

Module 1

Overview

Introduction: Streams in mechanical engineering and their relevance/significance, role of mechanical engineers in solving the real case problems (with examples), careers in mechanical engineering.

Realization of some of the engineering solutions through principles of mechanical engineering (with a schematic diagram): Energy conversion: Introduction and basic working principles of Pelton Turbine and Centrifugal pump.

Vehicle systems: Identification of parts of vehicle systems such as steering system, brake system, gear system, working principle of Power steering.

Flying machines: Classification, basic parts involved in drone making, working principle of Drones. Refrigeration and air conditioning principles.

Streams in mechanical engineering and their relevance/significance.

Streams in Mechanical Engineering:

- Thermal, Design, Manufacturing, Mechatronics, Fluid Mechanics

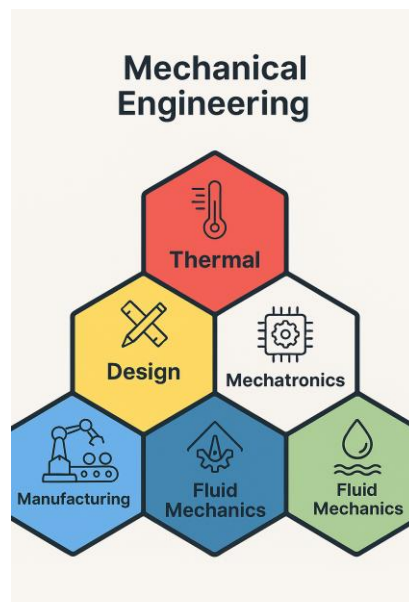


Figure 1: Schematic Representation of Streams in Mechanical Engineering

Thermal Engineering

- Thermal engineering is the branch of mechanical engineering that deals with the study and application of heat energy—its generation, transfer, conversion, and utilization. It encompasses **thermodynamics**, **heat transfer** (conduction, convection, radiation), and **energy systems** like engines, boilers, HVAC, and power plants.

Design Engineering

Design engineering focuses on the **conceptualization, modeling, and optimization** of mechanical systems and products. It involves **CAD tools**, **material selection**, **mechanical analysis**, and **prototyping**, ensuring that designs meet performance, safety, and manufacturability criteria.

Manufacturing Engineering

- Manufacturing engineering is the discipline that develops and improves **processes, tools, and systems** for producing high-quality goods efficiently. It integrates **mechanical principles**, **automation**, **lean manufacturing**, and **quality control** to transform raw materials into finished products.

Mechatronics Engineering

- Mechatronics is an interdisciplinary field combining **mechanical**, **electrical**, **electronics**, and **computer engineering** to create intelligent systems. It powers **automation**, **robotics**, **control systems**, and **smart devices**, enabling seamless interaction between hardware and software.

Fluid Mechanics

- Fluid mechanics is the study of the behavior of **liquids and gases** under various forces and conditions. It includes **fluid statics** (fluids at rest) and **fluid dynamics** (fluids in motion), and is foundational to applications like **aerodynamics**, **hydraulics**, and **CFD simulations**.

Relevance & Significance

- Mechanical engineers invent machines and structures that exploit those elements in order to serve a useful purpose and solve a problem.
- An engineer creates a machine or product to help someone solve a technical problem. The engineer might start from a blank sheet of paper, conceive something new, develop and refine it so that it works reliably, and — all the while—satisfy the constraints of safety, cost, and manufacturability.



Figure 2: Robots are used extensively in automated industrial assembly lines that require precision



Figure 3: Close-up view of a Space Shuttle main engine during a test in which it is swiveled to evaluate steering performance during flight conditions. Courtesy of NASA.

Relevance in Infrastructure, Mobility, Energy, Automation

Each stream addresses **specific societal and industrial needs**, making them vital to progress and innovation:

Thermodynamics & Energy Systems

Crucial for designing efficient engines, power plants, and sustainable energy solutions. With the global push for clean energy, this stream is more relevant than ever.

Manufacturing & Production Engineering

Powers the backbone of industrial economies. From automotive to aerospace, this stream ensures products are made efficiently, safely, and at scale.

Design & CAD/CAE

Enables engineers to visualize, simulate, and optimize products before they're built—saving time, cost, and resources. It's essential in everything from consumer electronics to heavy machinery.

Fluid Mechanics & Thermal Sciences

Vital for designing systems involving air, water, and other fluids—think aircraft, HVAC systems, and hydraulic machines.

Mechatronics & Robotics

Integrates mechanical systems with electronics and computing. It's the future of automation, smart manufacturing, and even AI-driven devices.

Biomedical Engineering

Applies mechanical principles to healthcare—prosthetics, surgical tools, and medical imaging devices. It's a life-saving stream with growing demand.

Environmental & Sustainable Engineering

Focuses on eco-friendly design and pollution control. Engineers in this stream help tackle climate change and resource conservation.

Significance for Your Career and Society

Career Alignment: Choosing the right stream helps match your interests with industry demand, leading to a more fulfilling and successful career.

Innovation Driver: Each stream contributes to technological advancement—whether it's cleaner energy, smarter machines, or better healthcare.

Global Impact: Mechanical engineers work on problems that affect millions—transportation, infrastructure, climate, and health.

Economic Value: Streams like manufacturing and robotics are central to national economies and global competitiveness.

Careers & Problem Solving in Mechanical Engineering

Career Role	Type of Job	Sector/Industries
Automotive Engineer	Design and test vehicles and components	Automotive, EVs
Aerospace Engineer	Develop aircraft, spacecraft, and satellites	Aerospace, Defense
Robotics & Mechatronics Engineer	Build intelligent machines and automation systems	Manufacturing, R&D, AI
Thermal & Energy Engineer	Optimize energy systems, HVAC, and thermal processes	Energy, Utilities, Construction
Manufacturing Engineer	Improve production efficiency and quality	FMCG, Automotive, Electronics
Biomedical Engineer	Design medical devices and healthcare tech	Healthcare, Biotech
Structural & Materials Engineer	Analyze materials and structures for strength and durability	Civil, Aerospace, R&D
R&D Engineer	Innovate new products and improve existing systems	Tech, Automotive, Aerospace

Marine Engineer	Design and maintain ships, submarines, and offshore system	Naval, Oil & Gas
Automation & Control Engineer	Develop control systems for industrial automation	Manufacturing, Robotics

Role Of Mechanical Engineers in Solving the Real Case Problems (With Examples)

Examples: **Solving Industrial, Environmental, and Mobility challenges**

Mechanical engineers apply core principles like thermodynamics, fluid mechanics, and materials science to address pressing issues in industrial operations, environmental sustainability, and modern mobility. Their problem-solving capabilities drive innovation across diverse sectors, from designing efficient power systems to developing life-saving medical devices.

Solving Industrial Challenges

Mechanical engineers optimize manufacturing and production processes, improve the reliability of machinery, and enhance automation to boost productivity and safety in industrial settings.

Examples:

Manufacturing process optimization:

- Developing automation and robotics systems for tasks like assembly, welding, and quality inspection to increase speed, precision, and consistency on production lines.
- Implementing additive manufacturing (3D printing) to create complex, lightweight parts, which can reduce material waste and shorten production timelines.
- Designing advanced tooling and fixtures to improve machining processes, resulting in higher product quality and reduced costs.

Engineering change and quality control:

- Analyzing equipment failures to determine the root cause and implementing corrective actions to prevent future breakdowns.
- Managing engineering changes to product designs by coordinating with various teams to ensure seamless and cost-effective implementation.

Energy and power systems:

- Designing and improving the efficiency of thermal systems, such as engines, turbines, and boilers, used in power generation.
- Developing new control systems for microgrids to integrate local energy sources and storage, increasing power resilience.

Solving Environmental Challenges

As environmental regulations become stricter, mechanical engineers play a central role in creating sustainable and eco-friendly solutions. Their work helps to reduce pollution, conserve resources, and advance the use of clean energy.

Examples:

Renewable energy systems:

- Designing more efficient wind turbine blade designs to maximize energy extraction.
- Developing solar thermal collectors and PV systems that optimize the absorption and conversion of solar energy.
- Engineering hydropower systems that can generate electricity with minimal environmental impact.

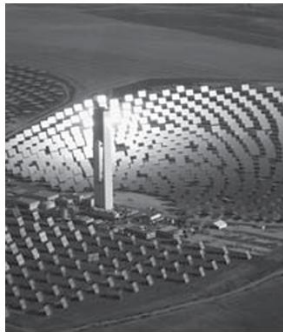
Sustainable manufacturing:

- Developing new recycling technologies and systems to convert waste into energy, reducing landfill usage.
- Conducting life-cycle assessments on products to evaluate their environmental impact from production to disposal and redesigning them for greater sustainability.

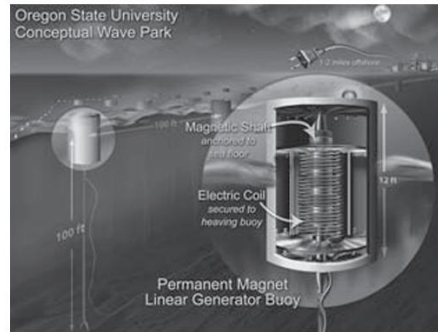
Pollution and emissions control:

- Designing advanced filtration systems for HVAC units and industrial processes to improve air quality and reduce harmful emissions.

- Developing catalytic converters, diesel particulate filters, and other technologies to minimize exhaust pollutants from vehicles and power plants.



(a)



(b)



(c)

Solving Mobility Challenges

Mechanical engineers are at the forefront of designing the next generation of transportation, focusing on improving efficiency, reducing emissions, and enhancing safety.

Examples:

Automotive Engineering:

- Developing advanced engines, transmissions, and drivetrains that improve vehicle performance and fuel efficiency.
- Innovating safety features, including crumple zones and impact-absorbing materials, to protect occupants during collisions.
- Creating electric and hybrid vehicle designs that reduce greenhouse gas emissions.

Aerospace Engineering:

- Designing and testing advanced aircraft and spacecraft, including their propulsion systems and aerodynamic surfaces.
- Improving the fuel efficiency and safety of aerospace systems by using advanced materials and optimizing design.

Smart and sustainable transport:

- Developing automated and robotic delivery systems for efficient urban logistics.
- Designing smart traffic management systems to optimize traffic flow and reduce congestion in urban areas.

- Creating alternative, zero-emission transportation options, such as pedal-powered generators and solar-powered electric bikes.

Realization of some of the engineering solutions through principles of mechanical engineering (with a schematic diagram):

1. Automotive suspension system

Problem statement: To provide a comfortable ride for passengers and maintain tire contact with the road, minimizing the impact of bumps and uneven surfaces.

Principle applied: Kinematics, dynamics, and mechanical vibration.

- Kinematics analyzes the motion of the suspension's linkages as the wheel moves up and down.
- Dynamics examines the forces and torques that cause this motion, such as those from road impacts.
- Mechanical vibration is used to design the springs and dampers (shock absorbers) that control and dissipate the energy from oscillations, preventing an overly bouncy ride.

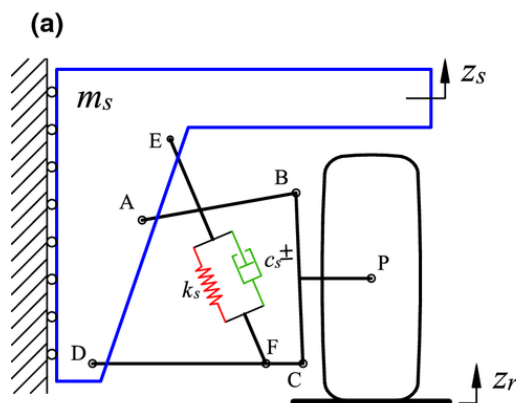


Figure 4: Schematic Diagram of a simplified double wishbone suspension system.

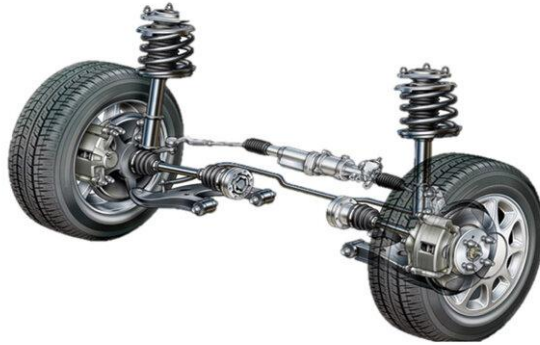


Figure 5: Pictorial view of double wishbone suspension system in a vehicle

Explanation:

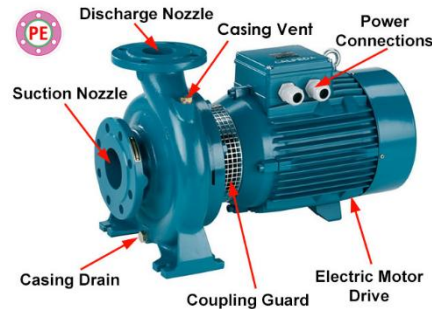
- **Control Arms (AB, DC):** These linkages manage the movement of the knuckle and wheel relative to the vehicle's chassis. The geometrical arrangement, determined through kinematics, controls the wheel's alignment and position.
- **Coil Spring (Ks):** The spring stores and releases potential energy from the vertical motion of the wheel. This is a fundamental application of spring mechanics.
- **Damper (Cs):** The damper dissipates the energy from the spring's oscillation through fluid resistance, converting mechanical energy into thermal energy. This is a core fluid dynamics and energy conversion principle.

2. Pumping water with a centrifugal pump

Problem Statement: To transfer fluid from a low-pressure area to a high-pressure area. This is a common requirement for residential plumbing, industrial processes, and water treatment plants.

Principle applied: Fluid mechanics and energy conversion.

- Fluid mechanics is central to designing the impeller and casing to efficiently move liquids.
- Energy conversion transforms the rotational kinetic energy from an electric motor into the fluid's kinetic and potential energy.
- Schematic diagram: A centrifugal pump uses an impeller to increase the pressure and flow rate of a fluid.



Explanation:

- Electric Motor (A): Provides the rotational energy to power the impeller.
- Impeller (B, E): As the impeller rotates, its curved vanes impart kinetic energy to the fluid particles, accelerating them outwards.
- Casing (F): The fluid is collected by the casing, which is designed to convert the fluid's high kinetic energy into high potential energy (pressure) as it moves toward the outlet.

3. Cooling an engine with a radiator

Problem: To dissipate excess heat generated by an internal combustion engine to prevent overheating and potential damage.

Principle applied: Thermodynamics and heat transfer.

- Thermodynamics governs the process of energy transfer and temperature change in the engine and cooling system.
- Heat transfer principles, specifically conduction, convection, and radiation, are used to transfer heat from the hot engine coolant to the cooler ambient air.

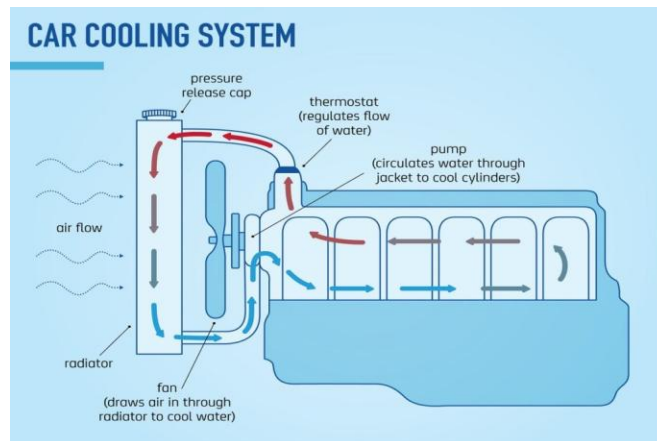


Figure 6: An engine cooling system uses a radiator to manage temperature.

Explanation:

- Hot Engine (A) to Hot Coolant (B): A water pump circulates coolant through the hot engine, and heat is transferred from the engine block to the coolant via conduction.
- Coolant to Radiator (D): The hot coolant flows through the radiator's small tubes, which have large surface areas to maximize heat transfer.
- Radiator to Ambient Air: As air is forced over the radiator's fins by a fan, heat is transferred from the tubes and fins to the air through forced convection. Some heat is also radiated from the radiator surface.
- Cooled Coolant (G) back to Engine (A): The now-cooler coolant returns to the engine, and the cycle repeats.

Energy Conversion

Energy conversion, also termed as energy transformation, is the process of changing one form of energy into another. Energy conversion occurs everywhere and every minute of the day. There are numerous forms of energy like thermal energy, electrical energy, nuclear energy, electromagnetic energy, mechanical energy, chemical energy, sound energy, etc. On the other hand, the term *Energy Transformation* is used when energy changes forms from one form to another. Whether the energy is transferred or transformed, the total amount of energy doesn't change, and this is known as the law of conservation of Energy.

The first law of thermodynamics states that

“Energy can neither be created nor destroyed, it can only be transformed from one form to another.”

This is also known as the “law of conservation of energy” or the “law of energy conversion”.

- Energy conversion is the process of changing one form of energy into another, such as mechanical energy to electrical energy in a generator, or light energy into chemical energy in a plant. This transformation happens constantly and adheres to the law of conservation of energy, meaning the total amount of energy in a closed system remains constant; it is neither created nor destroyed, only changed in form or location. Various devices and systems, from simple tools to complex power plants, are used to convert raw energy into forms useful for human applications.

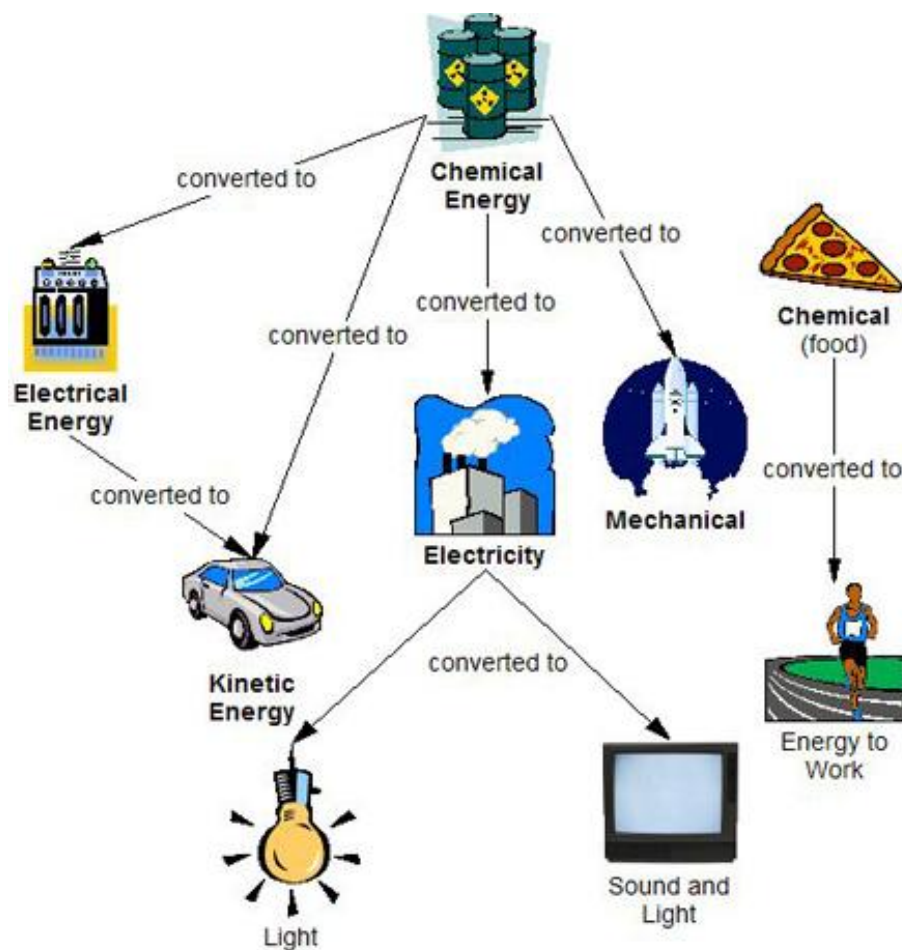


Figure 7: The Figure shows how different forms of energy can be converted to another form of energy.

Pelton Turbine

A Pelton turbine is a type of impulse turbine that converts the potential energy of high-head water into **kinetic energy** via a nozzle, then uses this high-speed water jet to drive a rotating runner with double-cupped buckets. Named after its inventor, **Lester Allan Pelton**, it is ideal for high-head, low-flow hydroelectric applications, where water from a significant height is directed by a nozzle to impinge on the buckets, causing them to rotate and generate mechanical power

Basic Working Principle of Pelton Turbine

1. Potential to Kinetic Energy:

Water is channeled from a high reservoir through a penstock and then through a nozzle, which creates a high-velocity jet of water by converting the water's potential energy into kinetic energy.

2. Impulse and Rotation:

This high-speed water jet strikes the spoon-shaped buckets on the circumference of the Pelton runner.

3. Momentum Transfer:

The water jet is split by the bucket's splitter and exits from the sides of the bucket, having transferred its momentum to the runner.

4. Continuous Operation:

This continuous application of force by the water jet on the buckets causes the runner to spin, generating rotational mechanical energy.

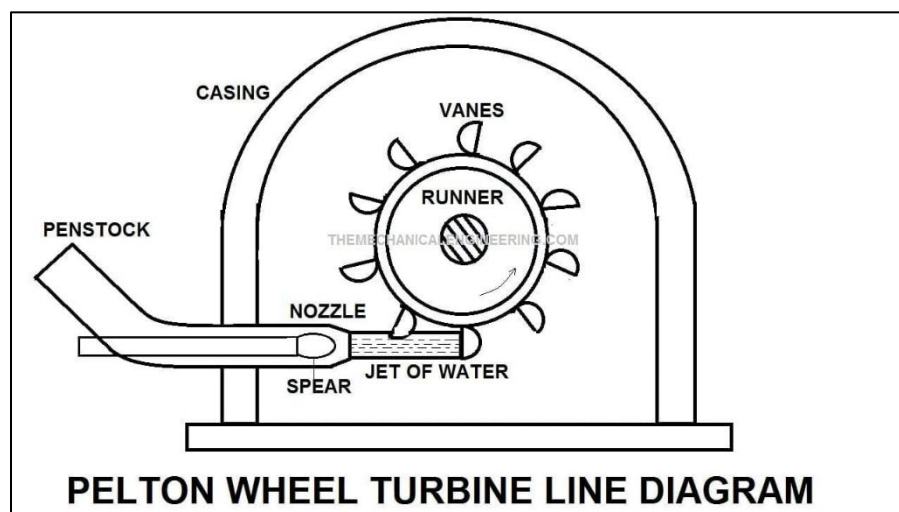


Figure 8: Schematic Diagram of Pelton Turbine

Key Components of Pelton Turbine

Nozzle: Controls the water flow and creates a high-velocity jet.

Runner with Buckets: The rotating part with specially shaped buckets that catch the water jet.

Casing: A protective housing that prevents water from splashing out and guides it to the tailrace.

Centrifugal Pump

A centrifugal pump is a type of dynamic pump that transfers fluid by converting rotational kinetic energy from a motor or engine into hydraulic energy, making it widely used for moving liquids such as water, chemicals, and oils across industrial processes, agriculture, and domestic water supply systems. It operates by using a rotating impeller to impart energy to the fluid, increasing its velocity and pressure. Fluid enters through the impeller's central "eye" and is propelled outward by centrifugal force. This high-velocity fluid then flows into a specially shaped casing—either a volute or diffuser—where its kinetic energy is converted into potential energy (pressure), and is efficiently directed to the pump's outlet

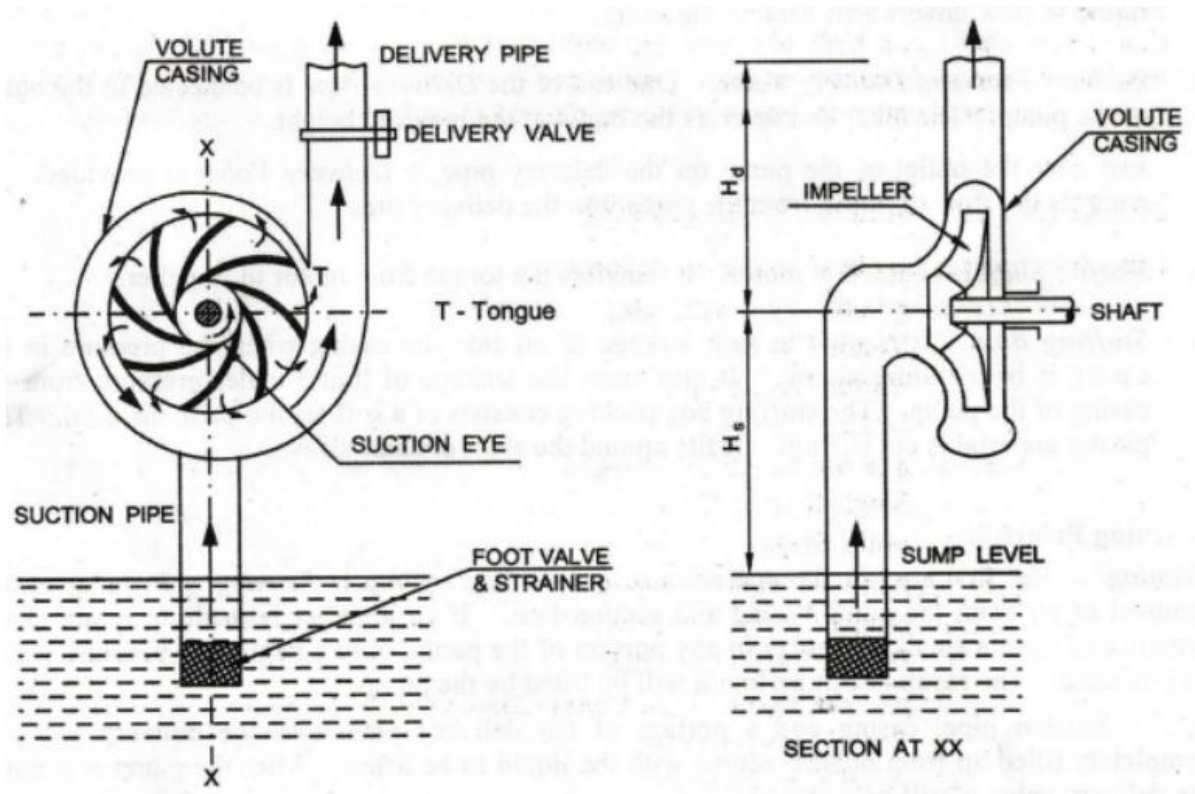


Figure 9: Constructional Details of Centrifugal Pump

Basic Working Principles

1. **Energy Input:** A motor or engine provides mechanical energy to the pump's rotating shaft, which spins the impeller.
2. **Fluid Suction:** The rotating impeller creates a low-pressure area at its center, known as the eye. This vacuum pulls fluid from the source into the impeller's eye along its axis.

3. **Centrifugal Force:** As the impeller rotates, it forces the fluid outward along its vanes. This action, driven by centrifugal force imparts high kinetic energy and velocity to the fluid.
4. **Energy Conversion (Volute/Diffuser):** The fluid, now moving at high speed, enters the pump casing.
 - **Volute Casing:** The casing is designed with a gradually increasing cross-sectional area. As the fluid flows through this expanding area, it slows down, and its velocity is converted into increased pressure.
 - **Diffuser:** Some pumps use a diffuser, a set of stationary blades surrounding the impeller, to achieve the same effect of slowing the fluid and converting its kinetic energy to pressure energy.
5. **Discharge:** The high-pressure fluid is then discharged from the pump's outlet nozzle to its destination.

In essence, the centrifugal pump creates a "force vortex flow," transforming the input mechanical energy into increased pressure and flow to effectively move the liquid.

Vehicle Systems

Vehicle systems and components comprise the engine, powertrain (transmission, drivetrain), chassis, body, suspension, steering, braking, fuel, cooling, electrical, exhaust, and safety systems. Each system relies on numerous specialized parts working together, such as the crankshaft and pistons in the engine, the battery and alternator in the electrical system, or the brake pads and rotors in the braking system, to enable the vehicle to start, move, steer, and remain safe.

Key Vehicle Systems and Their Components

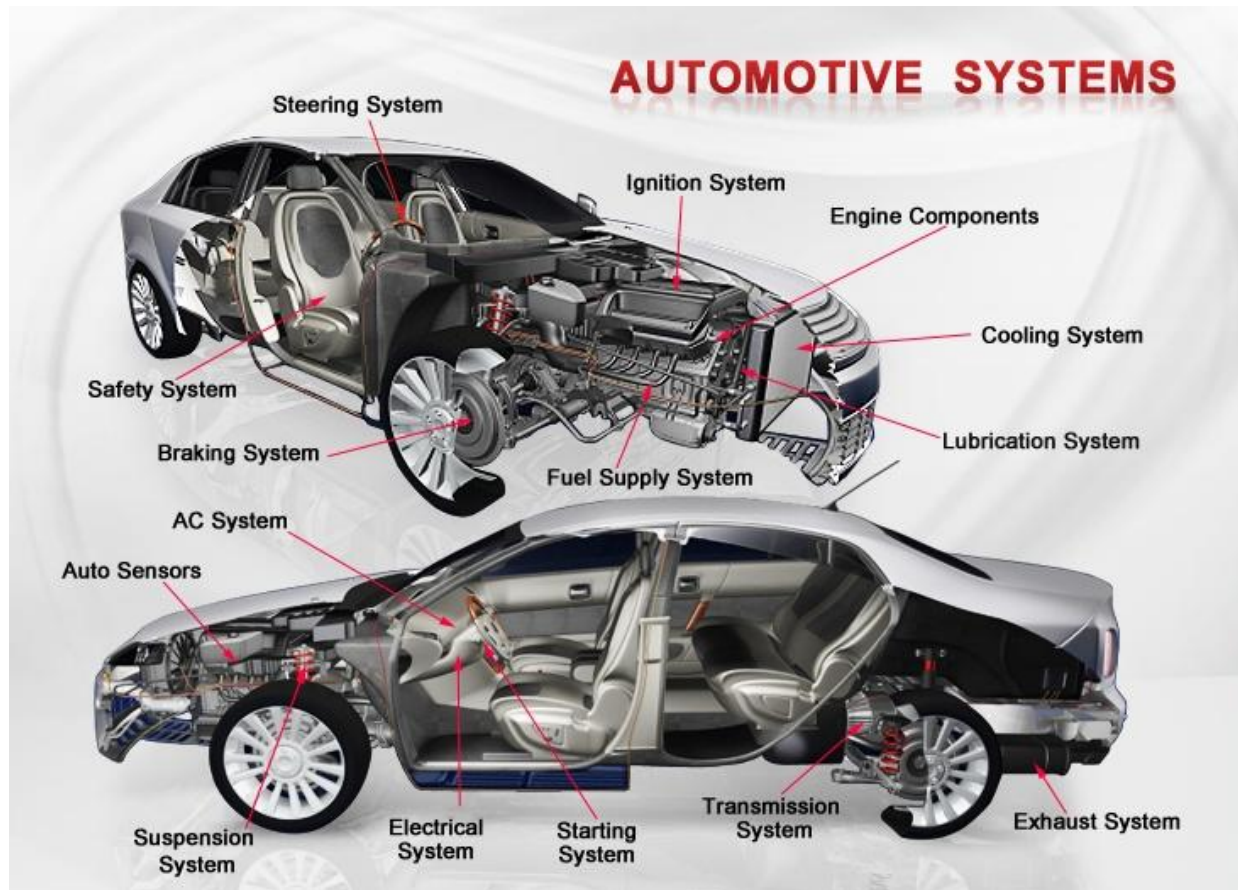


Figure 10 :Figure 10: Key Elements of Vehicle systems and their components

Engine:

The engine converts fuel into mechanical energy to power the vehicle. Key components include the cylinder block, pistons, crankshaft, camshaft, and cylinder head.

- **Powertrain:**

This system transmits power from the engine to the wheels. Components include the transmission (gearbox), driveshaft, and differential.

- **Chassis & Body:**

The chassis is the vehicle's structural frame, while the body provides the occupant space and is built onto the frame.

- **Suspension:**

This system improves ride quality and handling by buffering road shocks. It includes components like springs, shock absorbers, and linkages.

- **Steering:**

Used for directional control, it comprises the steering column, rack-and-pinion gears, and power steering pump.

- **Braking System:**

Slows or stops the vehicle using components such as brake pads, rotors, brake lines, and the hydraulic master cylinder.

- **Fuel System:**

Supplies fuel to the engine. Key parts include the fuel tank, fuel injection system, and throttle body.

- **Cooling System:**

Manages engine temperature with components like the radiator, cooling fans, and water pump.

- **Electrical System:**

Powers vehicle components and recharges the battery. It includes the battery, alternator, starter motor, and various wiring and fuses.

- **Exhaust System:**

Expels exhaust gases and reduces emissions with parts like the catalytic converter, muffler, and oxygen sensors.

- **Safety Systems:**

Features designed to protect occupants, including airbags, seatbelts, and lighting systems.

- **Wheels and Tires:**

Provide the crucial contact with the road.

Steering System

Components of Steering System

The following are the main components of steering system.

1. Steering wheel: It is the control wheel to steer a vehicle by the driver. It contains traffic indicator switch, light switch, wiper switch etc.

2. Steering column or shaft: The steering shaft is fitted inside the hollow steering column. When the steering wheel is turned, the steering shaft will also be rotated. Due to this, the motion is transmitted to the steering box

3. Steering gear box: The pitman arm is splined to the steering gear box rocker arm at one end and the other end is connected to the drag link by a ball joint.

4. All other Links:

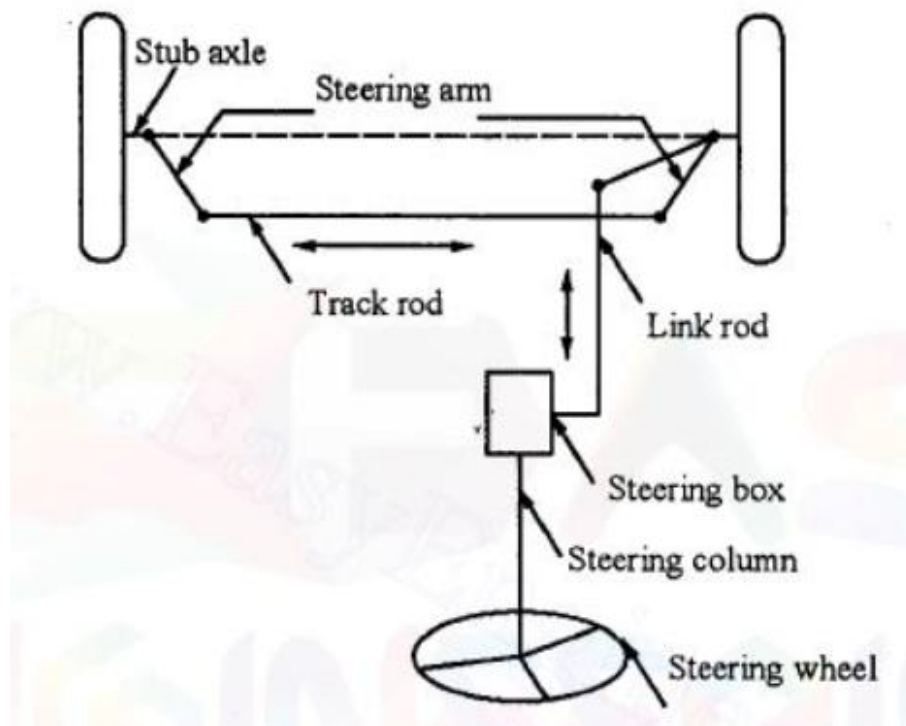


Figure 11: Layout of a typical Steering system

Braking System

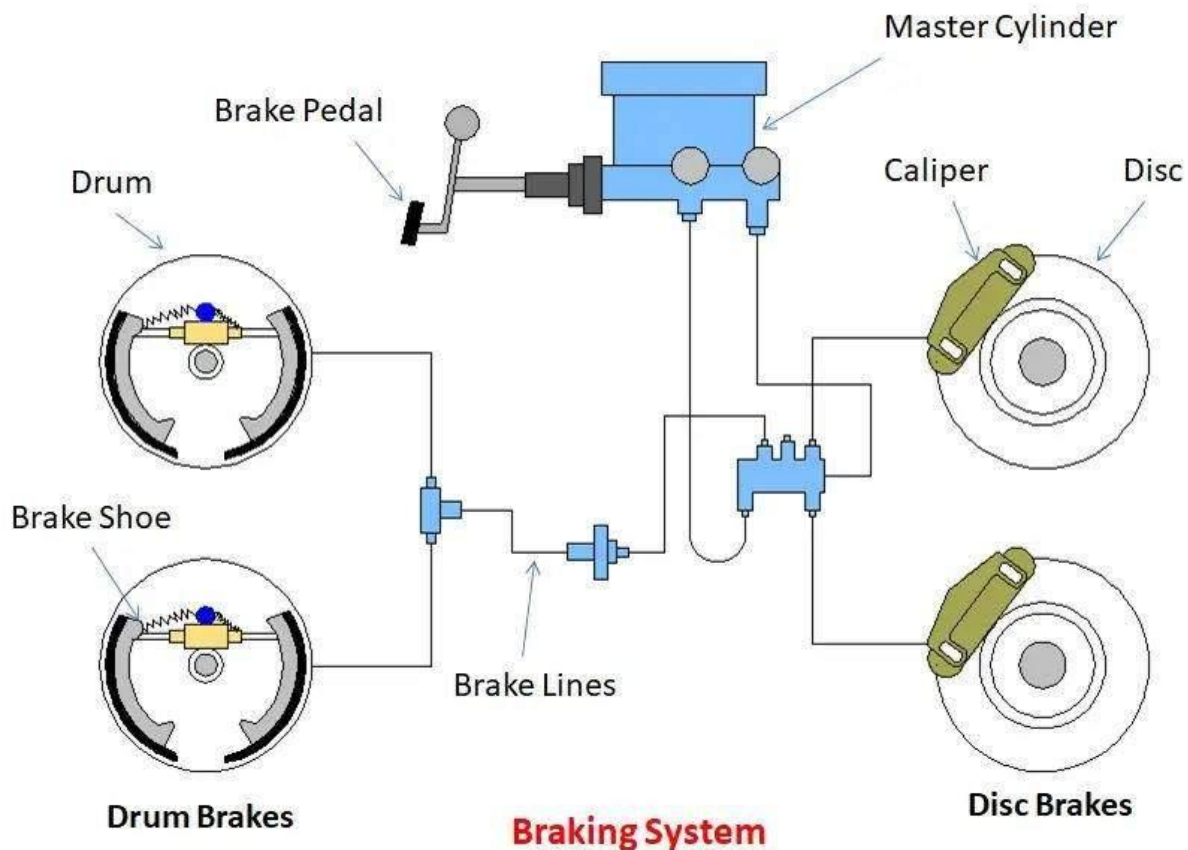


Figure 12: Basic Layout and components of Braking System

A vehicle's braking system uses friction or electromagnetism to convert the vehicle's kinetic energy into heat or electrical energy, slowing it down or stopping it. The driver initiates the process by pressing a pedal or lever, which generates hydraulic pressure through a master cylinder, or mechanical force through other systems. This force is transmitted to the wheels, where it presses brake pads against a rotating disc (disc brakes) or brake shoes against a rotating drum (drum brakes). Modern systems often incorporate advanced features like anti-lock braking systems (ABS) to prevent skidding and regenerative braking in hybrid and electric vehicles to recover energy.

Gear System

A car's gear system, or transmission uses gears of different sizes to adjust the engine's power and speed to the wheels, allowing the car to accelerate, maintain speed, or drive in reverse. It consists of a clutch to engage/disengage the engine, and a gearbox with shafts and gears. When shifting, the driver uses a gear lever to select the appropriate gear ratio, enabling the engine to operate within its optimal power band for different driving conditions.

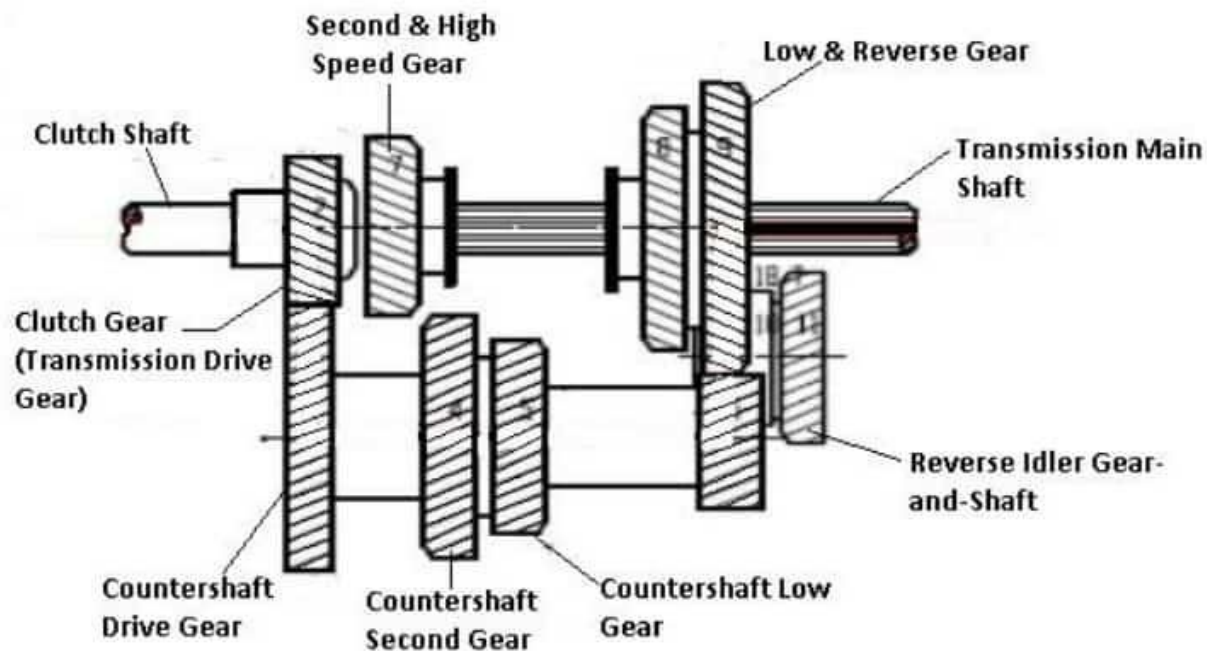


Figure 13: Simple Diagram of Mesh Gear Box

Key Components

- **Clutch:** Connects and disconnects the engine from the gearbox.
- **Drive Shaft:** Transmits engine power to the clutch and then to the gearbox.
- **Counter Shaft:** A shaft with several gears of different sizes to produce the necessary torque.
- **Main Shaft (Output Shaft):** Transfers the power from the gearbox to the driveshaft.
- **Gears:** Different-sized gears that intermesh to change the gear ratio.

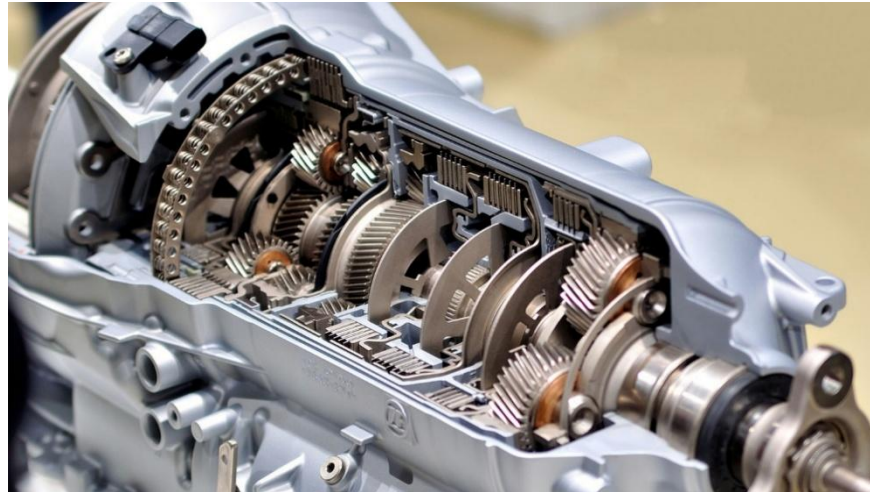
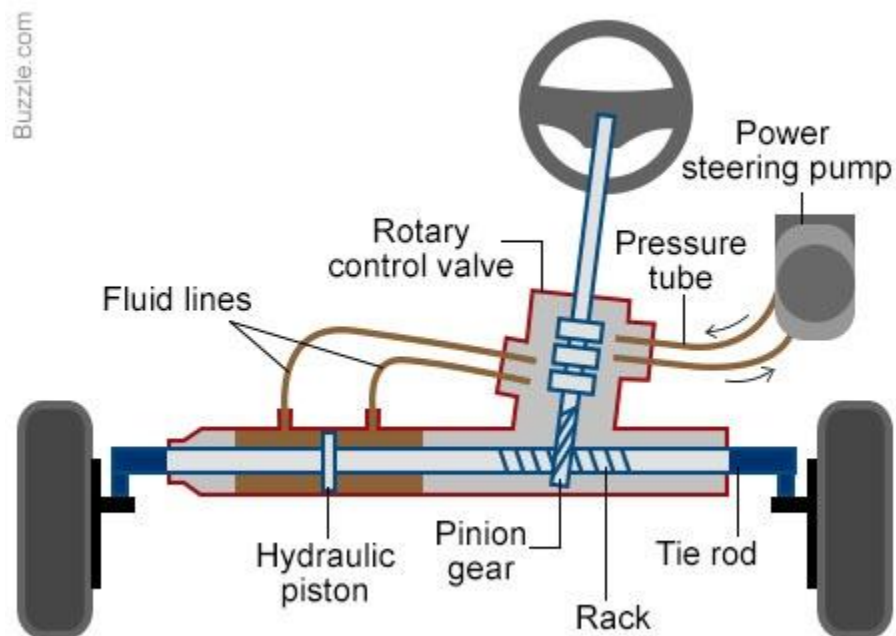


Figure 14: Pictorial View of Meshed Gear Box

Power Steering System



1. **Steering Input:** You turn the steering wheel, sending a signal through the steering column.
2. **Pump Operation:** The engine-driven power steering pump starts, pressurizing and moving hydraulic fluid from the reservoir.

3. **Fluid Delivery:** This pressurized fluid travels through pressure hoses to the steering gears.
4. **Piston Movement:** The high-pressure fluid acts on a piston inside a hydraulic cylinder.
5. **Mechanical Assist:** The movement of the piston translates into a force on the steering rack, which then steers the vehicle's wheels.
6. **Return Flow & Cooling:** After the fluid has done its work, it flows back through return hoses to the reservoir, dissipating heat generated during the process.
7. **Variable Assistance:** The system provides more assistance at low speeds (when more effort is needed to turn the wheels) and less assistance at higher speeds to enhance stability.

Flying Machines

Classification of Flying Machines

Flying machines are broadly categorized based on their design and method of flight:

Category	Subtypes / Classes	Examples
Fixed-Wing Aircraft	Single-engine, multi-engine, jet, glider	Boeing 747, Cessna 172, fighter jets
Rotorcraft	Helicopter, gyroplane	Bell 206, Sikorsky UH-60
Lighter-than-Air	Airships, balloons	Goodyear Blimp, hot air balloon
Powered Lift	VTOL aircraft	V-22 Osprey
Unmanned Aerial Vehicles (UAVs)	Fixed-wing, rotary-wing, hybrid drones	DJI Phantom, Parrot Anafi

Fixed Wing Aircraft:



Figure 15: Pictorial View of Fixed Wing Aircraft

Rotar Craft:



Figure 16: Pictorial View of a Rotar Craft

Air Balloons



Figure 17: Pictorial View Air Ballon

Powered Lift



Figure 18: Pictorial View of VTOL Aircraft

Unmanned Aerial Vehicle (UAVs)



Figure 19: Pictorial View of Unmanned Aerial Vehicle

What is Drone?

A drone is an unmanned aerial vehicle (UAV) or unmanned aircraft system. It is essentially a flying robot this is controlled remotely or can fly autonomously with software-controlled flight plans embedded in this system that work in conjunction with sensors and global positioning system (GPS).

Drones (UAVs) fall under the unmanned category and can be further classified into:

- **Quadcopters** (4 rotors)
- **Hexacopters** (6 rotors)
- **Octocopters** (8 rotors)
- **Fixed-wing drones**
- **Hybrid VTOL drones**

Classification

1. Multi-Rotor Drones.

Multi-rotor drones are the easiest and economical among the classes of drones. They also offer greater control over position and framing, and hence they are perfect for aerial photography and surveillance. They are called multi-rotor because they have more than one motor, more commonly tricopters (3 rotors), quadcopters (4 rotors), hexacopters (6 rotors) and octocopters (8 rotors), among others. By fare, quadcopters are the most popular multi-rotor drones.

- **Strengths:** Can hover, take off and land vertically, and are very agile.
- **Design:** Four rotors arranged in an X or + configuration.
- **Limitations:** Typically have shorter flight times compared to fixed-wing drones.
- **Flight:** Vertical takeoff/landing, hover capability, agile maneuvering.
- **Use Cases:** Surveillance, delivery, inspection, aerial photography.



Figure 20: Pictorial View of Multi Rotor Drone

2. Fixed-wing drones

These drones are a type of unmanned aerial vehicle (UAV) that fly more like traditional airplanes than the typical quadcopters you might be used to. Instead of using rotating

propellers to hover, they rely on aerodynamic lift generated by their wings to stay aloft. Fixed wing drones cover longer distances, map much larger areas, and loiter for long times monitoring their point of interest. This drone type can fly at a high altitude, carry more weight and are more forgiving in the air than other drone types.



Figure 21: Pictorial View of Fixed Wing Drone



- **Strengths:** Good for longer flight times and covering larger areas.
- **Design:** Rigid wings that generate lift through forward motion.
- **Flight:** Requires runway or catapult launch; efficient for long-range missions.
- **Limitations:** Cannot take off or land vertically or hover in place.
- **Use Cases:** Mapping, surveying, agricultural monitoring.

3. Single-Rotor Drones

Single-rotor drone types are strong and durable. They look similar to actual helicopters in structure and design. A single-rotor has just one rotor, which is like one big spinning wing, plus a tail rotor to control direction and stability.

Advantages: A single rotor helicopter has the benefits of much greater efficiency over a multi-rotor. A single rotor helicopter allows for long blades, which are more like a spinning wing than a propeller, giving greater efficiency.



Figure 22: A pictorial View of a Single Rotor Drone

- Application or used in:
- Aerial LIDAR Laser scan.
- Drone surveying
- Carrying heavy payloads.

4. Fixed Wing Hybrid VTOL

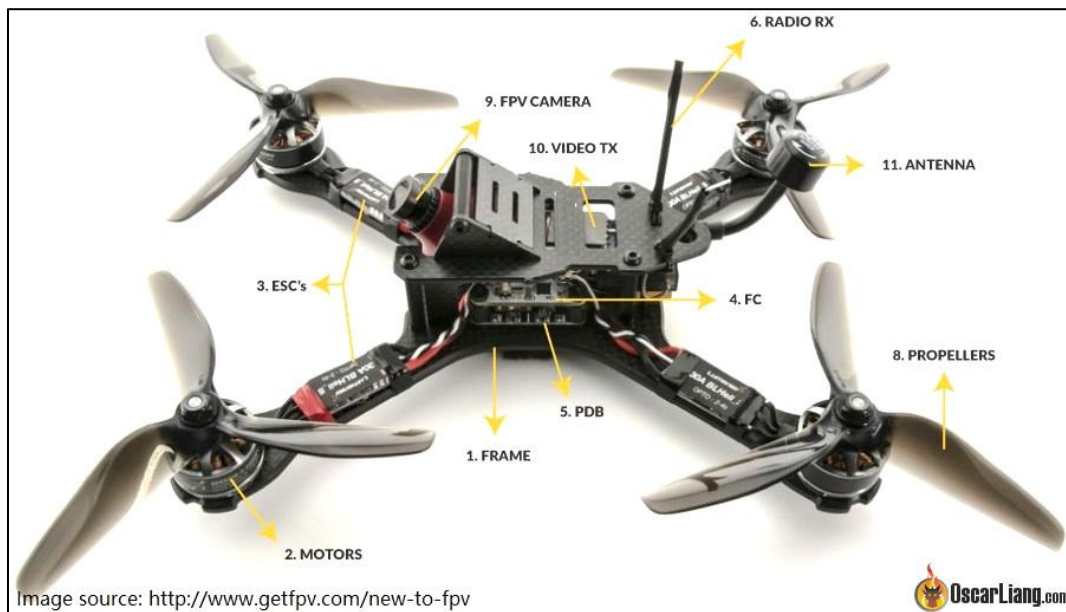
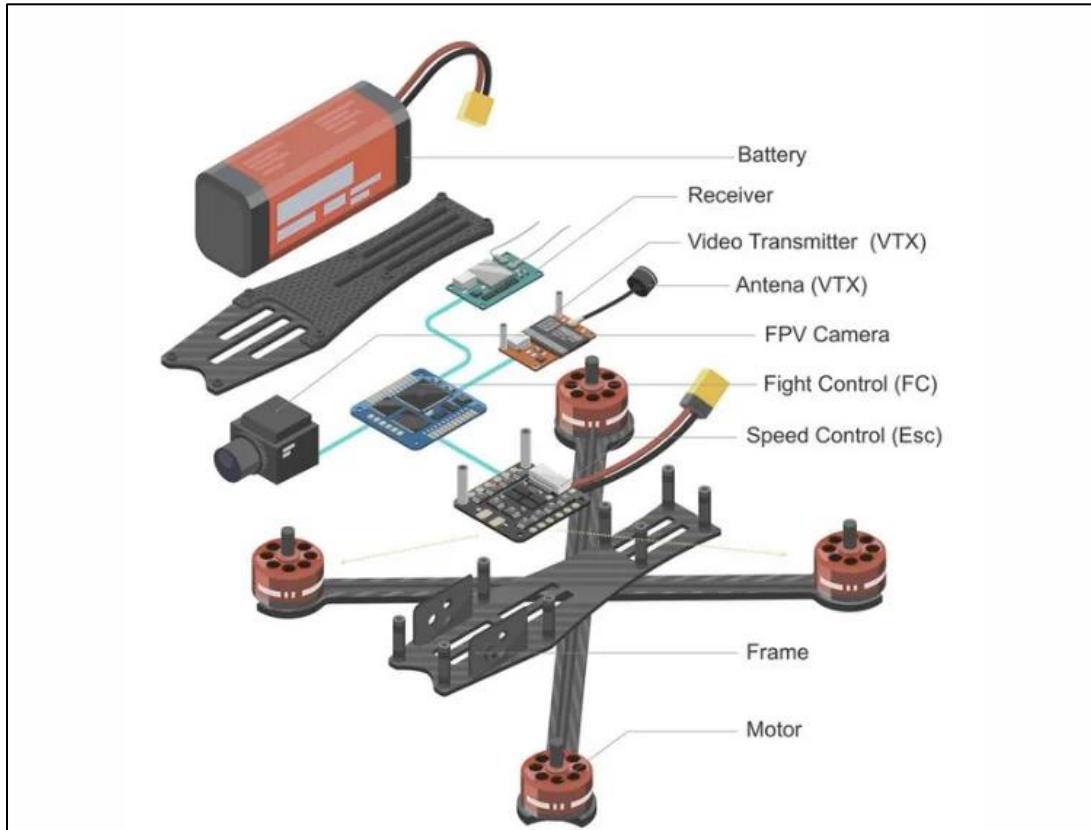
Hybrid VTOL drone types merge the benefits of fixed wing and rotor-based designs. This new category of hybrids are only a few on the market, but as technology advances, these options can be much more popular in the coming years.



Basic Parts Involved in Drone Making

Here's a schematic-style breakdown of essential drone components:

Component	Function
Frame	Structural skeleton; holds all parts together
Motors	Drive the propellers to generate thrust
Propellers	Create lift and directional control
Electronic Speed Controllers (ESC)	Regulate motor speed based on flight controller signals
Flight Controller	The "brain"; processes sensor data and controls stability
Battery (Li-Po)	Powers motors and electronics
GPS Module	Enables navigation, geofencing, and return-to-home features
Sensors	IMU (gyroscope + accelerometer), barometer, magnetometer, sometimes obstacle avoidance. etc.
Camera / Payload	For imaging, surveillance, or delivery tasks Used for aerial photography, videography, or other mission-specific tasks
Communication System	Transmits data and receives commands from ground control(via radio or wifi)



Working Principle (for Rotary-Wing Drones)

Rotary-wing drones, like quadcopters, control their movement by precisely adjusting the speed of their individual motors and, consequently, the thrust produced by their propellers.

1. **Vertical Lift:** To ascend, the flight controller increases the speed of all four motors simultaneously, creating more upward thrust than the drone's weight. To descend, it decreases motor speeds.
2. **Pitch (Forward/Backward):** To move forward, the rear motors speed up, and the front motors slow down, tilting the drone forward and creating forward thrust.
3. **Roll (Left/Right):** To move sideways, the motors on one side speed up while the motors on the other side slow down, tilting the drone in the desired direction.
4. **Yaw (Rotation):** To rotate, the flight controller increases the speed of two diagonally opposite motors and decreases the speed of the other two, creating a twisting force that causes the drone to yaw.
5. **Hovering:** For stable flight and hovering, the flight controller maintains a constant, balanced output from all motors. The flight controller uses sensor data (IMU, GPS) to:
 - Stabilize flight
 - Execute maneuvers
 - Maintain altitude
 - Return to home autonomously

Refrigeration cycle: Vapour compression cycle(VCR)

The vapor compression refrigeration (VCR) cycle is the most common method used for air conditioning and refrigeration. It involves four main stages where a circulating refrigerant changes phase from liquid to gas and back, absorbing and releasing heat in the process.

The four stages of the VCR cycle:

Evaporation: The cold, low-pressure liquid refrigerant passes through the evaporator coil. Heat from the surrounding area (the space to be cooled) is absorbed by the refrigerant, causing it to boil and turn into a gas.

Compression: The low-pressure refrigerant vapor is drawn into the compressor, which pressurizes it into a high-pressure, high-temperature gas. This requires an external work input.

Condensation: The hot, high-pressure gas is then sent to the condenser coil, where a fan blows cooler air across it. As the refrigerant cools, it condenses back into a high-pressure liquid, releasing the absorbed heat to the outside environment.

Expansion (Throttling): The high-pressure liquid passes through an expansion device (a throttling valve), which causes a sudden pressure drop. This expansion cools the refrigerant to a low-pressure, low-temperature liquid-vapor mixture, and the cycle begins again.

Main components

Compressor: A mechanical pump that compresses the refrigerant vapor, increasing its pressure and temperature. It is the core of the refrigeration system, forcing the refrigerant to circulate.

Condenser: A heat exchanger, typically consisting of a coil and a fan, where the hot, pressurized refrigerant releases its heat and condenses into a liquid.

Expansion Valve (or Throttling Valve): A valve that expands the liquid refrigerant, which causes a drop in its pressure and temperature before it enters the evaporator.

Evaporator: The indoor heat exchanger where the cold refrigerant absorbs heat from the surrounding air and evaporates into a gas.

Refrigerant: The working fluid that cycles through the system, absorbing and releasing heat as it changes phase.

Schematic diagram

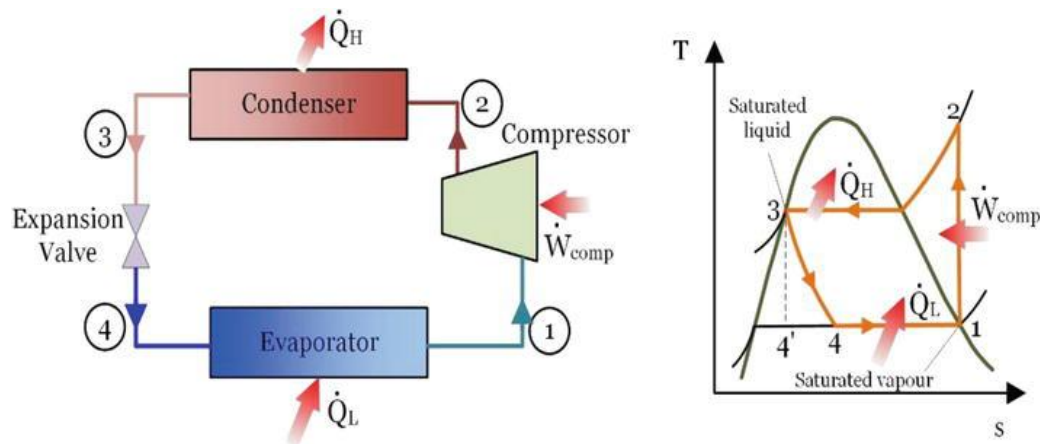
A simple schematic of the vapor compression cycle shows the four main components connected in a closed loop.

Point 1: Low-pressure, low-temperature vapor enters the compressor.

Point 2: High-pressure, high-temperature superheated vapor exits the compressor.

Point 3: High-pressure, high-temperature liquid exits the condenser.

Point 4: Low-pressure, low-temperature liquid-vapor mixture exits the expansion valve.



Applications of the VCR cycle

- **Domestic Refrigeration:** Home refrigerators and freezers.
- **Air Conditioning:** Comfort cooling for homes, offices, and vehicles.
- **Commercial Refrigeration:** Display and storage units in retail stores.
- **Industrial Refrigeration:** Used in chemical plants, petrochemical refineries, food processing, and cold storage warehouses.
- **Transportation:** Refrigerated trucks, railroad cars, and marine transport.
- **Medical:** Cryogenic refrigeration for MRI scanners and other specialized applications.
- **Electronics Cooling:** Maintaining low temperatures for servers and large computers.

Air Conditioning

Air conditioning is the process of modifying the properties of air to a more comfortable condition, which includes regulating temperature and humidity. The fundamental working principle for most AC systems is the vapor compression cycle to transfer heat from an indoor space to the outdoors. Air conditioners also filter the air and reduce humidity levels to create a more comfortable environment. Different types of systems are engineered for different applications, from cooling a single room to conditioning an entire skyscraper or factory.

The vapor compression refrigeration cycle

The working principle of most modern air conditioning systems is based on a continuous, closed-loop process that circulates a chemical refrigerant through four main components.

1. **Evaporation:** The refrigerant starts as a cold, low-pressure liquid. As warm indoor air is blown over the evaporator coils, the refrigerant absorbs the heat and evaporates, turning into a low-pressure gas. This is the phase that removes heat and humidity from the air.
2. **Compression:** The refrigerant gas is then drawn into the compressor, which increases its temperature and pressure. The compressor acts as the "heart" of the system, pumping the refrigerant through the cycle.
3. **Condensation:** The hot, high-pressure gas is then sent to the condenser coils, which are located outside. A fan blows ambient outdoor air over the coils, causing the refrigerant to release its heat and condense back into a high-pressure liquid.
4. **Expansion:** The high-pressure liquid travels to an expansion valve, which restricts its flow. This causes a sudden drop in pressure, and consequently, a significant temperature drop. The now-chilled refrigerant returns to the evaporator, and the cycle repeats.

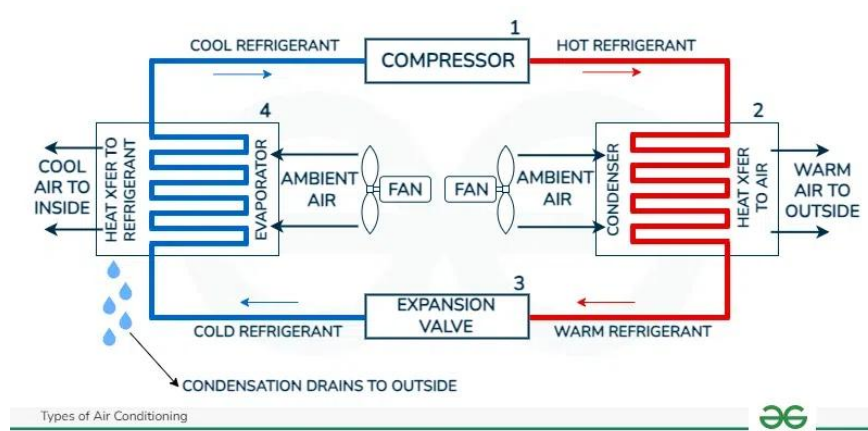


Figure 23: A schematic Diagram of Air Conditioning system

Types of AC systems

There are several types of air conditioning systems, each designed for different space and application requirements.

- **Window AC units:** A compact, self-contained unit that fits into a window opening. It is a cost-effective and easy-to-install option for cooling single rooms.
- **Split AC systems:** Consist of an indoor unit containing the evaporator and an outdoor unit housing the compressor and condenser. These units are connected by refrigerant lines and offer quieter operation inside because the noisiest components are kept outside.

- **Central AC systems:** Designed to cool large homes or entire commercial buildings through a network of ducts. These systems can be integrated with a building's heating and ventilation to form a complete HVAC system.
- **Ductless mini-split systems:** Similar to a split system but use multiple indoor units connected to a single outdoor unit. This allows for individual temperature control, or zoning, for different rooms without the need for ductwork.
- **Packaged AC systems:** An all-in-one heating and cooling solution where all components (compressor, condenser, evaporator) are enclosed in a single outdoor cabinet. They are often used for rooftop installations in commercial settings or for houses with limited indoor space.
- **Portable AC units:** Self-contained units on wheels that can be moved from room to room. They use a flexible hose to vent exhaust heat through a window and are useful for temporary cooling.
- **Chillers:** Large-scale refrigeration systems used in central AC systems for large commercial, institutional, and industrial facilities. They cool water or other liquid. Which is then circulated through a facility's air handling units to absorb heat.



Figure 24: A pictorial view of type of Air Conditioning

Air conditioners Engineering Applications

Beyond residential and commercial comfort, air conditioning and its underlying principles are critical in many engineering fields.

- **Manufacturing and Industrial processes:**
 - Precision manufacturing: Maintaining a constant temperature is vital for precision parts to prevent thermal expansion that could alter dimensions.
 - Semiconductor manufacturing: Cleanrooms use air conditioning to maintain strict temperature, humidity, and particle-free conditions for producing microchips.
 - Textile industries: Controlling temperature and humidity helps prevent static electricity and maintains material strength.
- **Data centers and server rooms:** To ensure reliability and prevent overheating, server rooms and data centers require continuous, powerful air conditioning. Chillers and specialized cooling systems are used to dissipate the massive amounts of heat generated by electronic equipment.
- **Medical and pharmaceutical:**
 - Hospitals and operating rooms: AC systems with advanced filtration provide sterile, temperature-controlled environments that reduce the risk of infection and aid patient recovery.
 - Research and laboratories: Chillers are used to cool sensitive medical equipment, chemical reactions, and cryogenic applications that require very low temperatures.
- **Food storage and transportation:** Refrigerated trucks, cold storage warehouses, and processing plants use large-scale refrigeration systems to preserve food and beverages.
- **Transportation:** Air conditioning is essential for comfort in vehicles, trains, aircraft, and ships.

Review Question?

1. What is Mechanical Engineering?
2. Which are the streams of Mechanical Engineering?
3. Explain the relevance and significance of Mechanical Engineering with examples.
4. Which are the careers in Mechanical Engineering, their role and sector.
5. What is the role of mechanical engineers in solving real case problems.
6. Explain the engineering solutions through principles of mechanical engineering with schematic diagram.
7. Define Law of conservation of energy and Explain.
8. What is Pelton Turbine? With a neat sketch explain the basic working principle of Pelton Turbine.
9. What is centrifugal Pump? With a neat sketch explain the basic working principle of Centrifugal Pump.
- 10 Explain the key vehicle systems and their components.
11. With a neat sketch explain the components of Steering system
12. With a neat sketch explain the components of vehicle Braking system.
13. With a neat sketch explain the Gear system.
14. With a neat sketch explain the key components of Power steering system.
15. Classify the flying machines.
16. What is Drone?
17. What are the classifications of Dones. Explain each of them with their applications.
18. List the parts Involved in drone making and mention its function.
19. Explain how a Rotary Wing Drone works.
20. With a neat sketch explain Vapour Compression Cycle.
21. List the applications of VCR cycle.
22. With a neat sketch explain the working of Air conditioning System.

23. List the types of AC system.
24. Write a short note on Air conditioners Engineering Applications.

Suggested Learning Resources: (Textbook/ Reference Book/ Manuals):

Textbooks:

1. Elements of Mechanical Engineering, K R Gopala Krishna, Subhash Publications, 2008
2. An Introduction to Mechanical Engineering, Jonathan Wickert and Kemper Lewis, Third Edition, 2012

Reference Books / Manuals:

1. Manufacturing Technology- Foundry, Forming and Welding, P.N.Rao Tata McGraw Hill 3rd Ed., 2003.
2. William D. Callister, Materials Science & Engineering, An Introduction, John Wiley & Sons Inc, 2010.
3. V. Ganesan, Internal Combustion Engines, Tata McGraw Hill Education; 4th edition, 2017.
4. Robotics, Appu Kuttan KK K. International Pvt Ltd, volume 1
5. Groover M. P.(2008). Automation, production systems, and computer integrated manufacturing, 3rd ed. Prentice Hall.
6. Dr SRN Reddy, Rachit Thukral and Manasi Mishra, “Introduction to Internet of Things: A Practical Approach”, ETI Labs

Web links and Video Lectures (e-Resources):

- <https://nptel.ac.in/courses/112104526>
- <https://nptel.ac.in/courses/112104616>
- <https://nptel.ac.in/courses/112104769>

- <https://theconstructor.org/practical-guide/pelton-turbine-parts-working-design-aspects/2894/>
- <https://www.mechstudies.com/centrifugal-pump/>
- <https://cfdflowengineering.com/working-principle-and-components-of-drone/>
- <https://youtu.be/i1ojp09VXHY>
- <https://www.theengineerspost.com/automatic-transmission/>
- <https://learnmech.com/continuously-variable-transmission-components-working-types/>