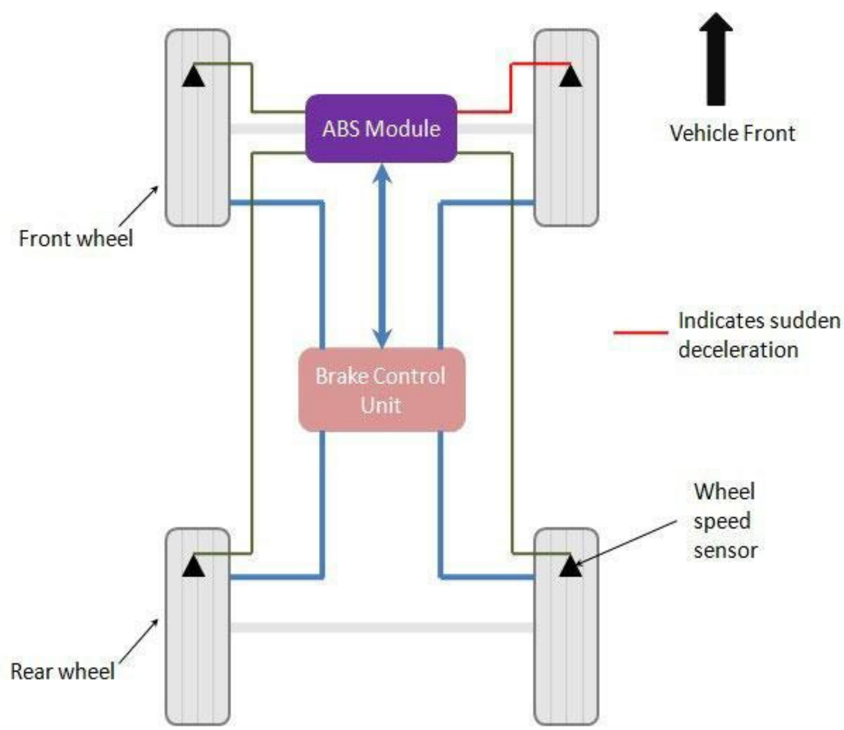
- **Reduced brake wear:** By handling a significant portion of the braking load, retarders decrease the use of friction brakes, extending their life.
- **Increased safety:** They help drivers maintain control on long descents by preventing the brakes from overheating, which can cause them to fail (brake fade).
- **Improved efficiency:** They allow for more consistent vehicle speed when going downhill, which can improve overall fuel efficiency.

Anti-Lock Braking System (ABS)

An automobile's Anti-Lock Braking System (ABS) works by rapidly pulsing the brakes to prevent wheels from locking up during hard braking, allowing the driver to maintain steering control. It achieves this using wheel speed sensors that detect when a wheel is about to lock, and an electronic control unit (ECU) that tells the hydraulic system to momentarily release and reapply pressure to that specific brake, repeating the process many times per second. This prevents skidding, which allows the driver to steer around an obstacle while braking hard.

How ABS works

- **Sensing:** Wheel speed sensors continuously monitor the rotation of each wheel.
- **Detection:** If the sensors detect that a wheel is slowing down too quickly and is about to lock up, they send a signal to the Electronic Control Unit (ECU).
- **Action:** The ECU signals a hydraulic control unit to reduce the brake pressure on that wheel. This is achieved by using valves to briefly reduce hydraulic pressure to the brake caliper.
- **Pumping:** The wheel begins to spin again. The ABS then reapplies pressure, and this release-and-reapply cycle happens hundreds of times per second, much faster than a human could pump the brakes.
- **Result:** The wheels continue to rotate, preventing the vehicle from skidding and allowing the driver to steer and maintain control.



UNIT-5

Automobile Electrical Systems and Advances in Automobile Engineering

Battery:

An automobile battery converts chemical energy into electrical energy to start the engine and power the vehicle's electrical systems. It is primarily a 12V lead-acid battery, consisting of six cells with lead plates submerged in a sulfuric acid electrolyte. When the engine is off, it powers all electronics; once running, the alternator recharges the battery while also supplying power to accessories and stabilizing voltage spikes.

Key functions

- **Starting the engine**:
  The battery provides the large amount of current needed to power the starter motor, which cranks the engine to life.
- **Powering electrical systems**:
  It supplies electricity to all of the car's electronic components, such as the headlights, radio, wipers, and climate control, especially when the engine is off.
- **Voltage stabilization**:
  The battery absorbs and stabilizes voltage spikes, preventing damage to sensitive electronics that can occur when a lot of energy is drawn or released by accessories.
- **Recharging**:
  The alternator recharges the battery as the engine runs. The battery provides additional power if the demand exceeds the alternator's output.

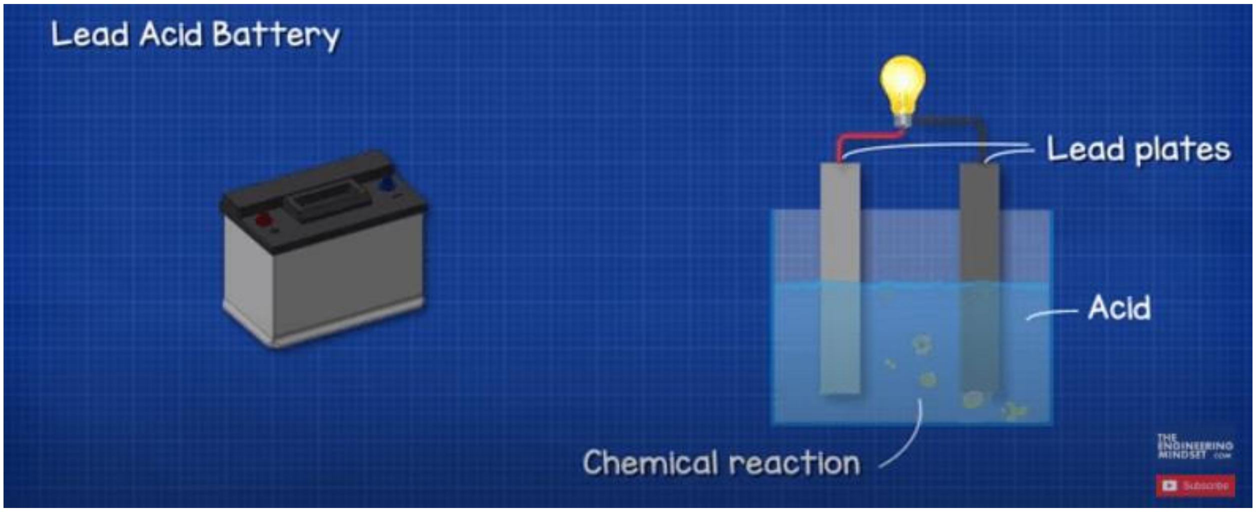
How it works

- **Chemical energy conversion**:
  The battery stores energy in chemical form. When a circuit is complete, a chemical reaction occurs between the lead plates and the sulfuric acid electrolyte.
- **Electron flow**:
  This reaction creates a flow of electrons from the negative terminal to the positive terminal, which is the direct current (DC) electricity that powers the vehicle.
- **Recharging**:
  The process can be reversed by supplying electricity from the alternator, which recharges the battery by reversing the chemical reaction.

Types of batteries

- **Lead-acid batteries**: The most common type. They can be "flooded," which requires maintenance like adding distilled water, or "sealed," which is maintenance-free and generally has a longer lifespan.

- **Lithium-ion batteries**: An alternative, though less common, type used in some modern cars.



General Automotive Electrical Circuit:

A general automotive electrical circuit diagram includes a power source (battery and alternator), a protection device (fuse or circuit breaker), a switch to control the circuit, the electrical load (like a light or motor), and a return path to ground, often the vehicle's chassis. These circuits can be complex but are a combination of basic circuits to perform functions like starting the engine, running lights, and powering accessories.

Key components of an automotive circuit

Power Source:

The car battery is the primary source, and the alternator charges the battery and powers the system when the engine is running.

Circuit Protection:

Fuses or circuit breakers are placed in the path to protect the circuit from overcurrent and short circuits.

Switch/Control:

A switch (like the ignition switch) or a control module (like a PCM) opens and closes the circuit, controlling when the power flows to the load.

Electrical Load:

This is the component that uses the electrical energy, such as a headlight, horn, starter motor, or sensor.

Ground:

The circuit needs a complete path for the current to flow back. In most modern cars, the negative side of the circuit is completed by connecting it to the vehicle's metal chassis, which serves as a common ground.

Example of a basic circuit: The Horn

- When the horn button is pressed, it closes a switch.
- This sends power from the fuse box through the switch to the horn relay.
- The relay, in turn, completes a separate, high-current circuit from the battery to the horn itself.
- The horn's ground is its physical connection to the car's chassis.

How to read a diagram

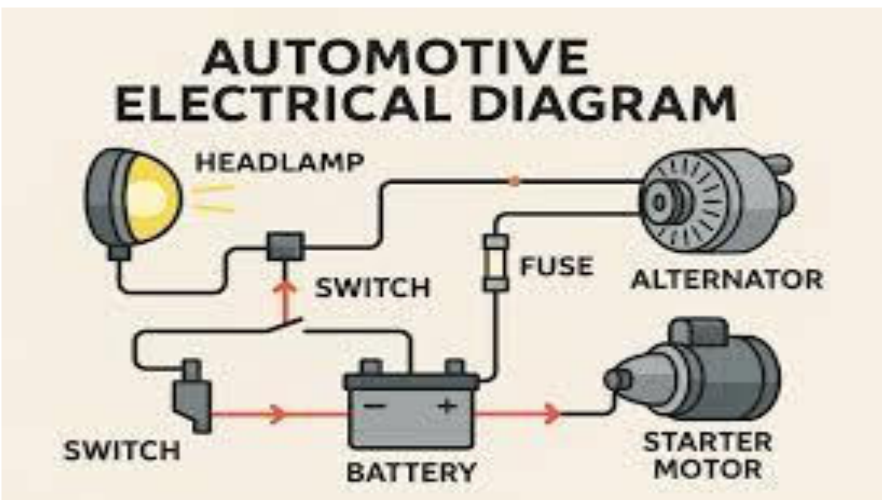
Start with the power source: Trace the path from a fuse (positive side) to the load.

Look for the load: Identify what the circuit powers, such as a light or motor.

Follow the return path: See where the circuit connects back to ground, which is usually the chassis.

Identify control points: Pay attention to switches, relays, and control modules that determine when the circuit is active.

Note symbols: Symbols for components and special connections (like splices, indicated by a dot) are crucial for understanding the exact layout.



Active Suspension System (ASS):

An Active Suspension System (ASS) uses sensors, a control unit, and actuators to actively adjust a vehicle's suspension for improved ride comfort, stability, and handling. It goes beyond passive systems by using actuators to adjust springs and dampers in real-time based on driving conditions, which can minimize body roll, nose dive, and vibrations from road imperfections. This is achieved through a continuous loop of sensing data, processing it, and sending commands to actuators to alter the suspension's stiffness or position.

How it works

Sensing:

Sensors monitor various vehicle and road conditions, such as wheel speed, acceleration, braking, and body movement.

Processing:

A central electronic control unit (ECU) analyzes the data from the sensors to determine the optimal suspension response.

Actuation:

The ECU sends commands to actuators, which are often hydraulically or pneumatically controlled, to make immediate adjustments to the suspension.

Adjustment:

These adjustments can involve:

Changing the stiffness of the shock absorbers.

Adjusting the position or height of the suspension.

Modifying the air springs or connecting/disconnecting sway bars.

Benefits

Improved handling:

By actively controlling body roll and maintaining tire contact with the road, it provides better stability and grip, especially during cornering.

Enhanced comfort:

It can significantly reduce the impact of bumps, potholes, and vibrations for a smoother and more comfortable ride.

Increased safety:

By minimizing unwanted body movements, it helps prevent skidding, reduces nose dive during braking, and provides a more stable platform.

Adaptability:

The system can adjust to different driving conditions, sometimes with user-selectable modes like "comfort" or "sport".

Types

Fully Active Suspension:

Uses actuators to control both the spring and damper forces, with the ability to both raise and lower the chassis independently at each wheel.

Adaptive or Semi-Active Suspension:

Adjusts the damping force (e.g., the firmness of the shock absorber) in response to changing road conditions but does not actively lift or lower the chassis.

Challenges

Complexity and cost:

Active suspension systems are more complex and expensive to manufacture than traditional suspension systems.

Power consumption:

Hydraulic actuators, in particular, can consume a significant amount of power.

Electronic Brakeforce Distribution (EBD)

Electronic Brakeforce Distribution (EBD) is a car safety feature that automatically adjusts the amount of brake force applied to each wheel based on road conditions, speed, and vehicle load. It works with other systems like the anti-lock braking system (ABS) to prevent wheel lock-up, shorten stopping distances, and improve steering stability by distributing the correct amount of force to each wheel, especially in emergency braking situations.

How it works

Speed sensors: Sensors on each wheel monitor their speed and the vehicle's overall speed.

ECU (Electronic Control Unit): The ECU receives data from the speed sensors to calculate the slip ratio (the difference between the wheel's speed and the vehicle's speed).

Brake force modulators: Based on the ECU's calculations, the modulators adjust hydraulic pressure to control the braking force applied to each wheel individually.

Key benefits

Shorter stopping distances:

By distributing brake force optimally, EBD helps reduce the distance needed to stop, especially in wet or dry conditions.

Improved stability:

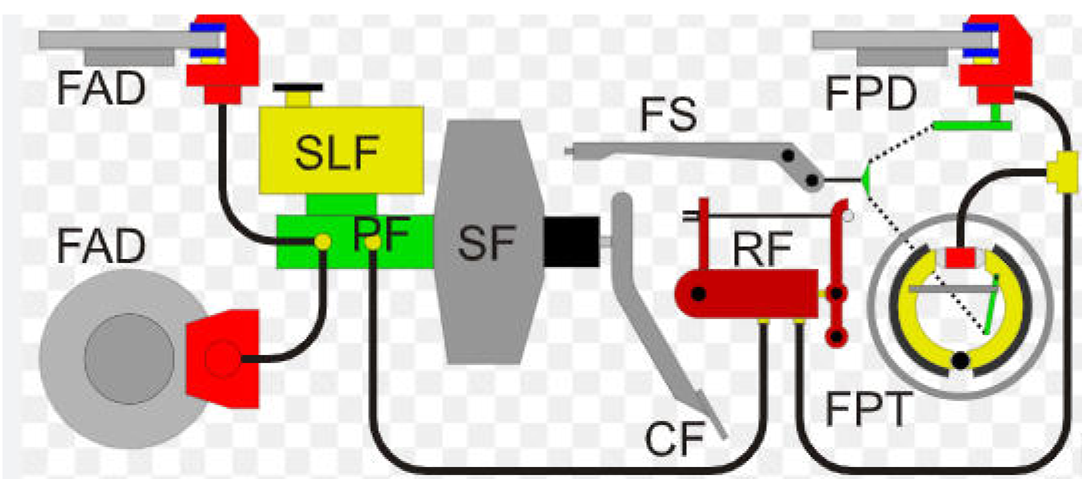
It helps prevent skidding and loss of control by ensuring the wheels have the best possible grip, even when braking during a turn or on a slippery surface.

Enhanced steering:

EBD helps maintain control during emergency maneuvers by applying the correct braking force to each wheel to improve handling.

Automatic adjustment:

It continuously adjusts brake force based on factors like how many passengers or how much luggage is in the car, which changes the vehicle's weight distribution.



Electronic Stability Program (ESP):

Electronic Stability Program (ESP), also known as Electronic Stability Control (ESC), is a safety feature that helps drivers maintain control of a vehicle during critical situations like skidding or swerving. It uses sensors to monitor the vehicle's intended path versus its actual movement and can intervene by applying brakes to individual wheels or reducing engine power to prevent loss of control. ESP integrates the functions of the anti-lock braking system (ABS) and traction control system (TCS) to improve stability.

Comparison of inputs:

ESP continuously compares the driver's steering input to the vehicle's actual motion, using sensors to measure factors like steering angle and yaw rate (the speed of rotation around the vertical axis).

Intervention:

If the system detects a discrepancy—for example, if the car is skidding or not following the intended path—it will intervene immediately.

Corrective action:

To correct the skid, ESP can apply the brakes to specific wheels to counteract the spin and reduce engine power to help the driver regain control.

Integrated systems:

ESP is built upon the foundation of ABS and Traction Control, managing both braking and engine power for more advanced stability control.

Additional functions

Hill hold control:

Prevents the vehicle from rolling backward when starting on an incline by briefly holding the brakes after the driver releases the brake pedal.

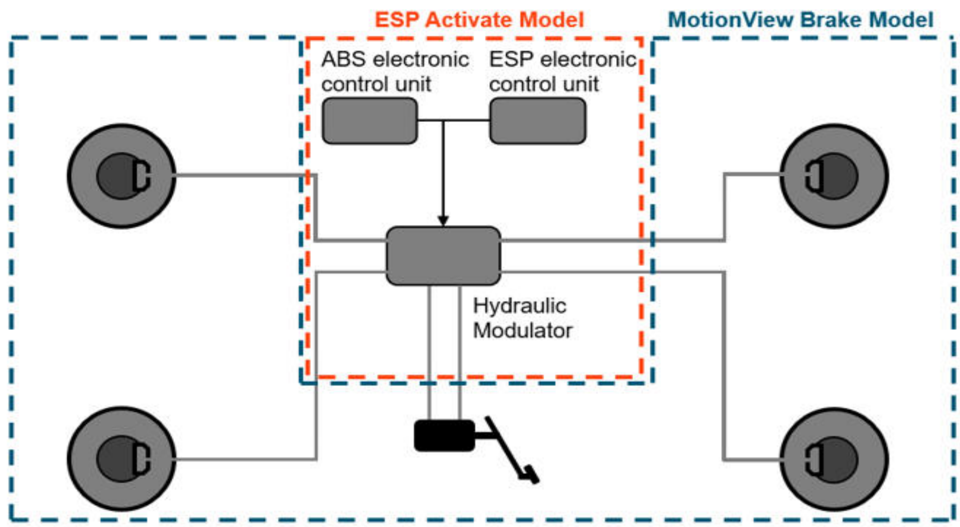
Rollover mitigation:

Helps prevent rollovers in vehicles with a high center of gravity by applying brakes and adjusting engine power.

When to use ESP

ESP should generally be left on for normal driving, as it is always working to enhance safety.

You might consider turning it off in specific situations like driving on a track or in very deep snow or mud where you want to maximize wheel spin and traction.



TRACTION CONTROL SYSTEM (TCS):

A traction control system (TCS) is an electronic safety feature that helps prevent a vehicle's wheels from spinning during acceleration, especially on slippery surfaces like snow, ice, or rain. It works by monitoring wheel speed and, if it detects one or more wheels spinning too fast, it automatically applies the brakes to that wheel or reduces power from the engine. This helps maintain stability, improve control, and enhance safety by ensuring the tires have the best possible grip on the road.

Monitors wheel speed:

TCS uses the same wheel speed sensors as the anti-lock braking system (ABS).

Detects loss of traction:

If the sensors detect a difference in wheel speed, it indicates a loss of grip.

Takes action:

The system can either:

Automatically apply the brake to the spinning wheel.

Reduce the engine power sent to the spinning wheel.

Maintains stability:

By correcting wheel spin, TCS helps keep the vehicle stable and in its intended path, preventing skidding.

When it is useful

Driving on slippery surfaces like snow, ice, or rain.

Navigating sharp turns, especially on wet or gravel roads.

Accelerating quickly from a stop.

Global Positioning System (GPS):

The Global Positioning System (GPS) is a satellite-based navigation system that provides real-time, 3D positioning, velocity, and time information anywhere on Earth. It consists of three segments: a space segment (satellites orbiting Earth), a control segment (ground stations to monitor and control the satellites), and a user segment (GPS receivers in devices like smartphones or dedicated devices). By receiving signals from at least four satellites, a receiver can calculate its precise location by measuring the time it takes for the signals to arrive.

Components and operation

Space Segment:

A constellation of satellites that continuously orbit Earth and broadcast navigation signals.

Control Segment:

Ground stations that track the satellites, ensuring they are in their correct orbits and that the signals are accurate.

User Segment:

The receiver device (e.g., in your phone or car) that picks up the satellite signals to calculate its position, velocity, and time.

How it works

1. **Signal Transmission:**

   Satellites transmit signals containing their position and the precise time.
2. **Signal Reception:**

   The GPS receiver on the ground receives these signals from multiple satellites.
3. **Distance Calculation:**

   The receiver calculates the distance to each satellite based on the time it took for the signal to arrive.
4. **Triangulation:**

   By knowing its distance from at least four satellites, the receiver can determine its exact three-dimensional location through a process called trilateration.

Common uses

Navigation: Guiding cars, boats, and aircraft to a destination.

Location Services: Providing location-based information on smartphones for apps like maps and ride-sharing services.

Surveying and Mapping: Used in science and other fields for precise land mapping.

Time Synchronization: Providing highly accurate time information for various applications.

HYBRID VEHICLE:

A hybrid vehicle is a car that uses both an internal combustion engine (like gasoline) and an electric motor for propulsion, combining two power sources to improve fuel efficiency. There are several types, including strong hybrids and mild hybrids, which recharge their batteries while driving, and plug-in hybrids (PHEVs), which can be charged from an external power source for a longer electric-only range.

How they work

Dual power sources:

A hybrid system seamlessly switches between or combines the gas engine and electric motor based on driving conditions and speed to optimize performance and efficiency.

Battery and engine:

A small, high-voltage battery powers the electric motor. The battery can be self-charged by the gas engine, or through regenerative braking (capturing energy from braking).

Plug-in option:

Plug-in hybrids have a larger battery that can be charged by plugging into an electrical outlet, allowing for a longer electric-only driving range before the gas engine is needed.

Types of hybrid vehicles

Mild hybrids:

Self-charging or strong hybrids:

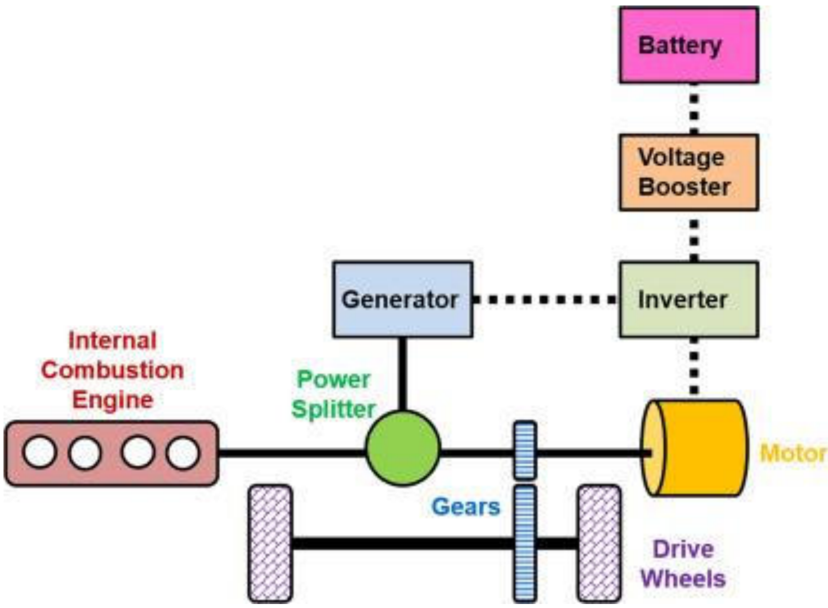
These are the most common type. The system uses the gas engine and an electric motor with a battery to drive the wheels. The battery is charged by the engine and by capturing energy during braking.

These have a smaller electric motor and battery that primarily assist the gas engine during acceleration or when starting from a stop. They are not capable of driving on electric power alone.

Plug-in hybrids (PHEVs):

These have a larger battery that can be charged by plugging in, giving them a more substantial all-electric driving range before the gas engine kicks in.

Examples of hybrid vehicles
Maruti Grand Vitara, Toyota Urban Cruiser Hyryder, Honda City e:HEV, Toyota Innova Hycross, and Toyota Camry Hybrid.



Fuel cells

Fuel cells are devices that convert chemical energy from a fuel into electricity through a direct electrochemical process, rather than combustion. They consist of two electrodes (an anode and a cathode) and an electrolyte, and require a continuous supply of fuel, like hydrogen, and an oxidant, like oxygen, to produce power, heat, and water. Unlike batteries, they do not run down or need recharging as long as fuel is supplied

How they work

Electrochemical reaction:

Fuel (e.g., hydrogen) is fed to the anode, and oxygen is fed to the cathode.

Electron flow:

The fuel reacts at the anode, producing electrons and ions. The electrons flow through an external circuit, creating an electric current, while the ions pass through the electrolyte.

Oxidation:

The ions, electrons, and oxygen combine at the cathode to form water, and the cycle repeats.

Continuous power:

Because fuel is continuously supplied, fuel cells can operate as long as there is a fuel source.

Key characteristics and benefits

Efficient:

Fuel cells are more energy-efficient than combustion engines.

Clean:

When using pure hydrogen, the only byproducts are heat and water, making them a clean energy source.

Versatile:

They can be used for a variety of applications, from powering vehicles to providing electricity for buildings.

Low maintenance:

They have fewer moving parts than combustion generators, leading to lower operational costs.

Types of fuel cells

Phosphoric Acid Fuel Cells (PAFC):

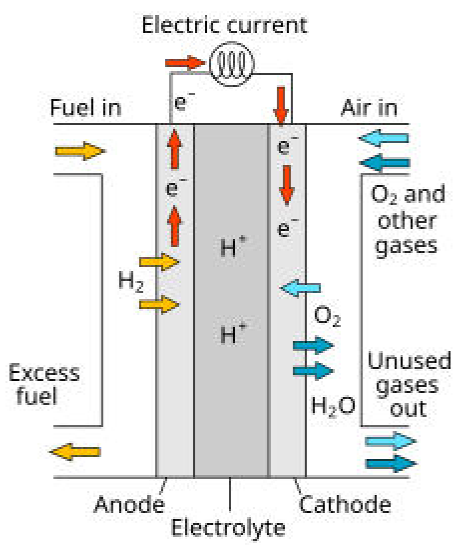
Use phosphoric acid as the electrolyte and can tolerate some carbon monoxide, allowing them to use various fuels after the sulfur is removed.

Solid Oxide Fuel Cells (SOFCs):

Use a ceramic material as the electrolyte and operate at very high temperatures (500−1000°C).

Molten Carbonate Fuel Cells (MCFCs):

Operate at high temperatures (1200°F or 650°C) and can use natural gas directly, as the high temperature allows for internal reforming.



Battery

- In most automobiles, the power source for the ignition is a battery and an alternator. In a battery ignition system, the battery provides power to the ignition coil.
- The battery used in this type of system is a lead acid storage battery. In addition to providing electricity to the ignition coil, the battery may also be used to power lights, horns, and other accessory circuits.
- A typical lead-acid storage battery is made up of several individual compartments called

cells.

- Each cell is made up of a series of lead plates. Small spaces between the plates are filled with an electrolyte solution.
- This solution is usually made from sulphuric acid diluted with water.
- Each cell produces approximately 2 V when the battery is fully charged, so a 12 V battery contains six cells
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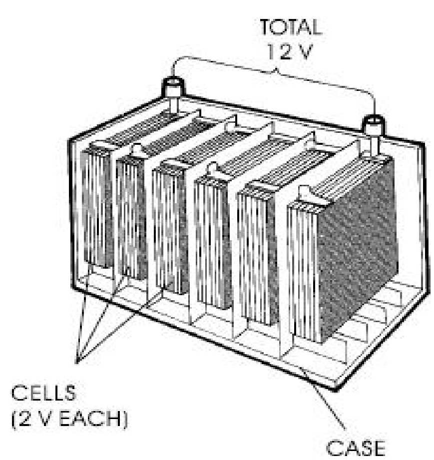
- Normally, a battery has a total output voltage of 12 volts of direct current, or 12 DC.
- The current produced by the battery is often measured in units called *ampere/hours (Ah).*
- In a battery ignition system, the alternator is used to recharge the battery as the engine operates.



Cut section of a battery