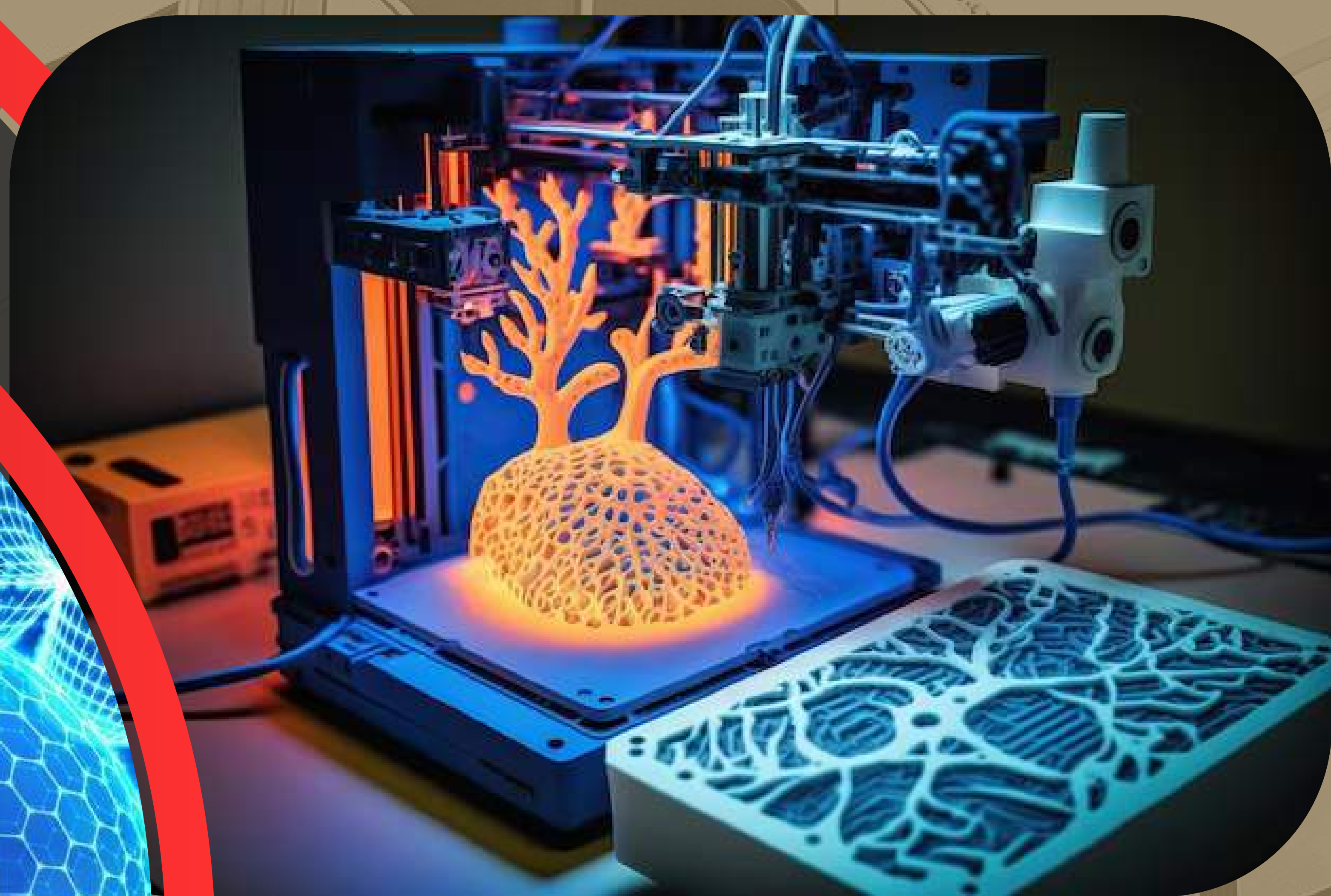
GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN

NEAR DAIRY CIRCLE, HOSUR ROAD, BENGALURU-560029, KARNATAKA
AFFILIATED TO VTU., BELAGAVI, RECOGNIZED BY GOVERNMENT OF KARNATAKA & A.I.C.T.E., NEW DELHI . WWW.GITW.IN

Dr. NAVEED
Assistant Professor
GITW-Bengaluru

Mechanical engineering is vital because it forms the backbone of modern industry and technology. It encompasses the design, development, and maintenance of machines and systems that drive industries like manufacturing, automotive, aerospace, and energy. Mechanical engineers innovate solutions that enhance efficiency, improve energy sustainability, and create advanced technologies such as robotics and automation. Their contributions are critical in building infrastructure, optimizing production processes, and developing renewable energy solutions, making mechanical engineering essential for societal advancement and economic growth.

Introduction to Mechanical Engineering/1BESC104D/204D



FIRST/SECOND
SEMESTER B.E DEGREE
2024

INTRODUCTION TO MECHANICAL ENGINEERING		Semester	I/II
Course Code	**1BESC104D/204D**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3-0-0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	50
Credits	3	Exam Hours	3
Examination type (SEE)	**Theory**		

Course outcomes

At the end of the course, the student will be able to:

1. Recognize the significance of mechanical engineering principles to solve the problems of social relevance.
2. Understand the working of I.C. engines, power transmission elements and future mobility vehicles.
3. Discuss the properties and applications of engineering materials, composite materials and smart materials.
4. Describe the working principles and applications of various manufacturing processes.
5. Explain the advances in mechanical engineering.

Module-1

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.

Number of Hours:8

Module-2

Engines: Introduction, petrol engine, diesel engines, Working of four Stroke engines, applications.
Insight into Future Mobility: Electric and Hybrid Vehicles, Components of Electric and Hybrid Vehicles. Advantages and disadvantages of EVs and Hybrid vehicles.
Power Transmission systems: Classification of gears, simple & compound gear trains, concepts of automatic and CVT transmission.

Number of Hours:8

Module-3

Engineering materials: Introduction, Classification, Ferrous and Non-Ferrous metals: Types, Properties and their applications.
Composite materials: Introduction, Constituents of a composite, Classification, Types of Matrix and Reinforcement materials, Advantages, Disadvantages and Applications of composite materials.

Smart materials: Introduction, Types - Piezoelectric materials, MR fluids, Shape memory alloys and Advantages, Disadvantages and Applications.

Number of Hours:8

Module-4

Manufacturing overview, classification of manufacturing processes, process selection criterion.
Principles of Welding, soldering, brazing.
Introduction to machine tools – lathe, drilling and milling machine.
Lathe operations: Turning, facing, knurling,
Drilling machine operations: Drilling, reaming, tapping.
Milling machine operations: End milling, face milling.
Introduction to CNC, components, advantages and applications.
Basic principles of 3D printing.

Number of Hours:8

Module-5

Advances in mechanical engineering

Automation technology: Definition of automation, types of automation, basic elements of automation.
Mechatronic systems: Definition of mechatronics, elements of mechatronics systems, examples.
Elementary sensors: Working principle and applications of Potentiometer, capacitive sensor and optical encoders.
Integrated system: Need for integration of technologies, ADAS (Advanced Driver Assistance System).

Number of Hours:8

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/

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped Classroom
- Simulation and Virtual Labs
- Partial Delivery of course by Industry experts
- ICT-Enabled Teaching
- Video demonstration

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE is at least 40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA):

CCA shall be conducted for 25 marks. It is evaluated through the learning activity which is aimed at enhancing the holistic development of students. The activity should align with course objectives and promote higher-order thinking and application-based learning.

Learning Activity : Case Study Presentation (Marks - 25)

Rubrics for Learning Activity:

Case Study Presentation (25 Marks)

Case Study topic should relate to key learning area from the syllabus and allow exploration of practical applications, challenges, and innovations relevant to engineering education and industry.

Performance Indicators	Excellent	Good	Satisfactory	Needs Improvement	Poor
Understanding of Case (5 Marks) (PO 1)	Demonstrates deep understanding **(5)**	Good understanding **(4)**	Adequate understanding. **(3)**	Limited understanding **(2)**	No clear understanding. **(0-1)**
Analysis & Critical Thinking (10 Marks) (PO 2)	Thorough, logical analysis with strong reasoning and innovative insights. **(9-10)**	Clear analysis with mostly logical reasoning. **(7-8)**	Basic analysis with some reasoning gaps. **(5-6)**	Weak analysis; mostly descriptive without reasoning. **(3-4)**	No clear analysis or reasoning. **(0-2)**
Documentation & Presentation Skills (5 Marks) (PO 9)	Documentation is complete, accurate, well-structured, follows all formatting guidelines. Well-structured, clear, confident delivery; excellent visuals. **(5)**	Documentation is mostly complete and accurate, well-organized, follows formatting guidelines with minor deviations. Good structure, clear delivery; visuals mostly effective. **(4)**	Documentation covers most required elements but has some inaccuracies or omissions. Average structure; delivery clear but lacks engagement. **(3)**	Documentation is incomplete with noticeable inaccuracies. Poor organization; visuals unclear. **(2)**	Documentation is largely missing or irrelevant, lacks structure. Unclear, disorganized presentation. **(0-1)**
Q&A Handling (5 Marks) (PO 9)	Confident, accurate, and concise responses. **(5)**	Good responses with minor gaps. **(4)**	Adequate responses; some uncertainty. **(3)**	Weak or hesitant responses. **(2)**	Unable to answer questions. **(0-1)**

GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN

Department of Mechanical Engineering

Near Dairy Circle, Hosur Road, Bengaluru , Karnataka 560029

INTRODUCTION TO MECHANICAL ENGINEERING

(1BESCK104D/204D)

As per New Syllabus (2025) Prescribed by V.T.U. (CBCS System)

For

FIRST / SECOND SEMESTER

(Bachelor of Engineering)

MODULE-01

Introduction, Energy, Vehicle System, Flying Machines, Refrigeration & AC

Dr.NAVEED M.Tech., PhD.

Assistant Professor

Department of Mechanical Engineering

MODULE-01

Syllabus:

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.

1.0 Introduction:

Meaning of Engineering:

The word “engineering” comes from a latin term “ingeniere” meaning “to design or to devise,” which reflects the essence of the profession. Engineers use their knowledge of mathematics, science, materials, communication, and business to design solutions that improve human life. Their work combines creativity with technical skill to turn ideas into useful and practical products.

Engineering vs. Science:

Although engineering and science are related, they serve different purposes. Scientists focus on discovering natural laws and understanding how things work, while engineers apply these scientific principles to solve real-world problems. Thus, engineering acts as a bridge between scientific discoveries and practical applications. For example, while a scientist may study how electricity behaves, an electrical engineer uses that knowledge to design motors, circuits, and power systems.

Use of Mathematical and Scientific Tools:

Engineers use mathematics, scientific principles, and advanced computer simulations to test and refine designs before building them. This reduces trial and error and leads to more accurate and efficient solutions. For instance, aerospace engineers simulate airflow over an aircraft wing on a computer before creating any physical prototype.

Engineering as a Driver of Society and Economy:

Engineering plays a major role in social and economic development. Almost every modern convenience—smartphones, vehicles, roads, factories—exists because of engineering. By transforming ideas into usable products and systems, engineering becomes an essential part of industrial growth and daily life. A clear example is civil engineers designing bridges and highways that support transportation and trade.

Roles and Responsibilities of Engineers:

Engineers design products, the machines that manufacture them, and the processes that ensure quality and safety. They plan and supervise the construction of buildings, transportation systems, and infrastructure. Some engineers work to extract raw materials responsibly, while others develop advanced materials that improve product performance. For example, mechanical engineers design automotive engines, and chemical engineers create materials used in batteries and medical equipment.

Impact on Environment and Society:

Today’s engineers must consider environmental impact, public safety, and sustainability in all their work. They help improve healthcare systems, food safety, water supply, and even financial operations through accurate and efficient systems. An example is environmental engineers designing water-treatment plants to provide clean drinking water and reduce pollution.

Ultimately, the goal of engineering is to create devices, structures, and systems that perform tasks more efficiently, accurately, and safely than before. Whether designing a small tool or a large infrastructure project, engineers aim to improve quality of life and advance society through innovation and practical solutions.

What Mechanical Engineering Covers:

Mechanical engineering deals with the study of forces, materials, energy, fluids, and motion. Mechanical engineers use this knowledge to create machines and systems that help society. Their work focuses on designing products that make life easier, safer, and more efficient.

Role of Mechanical Engineering in Industries and Society:

Mechanical Engineering is one of the basic branches of engineering and its fundamental principles are used in the design, development and construction of nearly all of the physical devices and systems we see around us including but not limited to automobiles, machines in all kind of factories, machinery used in building construction, road construction, agriculture, etc.

Mechanical Engineers in the energy sector are responsible to design and operate various power plants related to fossil fuel, hydroelectric, nuclear etc., They are involved in all aspects of the production and conversion of energy from one form to another. Mechanical Engineers are also involved in exciting projects such as developing alternatives to thermal energy, power cycle devices, fuel cells, gas turbines, and innovative uses of coal, wind, and tidal flow.

Mechanical Engineering plays a critical role in manufactured technologies, from cars to airplanes to refrigerators. It enables us to do many daily activities with ease, as it brings helpful technologies to our modern society. It is one of the most important subdivisions of engineering, because without it, many of the technologies we use every day would not be available.

Mechanical Engineers are involved with the design, construction and operations of all kinds of machinery. They conceptualize design for any product to be manufactured. They also develop, test and manufacture the state-of-the-art machinery. Manufacturing sector encompasses a set of industries to make or produce anything in a factory and therefore, it requires a great deal of specialized knowledge.

Without Mechanical Engineering, we would not have things like engines, generators, elevators or even air conditioning. While we might not even realize it, we most likely use something that has been mechanically engineered every day.

Top Ten Achievements of Mechanical Engineering:

Achievement	Brief Description
Automobile	Mechanical engineers created efficient engines and mass-production methods, making cars affordable and transforming transportation.
Apollo Program	Engineers designed rockets, spacecraft, and systems that enabled humans to land on the Moon and return safely.
Power Generation	Engineers developed machines that convert fuel, wind, water, and nuclear energy into electricity for homes and industries.
Agricultural Mechanization	Farming machines like tractors and harvesters increased food production and reduced manual labor.
Airplane	Engineers advanced aircraft engines, structures, and safety systems, making global air travel possible.
Integrated-Circuit Mass Production	Precision machines built by engineers enabled large-scale production of microchips used in computers and electronics.
Air Conditioning & Refrigeration	Engineers invented safe, efficient cooling systems that preserve food and protect people from extreme heat.
Computer-Aided Engineering (CAE)	Software tools created by engineers allow designs to be tested on computers, reducing time and cost.
Bioengineering	Mechanical engineers designed prosthetics, artificial organs, and medical devices that improve healthcare.
Codes & Standards	Engineers developed safety rules and technical standards that make machines, buildings, and products safe and reliable worldwide.

1.1 Streams in Mechanical Engineering and Their Relevance/Significance

Design Engineering:

This stream focuses on creating and improving machines, components, and systems using design principles, CAD software, simulations, and material selection.
Significance: Ensures products are safe, efficient, and reliable. Important in automotive, aerospace, robotics, and manufacturing industries.

Thermal Engineering:

Deals with heat transfer, thermodynamics, boilers, turbines, engines, HVAC, and energy conversion systems.
Significance: Essential for designing power plants, engines, refrigeration, and energy-efficient systems that address global energy needs.

Manufacturing Engineering:

Involves production processes, machining, CNC, automation, and quality control.
Significance: Enables mass production of high-quality goods at low cost. Important for automotive, electronics, aerospace, and consumer product industries.

Fluid Mechanics & Hydraulic Engineering:

Studies fluid behavior and its applications in machines and systems.
Significance: Important for pumps, turbines, compressors, pipelines, aircraft aerodynamics, and renewable systems like wind turbines.

Materials & Metallurgical Engineering:

Focuses on material properties, testing, and selection for engineering applications.
Significance: Helps choose suitable materials for strength, durability, safety, and performance in automotive, aerospace, biomedical, and construction fields.

Mechatronics & Automation:

Combines mechanical engineering with electronics, sensors, control systems, and programming.
Significance: Drives robotics, industrial automation, smart manufacturing, and modern intelligent machines.

Robotics Engineering:

Covers the design, development, and control of robots.
Significance: Improves precision in manufacturing, reduces human risk in hazardous jobs, and supports automation in healthcare, agriculture, and space missions.

Automobile Engineering:

Focuses on vehicle design, engines, powertrain systems, and technologies like EVs and hybrids.
Significance: Helps create safer, cleaner, and more efficient transportation systems.

Aerospace Engineering:

Involves aircraft and spacecraft design, propulsion, aerodynamics, and flight systems.
Significance: Supports aviation growth, defense technology, satellite systems, and space exploration.

Energy Engineering:

Works with renewable and non-renewable energy systems such as solar, wind, nuclear, and thermal power.
Significance: Helps meet global energy demands and leads the shift toward sustainable energy sources.

Industrial Engineering:

Optimizes processes, workflows, logistics, and supply chains.
Significance: Improves productivity, reduces waste, and increases efficiency in manufacturing and service industries.

Marine Engineering:

Deals with the design and operation of ships, submarines, and ocean equipment.
Significance: Supports global shipping, naval defense, offshore oil and gas, and underwater exploration.

Stream	What It Focuses On	Relevance / Significance
Design Engineering	Designing machines, components, CAD modeling, simulation	Ensures products are safe, efficient, reliable; used in automotive, aerospace, robotics
Thermal Engineering	Heat transfer, thermodynamics, engines, HVAC, power plants	Essential for energy systems, refrigeration, engines, climate control
Manufacturing Engineering	Production processes, machining, CNC, automation, quality control	Enables mass production of high-quality products at low cost
Fluid Mechanics & Hydraulics	Behavior of liquids and gases, pumps, turbines, aerodynamics	Important for pipelines, aircraft design, turbines, wind energy
Materials & Metallurgy	Material properties, testing, material selection	Ensures durability, safety, and performance of engineering products
Mechatronics & Automation	Integration of mechanics, electronics, sensors, controls	Drives robotics, smart manufacturing, automated machines
Robotics Engineering	Design and control of robots	Useful for precision manufacturing, medical robots, and hazardous tasks
Automobile Engineering	Vehicle design, engines, EVs, safety systems	Helps develop safer, cleaner, and more efficient transportation
Aerospace Engineering	Aircraft and spacecraft design, propulsion, aerodynamics	Supports aviation, defense, satellites, and space exploration
Energy Engineering	Renewable/non-renewable energy systems, solar, wind, nuclear	Helps meet global energy demand and supports sustainable development
Industrial Engineering	Process optimization, logistics, supply chains	Increases productivity and reduces waste in industries
Marine Engineering	Ships, submarines, underwater systems	Important for shipping, naval defense, and offshore operations

1.2 Role of Mechanical Engineers in Solving Real Case Problems (with Examples):

Mechanical engineers play a vital role in identifying real-world problems, analyzing their causes, and designing practical, safe, and efficient solutions. They apply principles of mechanics, thermodynamics, materials science, and design to improve systems and machines. They use simulations, prototypes, and testing to ensure reliability. They also consider cost, safety, environmental impact, and user comfort, making their solutions useful for society.

Improving Road Safety (Example: Airbags & ABS Brakes)

Mechanical engineers developed airbags, anti-lock braking systems, and crumple zones to reduce injuries during accidents. These innovations use sensors and smart materials to protect passengers. Impact: Reduced fatal accidents and improved vehicle safety.

Reducing Heat in Mobile Phones & Laptops

Mechanical engineers designed cooling fans, heat sinks, and thermal materials to manage overheating in electronics. Impact: Devices perform better, last longer, and remain safe to use.

Providing Clean Water in Rural Areas

They created hand pumps, low-cost water purifiers, and gravity-based filters to solve water scarcity and contamination. Impact: Safe drinking water becomes accessible to rural communities.

Solving Urban Traffic Problems (Metro Rail Systems)

Mechanical engineers helped design metro train components such as braking systems, ventilation, and energy-efficient motors. Impact: Reduced traffic, pollution, and travel time in cities.

Improving Healthcare (Artificial Limbs & Medical Devices)

They developed prosthetic limbs, artificial joints, ventilators, wheelchairs, and surgical tools using biomechanics and materials engineering. Impact: Improved patient recovery and quality of life.

Disaster Response and Rescue Technologies

Mechanical engineers designed earthquake-resistant buildings, shock absorbers, and rescue robots for search operations. Impact: Faster rescue efforts and more lives saved during disasters.

Reducing Energy Use in Buildings (Efficient HVAC Systems)

They created energy-efficient heating, ventilation, and air-conditioning systems to reduce electricity consumption. Impact: Lower energy bills and better indoor comfort.

Sustainable Energy Solutions (Wind Turbines & Solar Trackers)

Mechanical engineers improved wind turbines, solar trackers, and renewable energy systems to increase efficiency. Impact: Cleaner energy production and reduced environmental pollution.

Problem Area	Role of Mechanical Engineers	Example	Impact
Road Safety	Design safety systems using sensors and materials	Airbags, ABS brakes, crumple zones	Fewer injuries and reduced accident deaths
Electronics Overheating	Develop cooling systems and thermal solutions	Heat sinks, cooling fans in laptops/phones	Devices run safely, faster, and last longer
Clean Water Supply	Create low-cost, reliable water systems	Hand pumps, simple purifiers, gravity filters	Safe drinking water for rural areas
Urban Traffic & Transport	Design efficient transportation components	Metro braking systems, motors, ventilation	Less traffic, less pollution, faster travel
Healthcare & Medical Devices	Apply biomechanics to design medical tools	Prosthetic limbs, artificial joints, ventilators	Better treatments and improved patient life
Disaster Response	Build safe structures and rescue machines	Earthquake-resistant designs, rescue robots	Faster rescue and reduced loss of life
Energy Efficiency in Buildings	Design efficient cooling/heating systems	Modern HVAC systems	Lower energy bills and improved comfort
Sustainable Energy	Develop renewable energy technologies	Wind turbines, solar trackers	Cleaner energy and reduced pollution

1.3 Careers in Mechanical Engineering:

Design Engineering:

Mechanical engineers in design focus on creating new machines, tools, engines, and mechanical systems. They use CAD software, simulations, and engineering principles to design products such as automobiles, robots, household appliances, and industrial machinery. This career path requires creativity, problem-solving skills, and strong technical knowledge.

Manufacturing Engineering:

Manufacturing engineers work on how products are made. They design production processes, select machines, supervise assembly lines, and ensure quality control. Their work helps industries produce goods efficiently, safely, and at low cost. They play a vital role in automotive plants, electronics factories, and consumer-goods manufacturing.

Automotive and Aerospace Engineering:

Mechanical engineers in this field work on vehicles, aircraft, spacecraft, and engines. They deal with aerodynamics, propulsion, structural design, and safety systems. Careers include designing car engines, electric vehicles, aircraft components, drones, and space-mission hardware. This field requires strong knowledge of materials, thermal systems, and mechanics.

Thermal and Energy Engineering:

This career focuses on heat transfer, thermodynamics, power plants, HVAC systems, refrigeration, and renewable energy. Engineers design boilers, turbines, solar systems, wind turbines, and air-conditioning systems. They help create efficient and sustainable energy solutions used in homes, industries, and power stations.

Robotics and Mechatronics:

Mechanical engineers in robotics combine mechanical design with electronics, sensors, and programming. They design industrial robots, automation systems, robotic arms, and smart machines used in manufacturing, hospitals, and research labs. This field is rapidly growing with the rise of Industry 4.0 and automation.

Biomechanics and Medical Devices:

In this field, mechanical engineers design prosthetic limbs, artificial joints, wheelchairs, surgical tools, and medical equipment. They apply principles of mechanics and materials to support human health and improve the quality of life for patients. This career blends engineering with biology and healthcare.

Consulting and Industrial Services:

Mechanical engineers often work as consultants, providing expert solutions to industries such as petroleum, chemical, food processing, plastics, manufacturing, and energy. They help companies solve technical problems, improve efficiency, and meet safety standards. This role requires strong analytical and communication skills.

Government and Public Sector Jobs:

Mechanical engineers are employed in railways, defense organizations, PWD, energy departments, space agencies, and national laboratories. They work on public infrastructure, transportation systems, defense technology, and national research programs. These jobs offer stability and opportunities to contribute to national development.

Research and Academia:

Mechanical engineers can pursue careers as researchers or professors in universities, engineering colleges, and research organizations. They work on developing new technologies, publishing research papers, and training the next generation of engineers. This path suits those interested in innovation and teaching.

Management, Finance, and Entrepreneurship:

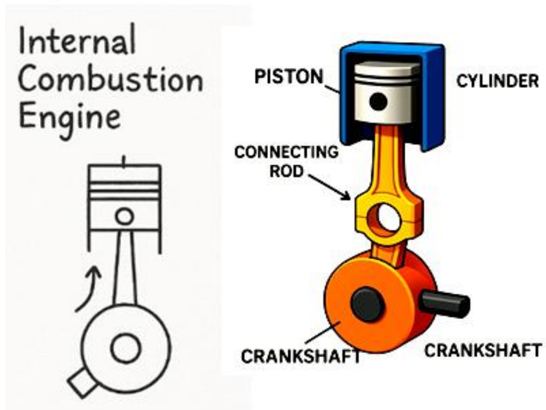
Because mechanical engineering builds strong analytical and problem-solving skills, many engineers succeed in managerial positions, technical sales, operations, finance, and start-ups. Some become project managers, business leaders, or start their own engineering companies.

Career Stream	What Mechanical Engineers Do
Design Engineering	Design machines, tools, vehicles, and mechanical systems.
Manufacturing Engineering	Plan production, operate machines, and ensure product quality.
Automotive & Aerospace	Work on engines, aircraft, EVs, propulsion, and safety systems.
Thermal & Energy Engineering	Design HVAC, power plants, turbines, solar/wind systems.
Robotics & Mechatronics	Build robots, automation systems, and smart machines.
Biomechanics & Medical Devices	Develop prosthetics, medical tools, and healthcare equipment.
Consulting & Industrial Services	Provide technical advice to industries (oil, chemical, food, etc.).
Government & Public Sector	Work in railways, defense, PWD, space agencies, research labs.
Research & Academia	Teach, conduct research, and develop new technologies.
Management & Entrepreneurship	Lead projects, manage operations, start engineering companies.

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

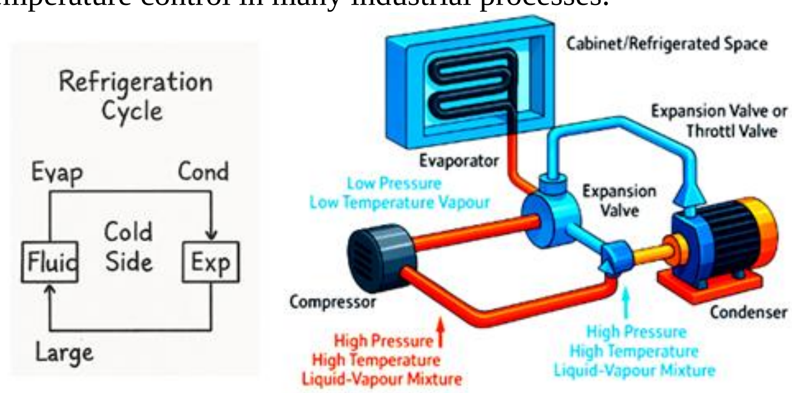
Internal Combustion Engine

The internal combustion engine is a key mechanical engineering solution based on the principles of thermodynamics and mechanics. Fuel burns inside the engine cylinder, producing high-pressure gases that push the piston downward. This linear motion is converted into rotational motion through the crankshaft, which ultimately powers the vehicle's wheels. Engineers use thermodynamic cycles, heat transfer, and material strength concepts to make engines efficient, powerful, and reliable.



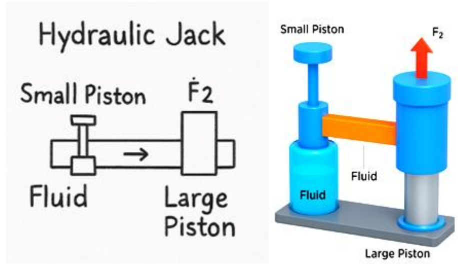
Refrigeration Cycle

The refrigeration or air-conditioning system works on the principles of thermodynamics and heat transfer. In this cycle, a refrigerant absorbs heat from the cold region in the evaporator. The compressor increases the pressure and temperature of the refrigerant, and the condenser releases the absorbed heat to the surroundings. The expansion valve then reduces the pressure so the cycle can repeat. This system allows food preservation, cooling of rooms, and temperature control in many industrial processes.



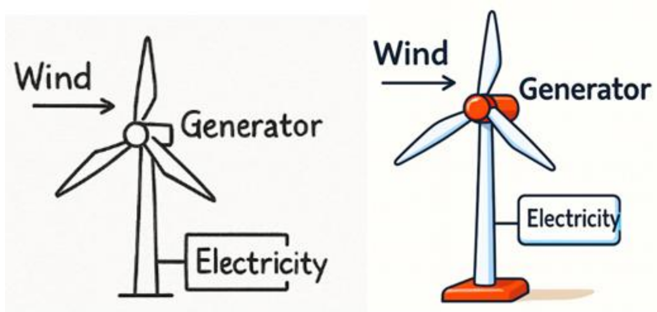
Hydraulic Jack

A hydraulic jack operates using fluid mechanics, specifically Pascal's Law, which states that pressure applied to an enclosed fluid is transmitted equally in all directions. When a small force is applied on a small piston, it creates a pressure that acts on a larger piston, generating a much larger upward lifting force. This principle allows mechanics to lift vehicles and heavy loads with minimal effort. Mechanical engineers design these systems to be safe, leak-proof, and efficient.



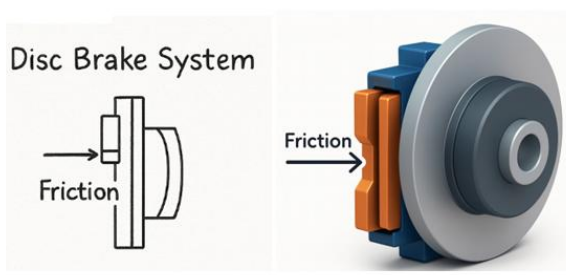
Wind Turbine

Wind turbines work on the principles of aerodynamics, mechanics, and energy conversion. When wind strikes the blades, it creates a lift force that rotates the rotor. This rotational motion is transferred through a shaft and gearbox to a generator, which converts mechanical energy into electrical energy. Mechanical engineers optimize blade shape, materials, and turbine efficiency to produce more electricity from available wind resources.



Disc Brake System

The disc brake system is an application of mechanics, friction, and materials engineering. When the driver presses the brake lever or pedal, hydraulic fluid transmits pressure to the caliper, causing the brake pads to press against the rotating disc. The friction generated between the pads and disc slows or stops the vehicle. Engineers design the system to withstand high temperatures, provide reliable braking performance, and ensure safety in all driving conditions.



1.5 Energy Conversion:

Energy conversion is the process of changing energy from one form to another so it can be used effectively in daily life and engineering applications. Energy itself cannot be created or destroyed; it only changes form. Mechanical engineers design machines and systems that convert energy efficiently—such as engines, turbines, refrigerators, and power plants. These systems make it possible to use natural resources like fuel, sunlight, wind, and water in a usable form such as electricity, motion, or cooling. Efficient energy conversion is important because it reduces waste, saves resources, and supports sustainable development. The following represent some live examples of energy conversion.

Device / System	Energy Converted From	Energy Converted To	Explanation
Car Engine (IC Engine)	Chemical energy of fuel	Mechanical energy	Fuel burns, produces heat, pushes piston, moves vehicle.
Thermal Power Plant	Heat energy from coal/oil/gas	Electrical energy	Heat produces steam → turbine rotates → generator makes electricity.
Hydroelectric Power Plant	Potential energy of stored water	Electrical energy	Falling water spins turbine connected to a generator.
Solar Panel (PV Cell)	Solar energy (sunlight)	Electrical energy	Sunlight is directly converted into electricity through photovoltaic cells.
Wind Turbine	Kinetic energy of wind	Electrical energy	Wind rotates turbine blades connected to a generator.
Refrigerator	Electrical energy	Cooling effect (heat transfer)	Compressor uses electricity to move heat from inside to outside.
Electric Motor	Electrical energy	Mechanical energy	Motor rotates shaft to run machines, fans, pumps, etc.
Generator (General)	Mechanical energy	Electrical energy	Rotating shaft induces current to produce electricity.

Turbines:

A turbine is a machine that converts the energy of moving fluids into rotational mechanical energy**.** When a fluid such as steam, water, or gas flows over the turbine blades, it makes them spin, and this rotation can be used to generate electricity or run machines.

There are different types of turbines based on the working fluid:

Steam Turbine – uses high-pressure steam from boilers.

Water (Hydraulic) Turbine – uses flowing or falling water, as in hydroelectric plants.

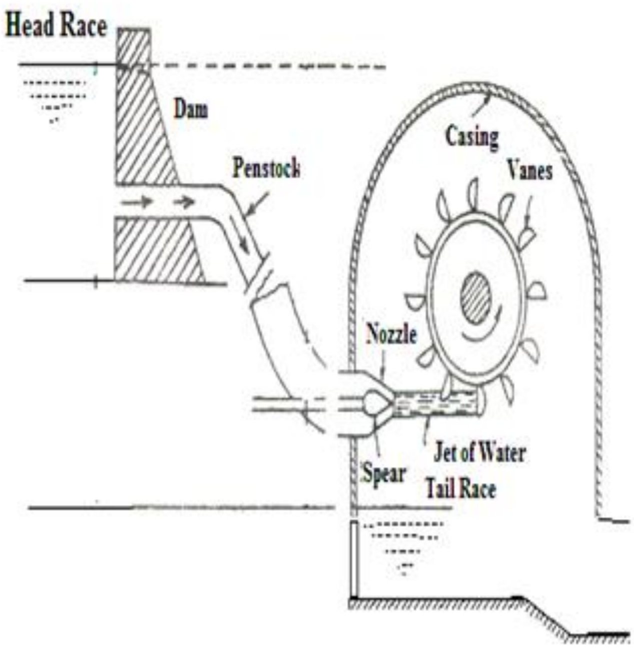
Gas Turbine – uses high-temperature, high-pressure gases from fuel combustion.

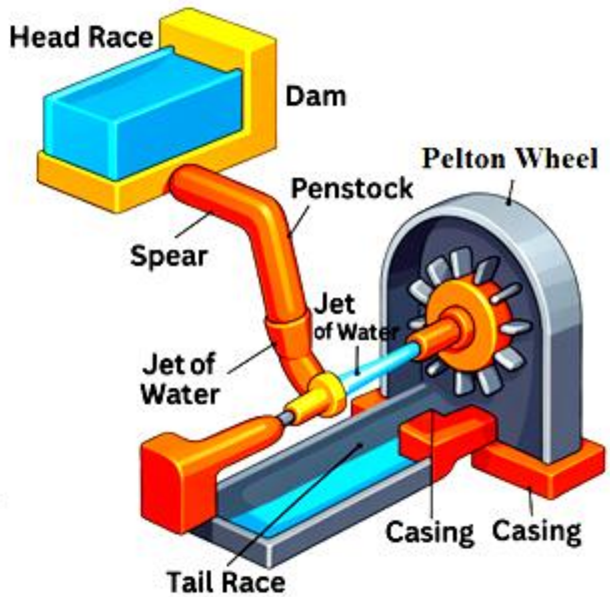
Hydraulic Turbines:

Hydraulic (water) turbines are the machines which convert the water energy (Hydro power) into Mechanical energy.The water energy may be either in the form of potential energy as we find in dams, reservoirs, or in the form of kinetic energy in flowing water. The shaft of the turbine directly coupled to the electric generator which converts mechanical energy in to electrical energy. This is known as "Hydro-Electric power".

Examples: Pelton Wheel, Francis Turbine and Kaplan Turbine.

1.6 Pelton Wheel: A Pelton wheel is an impulse turbine that converts the kinetic energy of a high-velocity water jet into mechanical rotational energy. The following figure illustrates construction details and operating principle.





Construction Details:

Part	Function
Head Race	Stores water at a high level to create potential energy.
Dam	Holds water and guides it to the penstock.
Penstock	A pipe that carries high-pressure water from the reservoir to the nozzle.
Spear (Needle)	Controls the flow and velocity of water jet coming from the nozzle.
Nozzle	Converts water pressure into a high-speed jet directed at the buckets.
Jet of Water	Strikes the Pelton wheel buckets to produce rotation.
Pelton Wheel (Runner with Buckets)	Converts the kinetic energy of the jet into mechanical rotation.
Vanes / Buckets	Split and deflect the jet water smoothly so maximum energy is transferred.
Casing	Encloses the turbine and prevents water from splashing out.
Tail Race	Carries used water away after it leaves the turbine.

Operating Principle:

In a Pelton wheel, high-pressure water from the head race flows through the penstock and enters the nozzle, which converts it into a high-velocity jet. The spear adjusts the jet flow. This jet strikes the double-cup buckets on the Pelton wheel, causing the runner to rotate due to impulse force. After hitting the buckets, the water loses its energy and falls into the tail race. The turbine thus converts the kinetic energy of the water jet into mechanical energy efficiently, especially at high heads and low flow rates.

VIDEO: https://drive.google.com/file/d/1YyQ_JNAzMSGCK6H3BdiGGtRtQ8PFHt3B/view?usp=drive_link

Pumps:

A pump is a machine that moves fluids—such as water, oil, or air—from one place to another by increasing their pressure or flow. Pumps add energy to the fluid so it can travel through pipes, reach higher levels, or be stored in tanks.

There are different types of pumps based on how they move the fluid:

Centrifugal Pump – Uses a rotating impeller to push water outward and increase pressure. It is commonly used in houses, industries, and irrigation systems.

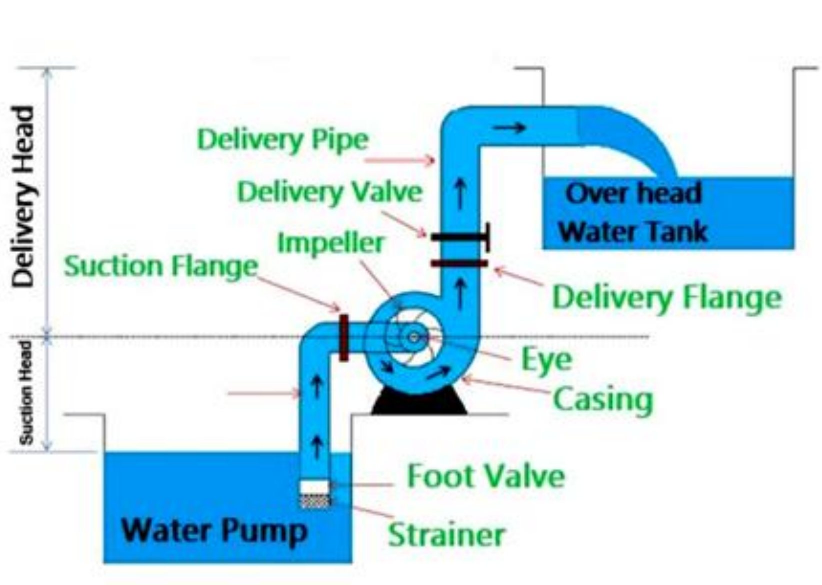
Reciprocating Pump – A type of positive displacement pump that uses a piston moving back and forth to draw in and push out fluid. These pumps are used in high-pressure applications like hydraulic systems and water supply for small-scale setups.

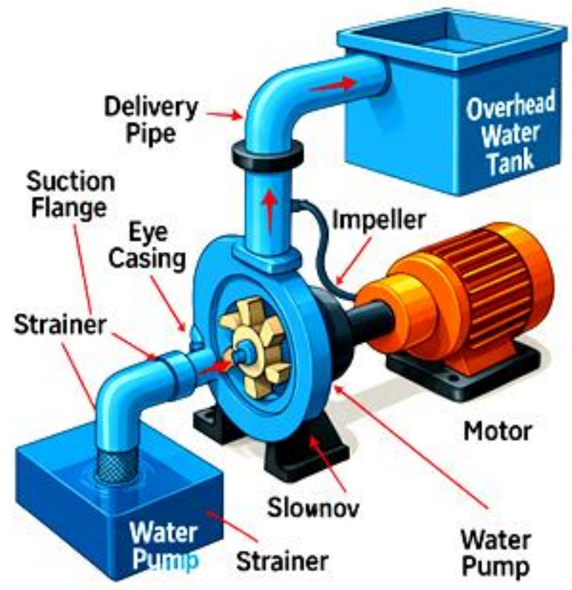
Rotary Pump – Uses rotating parts like gears, screws, or vanes to move viscous fluids smoothly, often used in lubrication, chemical transfer, and fuel systems.

1.7 Centrifugal Pump: A centrifugal pump is a machine that uses a rotating impeller to move fluid by converting mechanical energy into pressure energy. The following figure illustrates construction details and operating principle.

Construction Details:

Part	Function
Impeller	Rotates at high speed to increase fluid velocity and pressure.
Casing (Volute / Eye Casing)	Encloses the impeller and directs water from inlet to outlet.
Suction Pipe	Carries water from the source to the pump.
Strainer	Filters out debris to prevent pump blockage.
Foot Valve	A one-way valve that prevents backflow and maintains priming.
Suction Flange	Connection point where the suction pipe attaches to the pump.
Delivery Pipe	Carries water from the pump to the overhead tank or discharge point.
Delivery Valve	Controls the flow of water in the delivery line.
Delivery Flange	Connection point for the delivery pipe.
Motor	Provides mechanical power to rotate the impeller.





Operating Principle:

A centrifugal pump works by rotating the impeller at high speed, which pushes water outward due to centrifugal force. Water enters the pump through the suction pipe and reaches the eye of the impeller, where its velocity increases as it moves outward. The casing converts this high-velocity water into high-pressure water, which then flows through the delivery pipe to the overhead tank. Thus, the pump converts mechanical energy from the motor into pressure energy to lift and move water efficiently.

Video:

https://drive.google.com/file/d/1VEDVNZT_9Q_sWKAL5jqkSn1i8HRBQkEF/view?usp=drive_link

Difference between Pelton Wheel and Centrifugal Pump

Point of Difference	Pelton Wheel	Centrifugal Pump
Basic Function	Converts water energy into mechanical energy	Converts mechanical energy into water energy (pressure/flow)
Type of Machine	Turbine (power generating device)	Pump (power consuming device)
Working Principle	Uses impulse of water jet	Uses centrifugal force created by rotating impeller
Working Fluid	High-velocity water jet	Water or other liquids at low–medium velocity
Application	Hydropower plants for electricity generation	Water supply, irrigation, industries
Energy Conversion	Hydraulic energy → Mechanical energy	Mechanical energy → Hydraulic energy
Operating Conditions	Works best under high head and low flow	Works well under low head and high flow
Main Component	Bucket-shaped blades mounted on runner	Impeller inside pump casing
Output	Produces shaft power to run generators	Delivers pressurized water to pipelines
Source of Input	High-pressure water from nozzle	Mechanical power from motor/engine

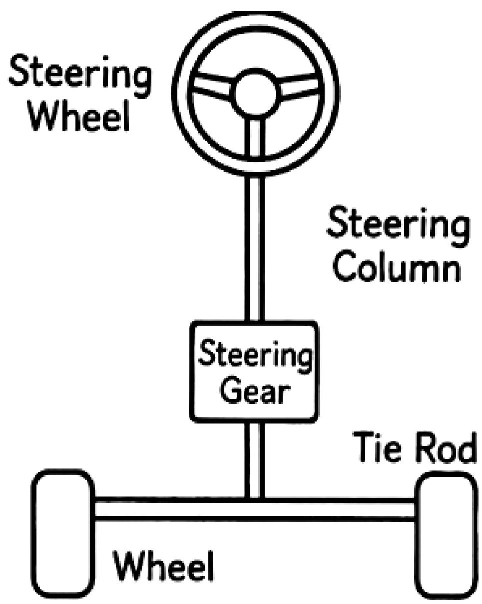
1.8 Vehicle Systems:

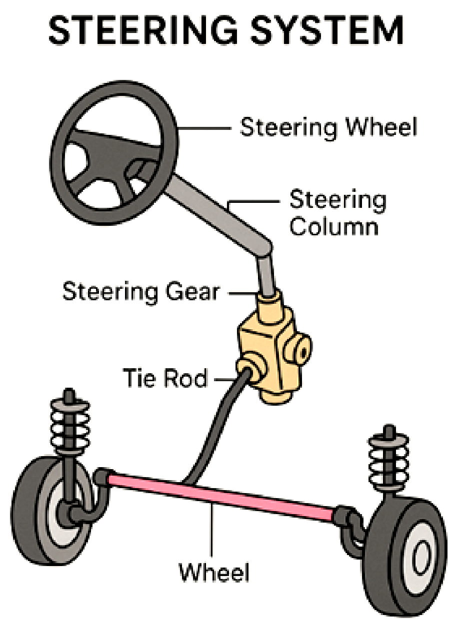
A vehicle system is a collection of different mechanical and electrical parts that work together to make a vehicle move, steer, stop, and operate safely. Every vehicle is made up of the following major systems represented in the table.

Vehicle System	Function (Simple Explanation)
Steering System	Helps the driver control the direction of the vehicle by turning the front wheels left or right.
Brake System	Slows down or stops the vehicle using friction between brake pads and wheels.
Gear System (Transmission)	Transfers engine power to the wheels and adjusts speed and torque for smooth driving.
Power Steering System	Reduces the driver's effort when turning the steering wheel using hydraulic or electric assistance.

1.9 Steering System:

The steering system is the part of a vehicle that allows the driver to control the direction of movement. It connects the steering wheel to the front wheels and helps turn them left or right smoothly. A good steering system provides stability, easy handling, and safe control of the vehicle at all speeds.





Steering Wheel: The steering wheel is the part held by the driver to control the direction of the vehicle. When the driver turns the wheel, this movement is passed into the steering system. Its function is to let the driver turn the vehicle smoothly and safely.

Steering Column: The steering column is the long shaft that connects the steering wheel to the steering gear. It carries the turning motion from the steering wheel down to the steering mechanism. Its function is to provide a firm, stable connection and transmit the driver's input accurately.

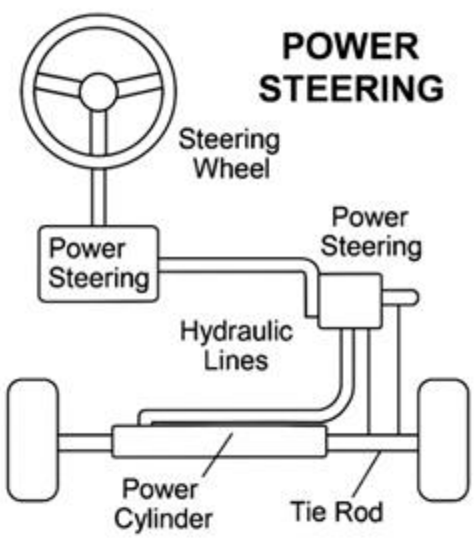
Steering Gear: The steering gear changes the rotary motion of the steering column into the side-to-side motion needed to turn the wheels. It also reduces the effort required from the driver. Its function is to convert the driver's turning input into controlled wheel movement.

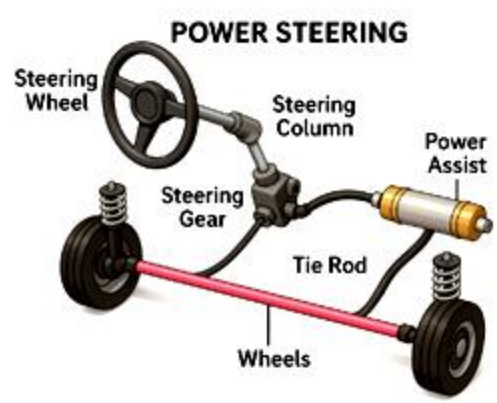
Tie Rod: The tie rod links the steering gear to the wheels. When the steering gear moves, the tie rod pushes or pulls the wheels to the left or right. Its function is to accurately transfer the steering motion to the wheels while allowing suspension movement.

Wheels: The wheels turn according to the movement received from the tie rods. Their function is to change the direction of the vehicle and maintain road grip during steering.

Part	Function (Brief)
Steering Wheel	Allows the driver to control the direction of the vehicle.
Steering Column	Transmits the driver's steering movement to the steering gear.
Steering Gear	Converts rotary motion into side-to-side motion to turn the wheels with less effort.
Tie Rod	Transfers movement from the steering gear to the wheels accurately.
Wheels	Turn left or right to change the direction of the vehicle.

1.10 Power Steering: Power steering is a system that uses hydraulic or electric assistance to help the driver turn the steering wheel with less effort. The following figure illustrates construction details and operating principle.





Construction Details:

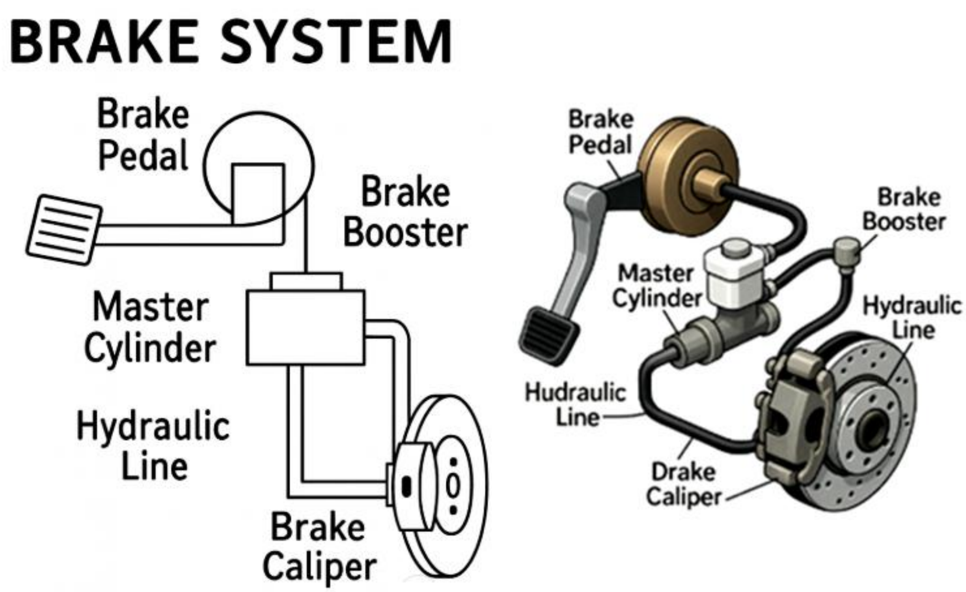
Part	Brief Description
Steering Wheel	The driver turns it to control vehicle direction.
Steering Column	Shaft that carries steering movement to the steering gear.
Steering Gear	Converts rotary motion into side-to-side motion for turning wheels.
Power Assist Unit / Pump	Provides hydraulic pressure to reduce steering effort.
Hydraulic Lines	Pipes that carry high-pressure and return fluid in the system.
Power Cylinder	Uses hydraulic pressure to push the steering linkage.
Tie Rod	Transfers steering movement to the wheels.
Wheels	Turn left or right based on the movement from the tie rod.

Operating Principle:

Power steering works by combining the driver's steering input with hydraulic assistance to make turning the vehicle much easier. When the driver rotates the steering wheel, the motion travels through the steering column to the steering gear. As the steering gear begins to move, it also operates a control valve located inside the power steering unit. This valve senses the direction in which the driver is turning and immediately opens a pathway for pressurized hydraulic fluid from the power assist pump.

The pump continuously supplies pressurized fluid, but this pressure is only used when the valve directs it toward the power cylinder. Based on the driver's turning direction, the valve sends hydraulic fluid to one side of the power cylinder. The fluid pressure pushes the piston inside the cylinder, creating a strong assisting force in the same direction as the driver's turn. This extra force helps move the tie rod more easily and turns the wheels with very little effort from the driver. Once the driver stops turning the wheel, the control valve returns to its neutral position, stopping the hydraulic assistance. This makes the steering smooth, light, and highly responsive, especially during low-speed driving or parking.

1.11 Brake System: A brake system is a vehicle mechanism that slows down or stops the wheels by converting the vehicle's kinetic energy into heat through friction. The following figure illustrates construction details and operating principle.



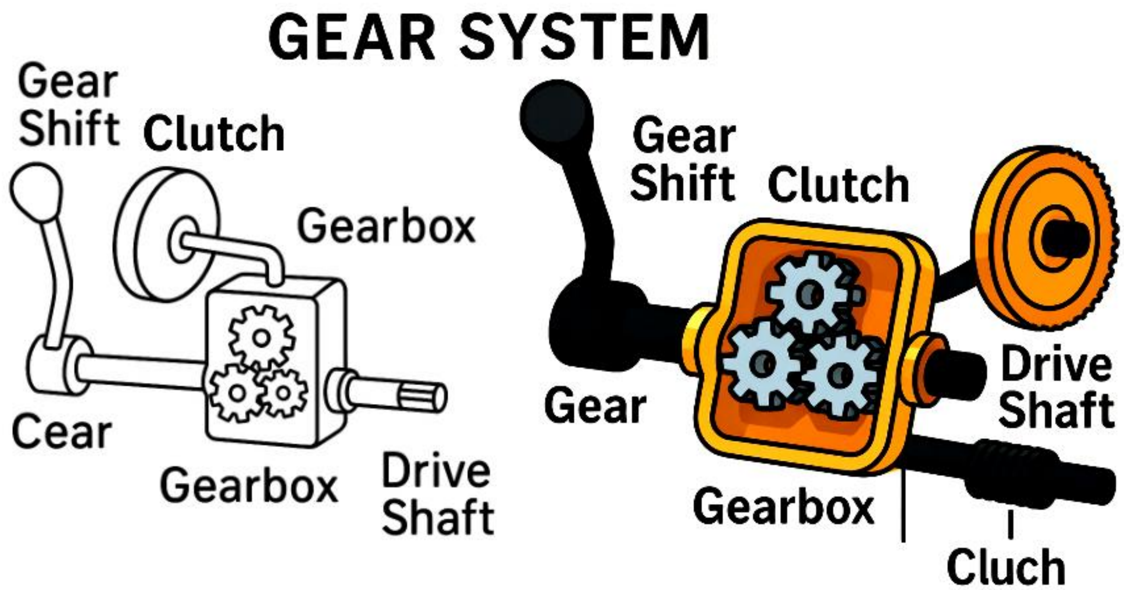
Construction Details:

Part	Function
Brake Pedal	Driver presses it to start the braking action.
Brake Booster	Amplifies the driver's foot force to make braking easier.
Master Cylinder	Converts pedal force into hydraulic pressure.
Hydraulic Lines	Carry pressurized brake fluid from the master cylinder to the brakes.
Brake Caliper	Uses hydraulic pressure to press brake pads against the disc.
Brake Disc (Rotor)	Rotates with the wheel and slows down due to friction from brake pads.

Operating Principle:

When the driver presses the brake pedal, the brake booster increases the force and sends it to the master cylinder. The master cylinder converts this force into hydraulic pressure, which travels through the hydraulic lines to the brake caliper. The caliper then squeezes the brake pads against the rotating disc, creating friction that slows down or stops the wheel. This entire process works smoothly due to the hydraulic system multiplying the driver's input force.

1.12 Gear System: A gear system is a mechanism that transmits power and controls the speed and torque between the engine and the vehicle's wheels using interconnected gears. The following figure illustrates construction details and operating principle.



Construction Details:

Part	Function
Gear Shift (Gear Lever)	Allows the driver to select and change gears manually.
Clutch	Connects and disconnects the engine from the gearbox to enable smooth gear changes.
Gearbox	Contains multiple gears of different sizes that adjust speed and torque.
Gears	Interlocking wheels that transmit power and change speed/torque ratios.
Drive Shaft	Carries power from the gearbox to the wheels of the vehicle.

Operating Principle:

The gear system works by using the clutch to temporarily disconnect the engine from the gearbox. When the driver selects a gear using the gear shift, different gear pairs inside the gearbox engage. This changes the speed–torque ratio, allowing the vehicle to move slowly with high power in low gears or move faster with lower torque in higher gears. The selected gear then transfers power through the drive shaft to rotate the wheels smoothly. This mechanism ensures efficient, controlled movement of the vehicle.

Flying Machines: Flying machines are vehicles designed to travel through the air by generating lift. They use aerodynamic forces, buoyant gases, or propulsion systems to stay airborne. Examples include airplanes, helicopters, drones, gliders, balloons, and airships.

1.13 Classification of Flying Machines:

The following represent classification of flying machines based on several parameters.

Classification Criteria	Types	Description	Examples
Based on Weight (Buoyancy)	Lighter-than-air, Heavier-than-air	Based on whether the vehicle floats or uses lift to fly.	Balloons, Airships / Airplanes, Helicopters, Drones
Based on Lift Generation	Aerostats, Aerodynes	Aerostats use buoyancy; aerodynes use aerodynamic lift.	Hot-air balloon / Airplane, Helicopter, Quadcopter drone
Based on Propulsion	Powered, Unpowered	Depends on whether an engine is used for thrust.	Jets, Helicopters, Drones / Gliders, Kites
Based on Wing Configuration	Fixed-wing, Rotary-wing, Flapping-wing, Tilt-rotor	Depends on how the wings or rotors create lift.	Airplane / Helicopter / Ornithopter / V-22 Osprey, Quad-drone
Based on Takeoff & Landing	CTOL – Conventional Take-Off and Landing STOL – Short Take-Off and Landing VTOL – Vertical Take-Off and Landing	CTOL needs long runways; STOL uses short runways; VTOL takes off vertically without a runway.	Airliner (CTOL), Bush plane (STOL), Helicopter/Drone/Harrier Jet (VTOL)
Based on Speed Range	Subsonic, Transonic, Supersonic, Hypersonic	Based on flight speed relative to sound speed.	Passenger jets / Fighter jets / Concorde / Spacecraft
Based on Application	Civil, Military, Cargo, Agricultural, Surveillance	Based on the purpose or mission.	Passenger aircraft / Fighter jets / Cargo planes / Crop dusters / Drones

1.14 Classification of Drones:

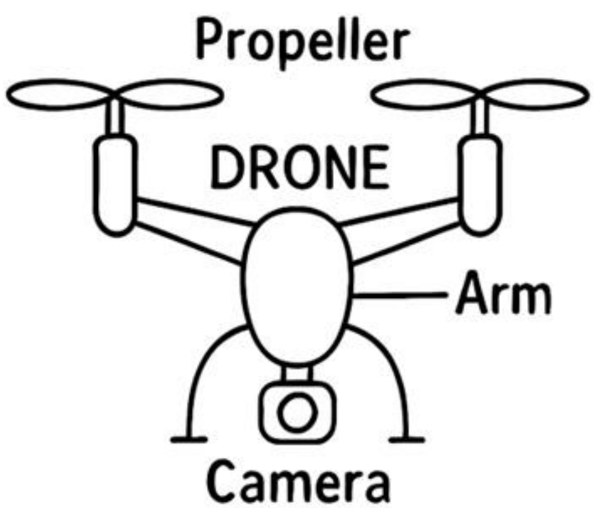
Classification Criteria	Type	Brief Description	Typical Applications
Based on Wing Type	Fixed-Wing Drone	Flies like an airplane; long endurance and high speed.	Mapping, surveying, long-distance monitoring.
	Rotary-Wing (Multirotor)	Uses multiple propellers; easy takeoff/landing; stable hover.	Photography, inspection, surveillance, delivery.
	Hybrid Drone	Combines fixed-wing + multirotor; VTOL capability with long range.	Military, surveying large areas, cargo transport.
Based on Number of Rotors	Quadcopter	4-rotor drone; most common and stable.	Civil use, videography, education.
	Hexacopter	6-rotor drone; higher lifting power and stability.	Agriculture, industrial inspection.
	Octocopter	8-rotor drone; heavy-duty lifting and redundancy.	Cinema filming, cargo supply, rescue operations.
Based on Range	Very Short Range	Up to 5 km range.	Hobby flying, indoor/outdoor recreation.
	Short Range	5–50 km.	Police patrol, inspection.
	Mid-Range	50–150 km.	Traffic monitoring, surveillance.
	Long Range	150–600 km.	Border security, disaster monitoring.
	Endurance UAV	Above 600 km (long missions).	Military reconnaissance, marine surveillance.
Based on Altitude	Low Altitude UAV	Flies below 1000 m.	Photography, agriculture.
	Medium Altitude UAV	1000–5000 m.	Surveying, atmospheric studies.
	High Altitude UAV	Above 5000 m.	Military, climate research.

Classification Criteria	Type	Brief Description	Typical Applications
Based on Purpose	Recreational/Hobby Drone	Small, lightweight drones for personal use.	Fun flying, basic photography.
	Agricultural Drone	Equipped for farming tasks.	Crop spraying, field analysis.
	Surveillance Drone	Designed for monitoring and patrol.	Police, security, border control.
	Delivery Drone	Designed to carry small loads.	Package delivery, medical supply transport.
	Inspection Drone	Built for industrial monitoring.	Powerline, pipeline, tower inspection.
	Military Drone	Advanced defense UAVs.	Reconnaissance, strike missions.
Based on Operation	Manual Control	Operated fully by a pilot using remote control.	Hobby, training drones.
	Autonomous Drone	Follows GPS routes; minimal control needed.	Surveying, mapping, delivery.
	Semi-Autonomous	Mix of manual and automated control.	Commercial drones, professional filming.

1.15Construction and Operating Principle of simple drone:

Construction Details:

The following figure illustrates construction details of a drone..



Part	Function
Propellers	Spin rapidly to create lift and allow the drone to fly.
Motors	Rotate the propellers at high speed.
Arms	Hold the motors and propellers in position.
Battery	Provides electrical power to the motors and electronics.
Camera	Captures photos and videos or provides live view for navigation.
Body/Frame	Supports all components and gives structure to the drone.

Operating Principle:

A drone flies by using its motors to spin the propellers, which create upward lift. By changing the speed of each motor, the drone can move forward, backward, sideways, or rotate in the air. The battery powers all components, while the onboard camera helps capture images or assist in navigation. The drone stays stable because its flight controller continuously adjusts motor speed to balance lift and control movement.

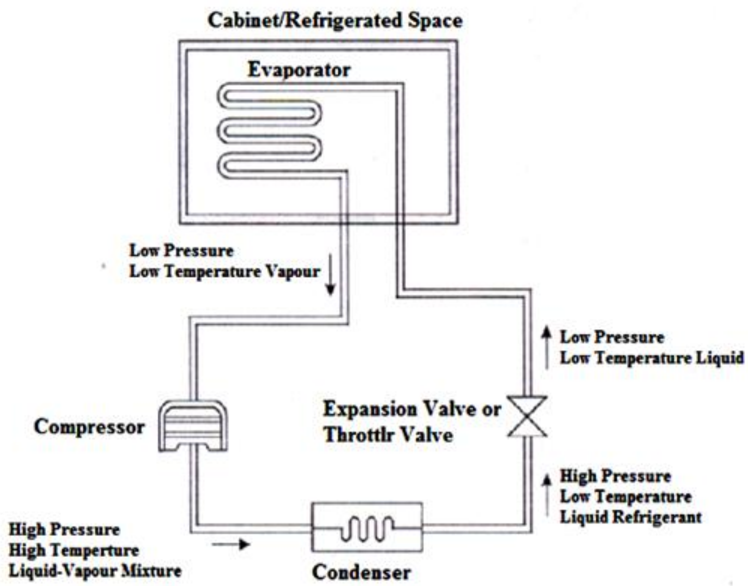
1.16 Refrigeration and Air-Conditioning Principles:

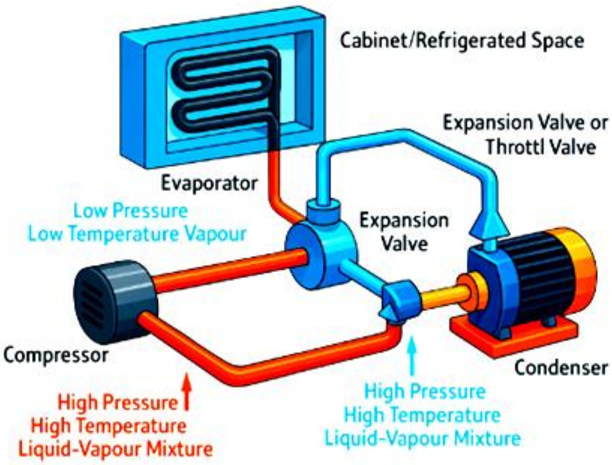
Refrigeration may be defined as a method of reducing the temperature of a system (eg-room or house) below that of the surroundings (atmosphere) & maintains it at the lower temperature by continuously abstracting the heat from it. For this process, a machine called refrigerator is used. This refrigerator with the help of an external source of energy removes heat continuously from a system (i.e., space within the refrigerator) at a lower temperature & transfers it to the surroundings (i.e., atmosphere) at a higher temperature. The refrigerator make use of a medium (or working fluid) called refrigerant ,which continuously extracts heat from the system & keep it cool at a temperature lower than the atmospheric temperature.

Refrigerators are mainly classified into Vapour Compression Refrigerators (VCR) and Vapour Absorption Refrigerators (VAR) **based** on how the refrigerant is circulated and how cooling is produced.

Principle of Refrigeration or Operation of Vapour Compression Refrigeration:

A vapour compression refrigeration system is a cooling system that removes heat by circulating a refrigerant through compression, condensation, expansion, and evaporation processes.





Construction Details:

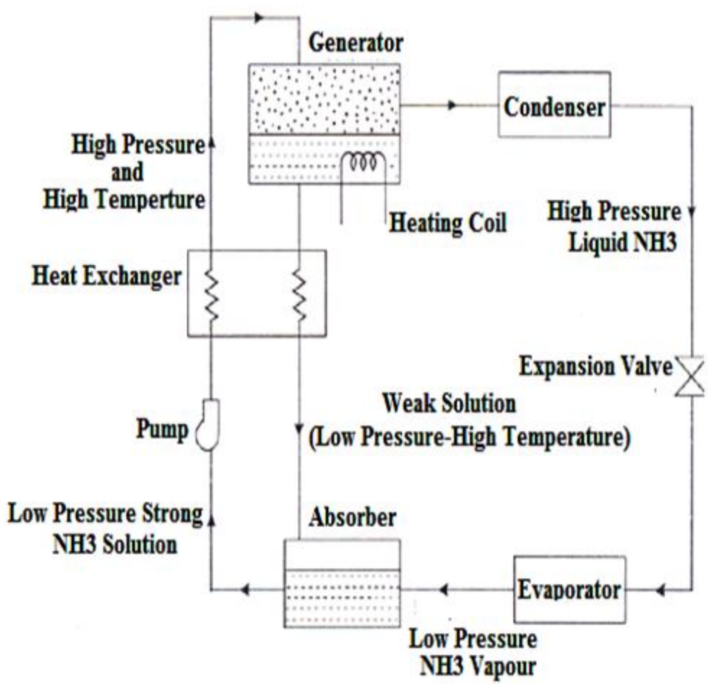
Part	Function
Compressor	Compresses low-pressure vapour into high-pressure, high-temperature vapour.
Condenser	Cools and condenses the high-pressure vapour into high-pressure liquid.
Expansion Valve (Throttle Valve)	Reduces the pressure and temperature of the refrigerant before entering the evaporator.
Evaporator	Absorbs heat from the refrigerated space and evaporates the low-pressure liquid into vapour.
Refrigerant	Working fluid that circulates through all components and carries heat.
Piping System	Connects all components and allows refrigerant to flow through the cycle.
Cabinet/Refrigerated Space	Area from which heat is removed to produce cooling.

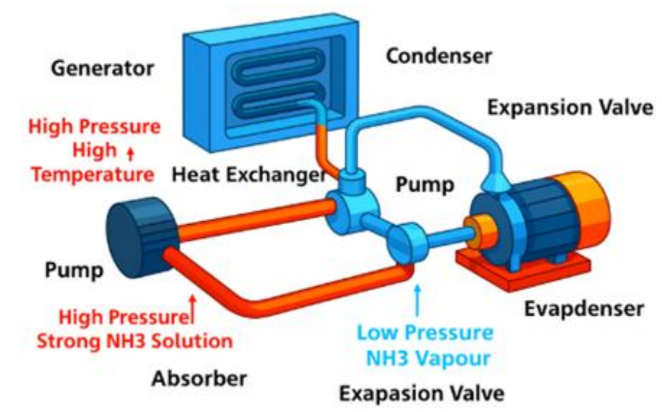
Operating Principle:

In operation, the liquid refrigerant (Freon-12) in the evaporator absorbs the latent heat from the system (cabinet/refrigerated space) which is to be cooled and undergoes a change of phase from liquid to vapour. The vapour refrigerant at low temperature and pressure is drawn into the compressor where it is compressed to a high pressure and temperature. The compressed vapour refrigerant then enters the condenser, where it is cooled and condensed to liquid phase by giving its latent heat to the surrounding medium (air or water). The high-pressure liquid refrigerant leaves the condenser and passes through the expansion valve where it is expanded to low pressure and temperature, which will be less than that of the temperature & pressure of the refrigerated space. The low pressure-low temperature refrigerant again enters the evaporator where it absorbs the latent heat from the system and evaporates. The low pressure-low temperature vapour is drawn into the compressor and the cycle repeats. Thus heat is continuously extracted from the system, thereby keeping the system at the required lower temperature.

Construction & Operating Principle Vapour Absorption Refrigerator:

A vapour absorption refrigerator is a cooling system that uses heat energy (instead of mechanical work) to circulate refrigerant by absorbing and releasing it through chemical solutions.





Construction:

Part	Function
Generator	Uses heat to separate refrigerant (NH_3) vapour from the strong solution.
Condenser	Converts high-pressure refrigerant vapour into high-pressure liquid.
Expansion Valve	Reduces pressure and temperature of liquid refrigerant before entering the evaporator.
Evaporator	Absorbs heat from the refrigerated space and converts liquid NH_3 into vapour.
Absorber	Absorbs NH_3 vapour into water, forming a strong solution again.
Pump	Circulates the strong solution from absorber to generator.
Heat Exchanger	Transfers heat between weak and strong solutions to improve system efficiency.
Strong Solution (NH_3 + Water)	Rich in ammonia; flows from absorber to generator.
Weak Solution	Low ammonia concentration; flows from generator back to absorber.

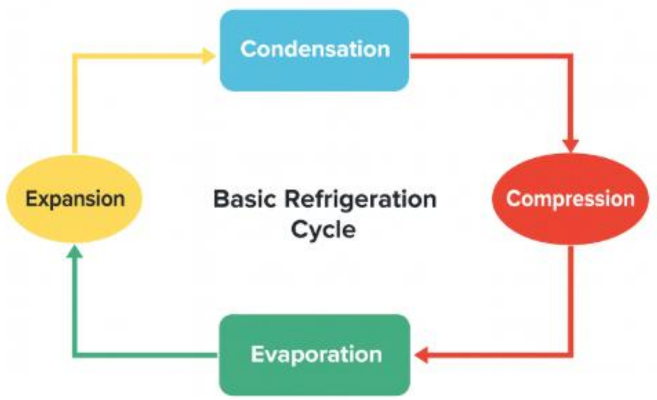
Operating Principle:

In operation, the liquid refrigerant (NH_3) in the evaporator absorbs the latent heat from the system (cabinet/refrigerated space) which is to be cooled and undergoes a change of phase from liquid to vapour. The vapour refrigerant at low temperature and pressure is drawn into the absorber to produce strong ammonia solution. It is then compressed & passed to the generator to produce strong ammonia vapour. It then enters the condenser, where it is cooled and condensed to liquid phase by giving its latent heat to the surrounding medium (air or water). The high-pressure liquid refrigerant leaves the condenser and passes through the expansion valve where it is expanded to low pressure and temperature, which will be less than that of the temperature & pressure of the refrigerated space. The low pressure-low temperature refrigerant again enters the evaporator where it absorbs the latent heat from the system and evaporates. The low pressure-low temperature vapour is drawn into the absorber to produce strong ammonia solution and the cycle repeats. Thus heat is continuously extracted from the system, thereby keeping the system at the required lower temperature.

Comparison between Vapour Compression System & Vapour Absorption System:

Principle	Vapour compression system	Vapour absorption system
Working method	Refrigerant vapour is compressed	Refrigerant vapour is absorbed.
Type of energy supplied	Works solely on Mechanical energy	Works solely on Heat energy
Mechanical work done	More due the compressor used.	Less due the pump used.
Refrigerant used	Freon-12	Ammonia
Capacity	Limited to 1000 tons of refrigeration.	More than 1000 tons of refrigeration can be produced.
Noise	More due the compressor used.	Almost quiet in operation.
Maintenance	High due the compressor.	Less.
Operating cost	More	Less
Leakage of Refrigerant	Is a major problem	Almost no Leakage problem.
COP	Relatively higher but reduces at part loads.	Relatively lower but increases at part or full loads.

Working Principle of Air Conditioning:



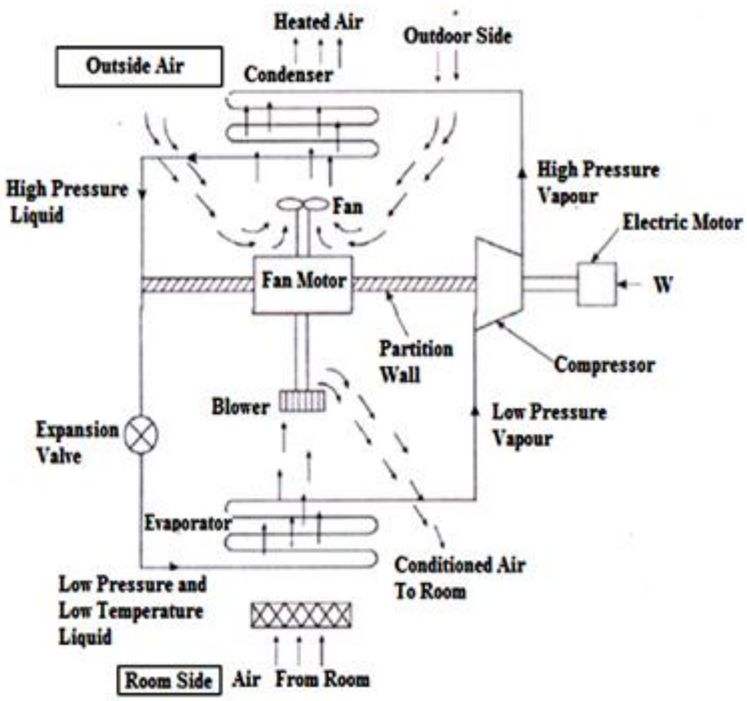
An Air conditioner is a machine which continuously draws the air from an indoor space (to be cooled) & cools it by refrigeration principles & discharge back into the same indoor space. Therefore Air conditioning may be defined as the process of simultaneous control of temperature, humidity, cleanliness and air-motion of the confined space.

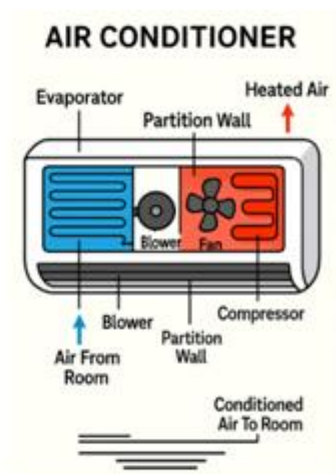
The principle of air conditioning is based on the laws of thermodynamics. An air conditioner operates using the refrigeration cycle as shown in fig. An air conditioner goes through four processes; compression, condensation, expansion, and evaporation. Typically, an air conditioner is made up of four major components; evaporator, compressor, condenser, and expansion valve. An air conditioner not just cools or reduces the temperature of the air, it also dehumidifies the air to a level that is comfortable to humans. An air conditioner also provides a certain degree of air filtration during the cooling process.

Construction & working principle of Room Air Conditioner:

A room-type air conditioner is a compact cooling unit that removes heat from a single room and expels it outside using a refrigeration cycle. The following figure illustrates construction details and operating principle of wall type room AC.

Part	Function
Evaporator Coil	Absorbs heat from the room air and cools it.
Blower (Indoor Fan)	Pulls warm air from the room and blows cooled air back into the room.
Partition Wall	Separates the indoor (cooling) section from the outdoor (heating) section.
Compressor	Compresses low-pressure vapour into high-pressure vapour and circulates refrigerant.
Condenser Coil	Releases heat to the outside air and cools the refrigerant into a liquid.
Outdoor Fan	Removes the heat from the condenser by blowing outside air over it.
Expansion Valve	Reduces the pressure and temperature of the refrigerant before entering the evaporator.
Air Filter	Removes dust and impurities from the room air before cooling.
Electric Motor	Provides power to drive the compressor and fans.
Conditioned Air Outlet	Delivers cooled air back into the room.
Air Intake (From Room)	Draws warm room air into the AC for cooling.





In operation, the blower sucks the warm air from the room through the air filter and the evaporator. The air from the interior passing over the evaporator coils is cooled by the refrigerant, which consequently evaporates by absorbing the heat from the air. The high temperature evaporated refrigerant from the evaporator is drawn by the suction of the compressor, which compresses it & delivers it to the condenser. The high-pressure-temperature refrigerant vapour now flows through the condenser coils. The condenser fan draws the atmospheric air from the exposed side-portions of the air conditioner which is projecting outside the building into the space behind it & discharges to pass through the center section of the condenser unit over the condenser coils. The high-pressure-temperature refrigerant passing inside the condenser coils condenses by giving off the heat to the atmospheric air. The cooled high pressure refrigerant from the condenser passes through the capillary tube, where it undergoes expansion & is again recirculated to repeat the cycle continuously.

QUESTION BANK:

5-MARK QUESTIONS (Short Answer / Explain Briefly)

1. Define engineering. Differentiate between engineering and science with suitable examples.
2. Write a short note on the significance of mechanical engineering in modern society.
3. List any five major streams of mechanical engineering and mention their importance.
4. Explain the role of mechanical engineers in solving real-world problems with any two examples.
5. Mention any five major achievements of mechanical engineering.
6. Define energy conversion. Write the energy conversion processes involved in (a) IC engine (b) Solar panel.
7. List any five systems/machines used for energy conversion with input and output forms of energy.
8. Write a short note on turbines and give examples.
9. Explain the difference between aerostats and aerodynes.
10. Draw the neat labelled diagram of a Pelton wheel and write its working principle.
11. List the main components of Pelton wheel and mention their functions.
12. Explain the working principle of a centrifugal pump.
13. Write any five differences between Pelton wheel and centrifugal pump.
14. What is a reciprocating pump? Mention its applications.
15. List the components of a steering system with their functions.
16. What is power steering? Explain its working in brief.
17. What is a brake system? Write short notes on disc brake components.
18. Describe any five parts of a gear system.
19. Mention the functions of clutch and gearbox in a vehicle.
20. Classify flying machines based on lift generation.
21. List the basic components of a drone with functions.
22. Write short note on VTOL, STOL and CTOL.
23. Describe drones and write their working principle.
24. Define refrigeration. Explain the necessity of refrigeration.
25. List the main components of a vapour compression refrigeration (VCR) system.
26. Write the working principle of vapor absorption refrigeration (VAR) system in brief.
27. Compare VCR and VAR systems (any five points).
28. Explain the four processes in basic refrigeration cycle.
29. Draw a neat labelled diagram of a room air conditioner.
30. Explain the functions of evaporator, condenser and expansion valve in a room AC.

10-MARK QUESTIONS (Long Answers / Detailed Explanation)

1. Explain in detail the various streams of mechanical engineering and their relevance in industry and society.
2. Describe the role of mechanical engineers in solving real-case problems. Give at least five examples.
3. Discuss major career opportunities available for mechanical engineers with examples.
4. Explain energy conversion with suitable examples from automobiles, power plants, and renewable energy systems.
5. Describe with diagrams the working principles of turbines and classify them.
6. Explain the construction and working principle of a Pelton wheel. Draw a neat labelled diagram.
7. Describe the construction and working of a centrifugal pump.

8. Compare Pelton wheel and centrifugal pump in detail with diagrams and applications.
9. Explain the construction and working of a steering system with a neat diagram.
10. Explain power steering system with diagram and describe the hydraulic assistance mechanism.
11. Illustrate the brake system of a vehicle and explain the working of disc brakes in detail.
12. Describe the gear system (transmission system) with a neat sketch. Explain its parts and working.
13. Classify flying machines based on different criteria and explain each with examples.
14. Classify drones based on different criteria and explain each with examples.
15. Draw the neat labelled diagram of a drone and explain the function of each part along with its working principle.
16. Explain the vapour compression refrigeration (VCR) system with construction, diagram and working principle.
17. Explain the vapour absorption refrigeration (VAR) system with a neat diagram and working.
18. Compare vapour compression and vapour absorption systems in detail.
19. With a neat diagram, explain the construction and working of a room air conditioner (Window AC/Wall AC).
20. Explain the complete refrigeration cycle with pressure-temperature changes in each component.

GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN

Department of Mechanical Engineering

Near Dairy Circle, Hosur Road, Bengaluru , Karnataka 560029

INTRODUCTION TO MECHANICAL ENGINEERING

(1BESC104D/204D)

As per New Syllabus Prescribed by V.T.U. (2025 CBCS System)

For

FIRST / SECOND SEMESTER

(Bachelor of Engineering)

MODULE-02

Engines & Vehicles

Dr.NAVEED M.Tech., PhD.
Assistant Professor
Department of Mechanical Engineering

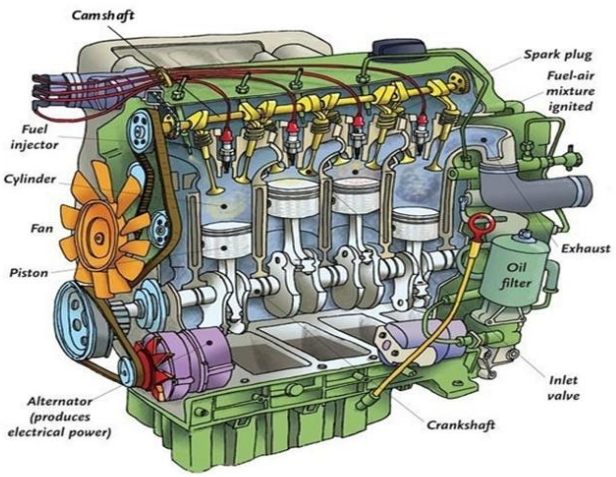
MODULE-02 **ENGINES & VEHICLES**

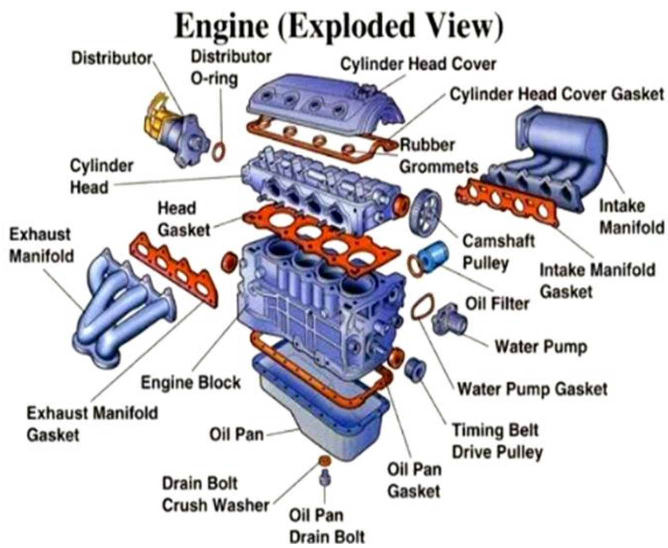
Syllabus:

Engine: Introduction, petrol engine, diesel engines, Working of four Stroke engines, applications. **Insight into Future Mobility:** Electric and Hybrid Vehicles, Components of Electric and Hybrid Vehicles. Advantages and disadvantages of EVs and Hybrid vehicles. **Power Transmission systems:** Classification of gears, simple & compound gear trains, concepts of automatic and CVT transmission.

2.0 Engine: Introduction:

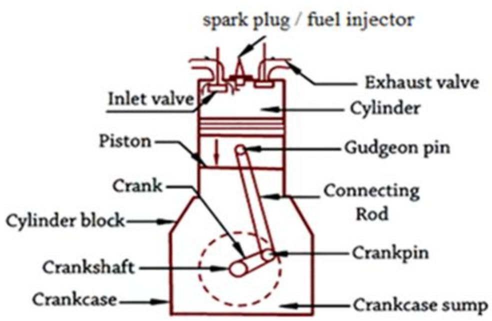
An engine is a machine that converts fuel into useful mechanical power. An IC Engine (internal combustion engine) is a Prime mover which converts heat energy released by the combustion of the fuel taking place inside the engine cylinder into mechanical energy in the form of rotary motion of crank shaft. Example: Petrol engines, Diesel engines, Gas engines, etc.

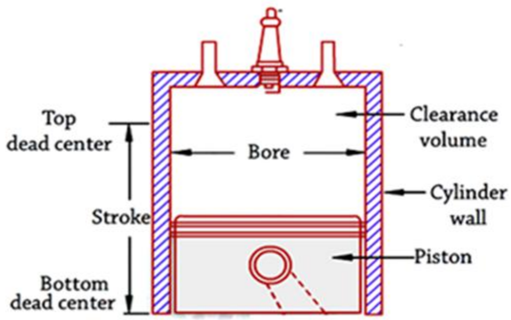


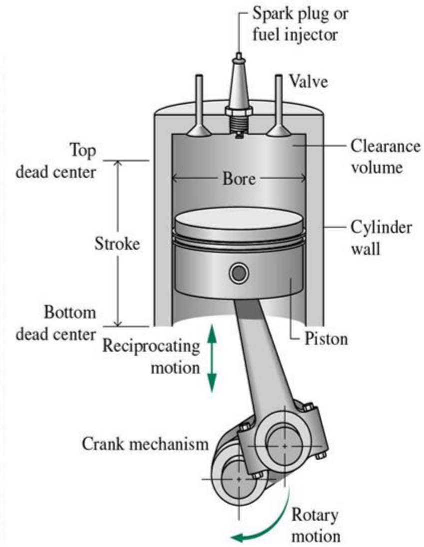


Parts of an IC Engine:

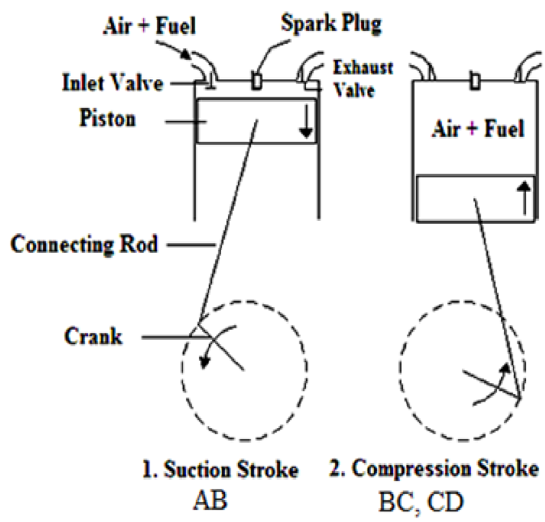
Part	Description
Cylinder	Main chamber where fuel burns and piston moves; contains a wear-resistant sleeve.
Piston	A hollow cylindrical part that moves up and down, transferring power to the crankshaft.
Piston Rings	Metal rings fitted on piston grooves to seal gases and prevent leakage during motion.
Connecting Rod	Connects piston to crank; converts piston’s reciprocating motion into rotary motion.
Crank & Crankshaft	Crank converts motion from connecting rod; crankshaft rotates to deliver power.
Crankcase	Enclosure that supports and protects the crankshaft and internal moving parts.
Valves & Cams	Valves control intake and exhaust flow; cams operate valves using timing mechanism.
Flywheel	Heavy wheel on crankshaft that maintains uniform rotation and smooth engine operation.

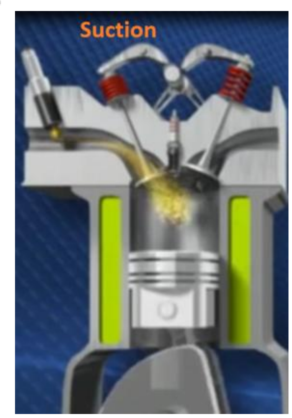






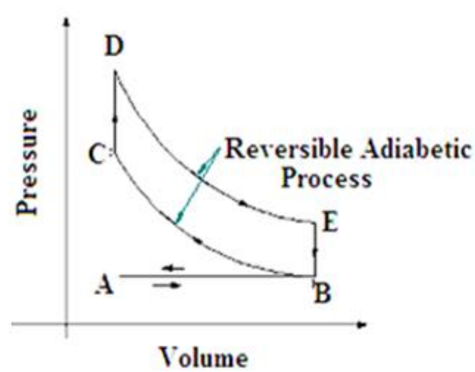
2.1 Construction & operating principle of 4 stroke petrol engine (Otto cycle, Constant volume cycle, S.I engine)

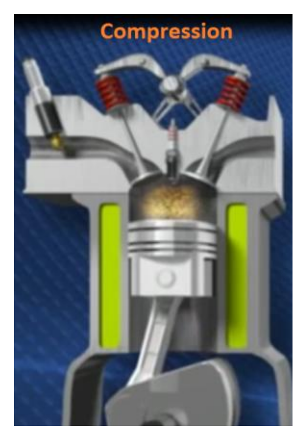


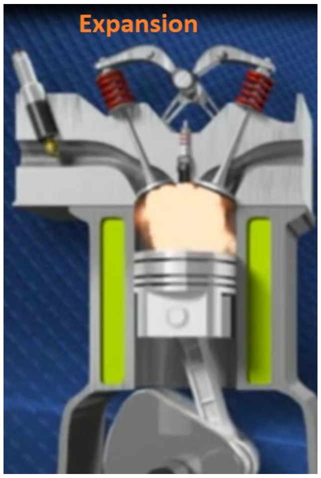


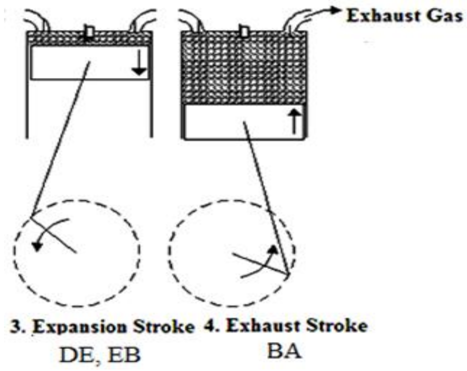
Suction stroke: During suction stroke the inlet valve opens with outlet valve closed & the piston travels from (Top Dead Center) TDC to (Bottom Dead Center) BDC & the crankshaft revolves by half rotation, causing the suction of air and fuel mixture from a carburetor. The energy required to perform this stroke is supplied by' cranking' only during the first cycle at the time of starting, while running, the flywheel supplies the mechanical energy. This stroke is represented by a line AB on the P-V diagram.

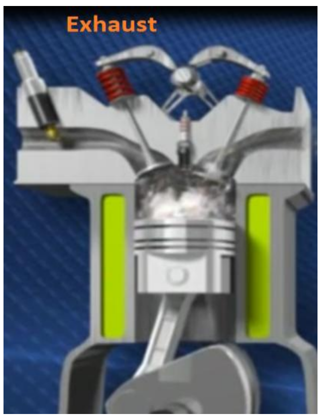
Compression stroke: During the compression stroke both inlet and exhaust valves are closed and the piston travels from the BDC to TDC & the crankshaft revolves further by half rotation, causing the compression of air and fuel mixture. This stroke is represented by a line BC on the P-V diagram. At the end of this stroke a spark is produced by a sparkplug, resulting in the combustion of the fuel and air & is represented by a line CD on P-V diagram.

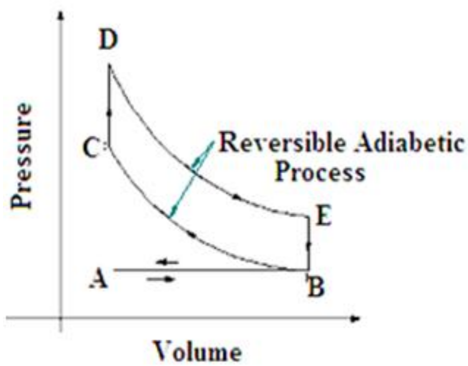






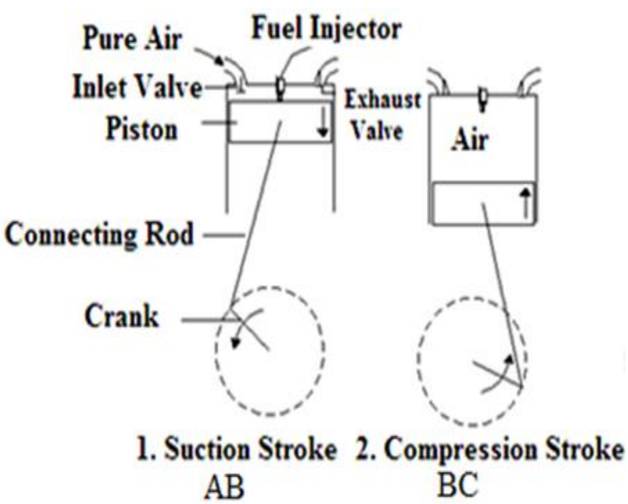


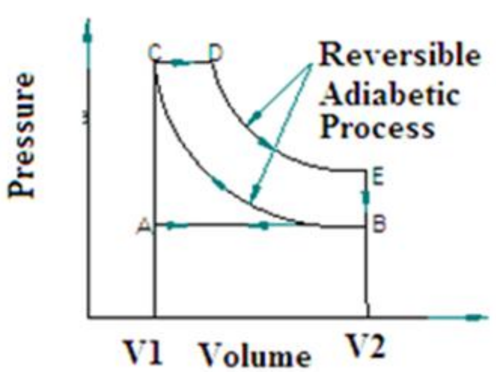




Working stroke/Power stroke/Expansion stroke: In this stroke the piston travels from TDC to BDC with both the valves remain closed & the crankshaft revolves half rotation. The piston is forced due to the expansion of the burnt gases .This linear motion of the piston is transmitted to the crankshaft through the connecting rod to produce mechanical power. This stroke is called as power stroke as the mechanical power is produced during this stroke. It is represented by the curve DE on a P-V diagram. As the piston moves further, the pressure of the hot gases gradually decreases at constant volume as represented by the line EB in PV diagram.

Exhaust stroke: During Exhaust stroke the exhaust valve opens with inlet valve closed and the piston travels from BDC to TDC, causing the exhaust of burnt gases from the cylinder & the crankshaft revolves half rotation. This stroke is represented by a line BA on the P-V diagram.

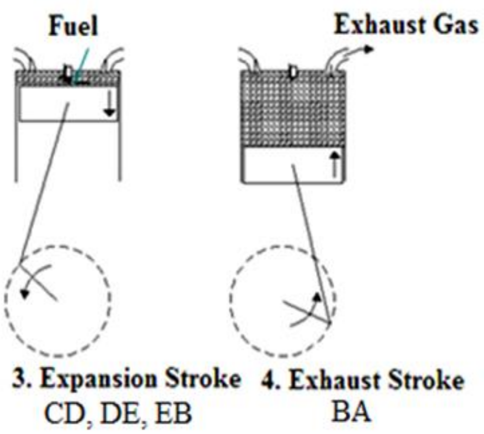


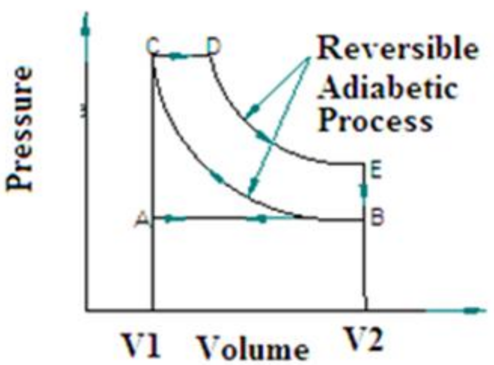


2.2 Construction & operating principle of 4 stroke diesel engine (Diesel cycle, Constant Pessure, C.I engine)

Suction stroke: During suction stroke the inlet valve opens with outlet valve closed & the piston travels from (Top Dead Center) TDC to (Bottom Dead Center) BDC & the crankshaft revolves by half rotation, causing the suction of pure air. The energy required to perform this stroke is supplied by 'cranking' only during the first cycle at the time of starting, while running, the flywheel supplies the mechanical energy. This stroke is represented by a line AB on the (Pressure -Volume) P-V diagram.

Compression stroke: During the compression stroke both inlet and exhaust valves are closed and the piston travels from the BDC to TDC & the crankshaft revolves further by half rotation, causing the compression of air. This stroke is represented by a line BC on the P-V diagram.At the end of this stroke a metered quantity of fuel is injected through the fuel injector, the high temperature of the air ignites the fuel as soon as it is injected. This is called Auto-ignition or Self-ignition





Working stroke/Power stroke/Expansion stroke: In this stroke the piston travels from TDC to BDC with both the valves remain closed & the crankshaft revolves half rotation. The burnt gases released by the combustion of the fuel that is continuously injected into the cylinder, force the piston to perform earlier part of this stroke at constant pressure till the injection of the fuel is completed. This constant pressure expansion with simultaneous combustion is represented by the line CD on PV diagram. The piston is forced further during the remaining part of this stroke due to the expansion of the burnt gases .This linear motion of the piston is transmitted to the crankshaft through the connecting rod to produce mechanical power. This stroke is called as power stroke as the mechanical power is produced during this stroke. It is represented by the curve DE on a P-V diagram. As the piston moves further, the pressure of the hot gases gradually decreases at constant volume as represented by the line EB in PV diagram.

Exhaust stroke: During Exhaust stroke the exhaust valve opens with inlet valve closed and the piston travels from BDC to TDC, causing the exhaust of burnt gases from the cylinder & the crankshaft revolves half rotation. This stroke is represented by a line BA on the P-V diagram.

Video: https://drive.google.com/file/d/1p4UHLQ-qo5vb3luVnZtJEfF-6TNVqtPJ/view?usp=drive_link

Comparisons between Petrol Engine & Diesel Engine.

Particulars	Petrol Engine	Diesel Engine
Theoretical cycle of operation	Works on Otto cycle also known as Constant volume cycle	Works on Diesel cycle also known as Constant pressure cycle
Fuel used	Petrol	Diesel
Admission of fuel	Petrol mixed with air is admitted during suction stroke itself	Only air is drawn during suction stroke while, at the end of compression stroke pressurized diesel is injected through the fuel injector.
Ignition of fuel	Petrol mixed with air is ignited by the spark plug	Diesel is ignited by the high temperature compressed air.
Compression ratio	Low compression ratio ranging from 7:1 to 12:1	High compression ratio ranging from 16:1 to 20:1
Engine speed	High engine speed of about 3000 rpm	Low engine speed of about 500 to 1500 rpm
Output power capacity	Low, due to low compression ratio	High, due to high compression ratio
Thermal efficiency	Lower, due to low compression ratio	Higher, due to high compression ratio
Noise & vibration	It is almost nil, due to low operating pressure	More, due to higher operating pressure
Applications	Used in Scooter, Motor cycle, Cars etc.	Used in trucks, Tractors, Buses etc.

Video: https://drive.google.com/file/d/1k-9_OLTc9gi9lHC450Ku-YE9-_FKqBPH/view?usp=drive_link

2.3 Applications:

Application of IC Engines in Power Generation:

I.C engines are heat engines which converts heat energy from the combustion of fuel to mechanical energy in the form of crank shaft rotation which can be connected to the generator shaft through the power transmission system to produce electrical energy.

The IC engines used for the electric power generation may be classified into different types such as

- Compression Ignition (CI) IC Engine: In this compressed air is used to ignite diesel to produce heat energy. It also uses piston cylinder arrangement to operate the crank shaft.
- Spark Ignition (SI) IC Engine: In this the petrol is ignited by the electrical sparks to produce heat energy. It uses piston cylinder arrangement to operate the crank shaft.
- Gasoline IC Engine: It is a kind of internal-combustion engine that generate power by burning a volatile liquid fuel (gasoline or a gasoline mixture such as ethanol) with ignition initiated by an electric spark.
- Gas Engines: A gas engine is an internal combustion engine which runs on a gas fuel, such as coal gas, producer gas, bio-gas, landfill gas or natural gas.
- Gas Turbine: A gas turbine is an internal combustion engine that can convert natural gas or other liquid fuels to mechanical energy. This energy then drives a generator that produces electrical energy.

Application of IC Engines in Agriculture:

Today, diesel engines power the majority of agricultural equipment in and around the world necessary to plant cultivate and harvest crops and transport them to markets or for processing and then delivered ultimately to the consumer. In addition to the farm machineries which are needed to grow and harvest crops, trucks and tractors are required to transport fertilizer, herbicides and pesticides, and even water to fields to help prepare them for planting and keeping the crop healthy while it is growing. Tractors allowed the entire agricultural industry to change. The use of engine-powered tractors allowed for faster planting and harvesting, along with the ability to manage pests and water crops in the event of droughts. This allowed for more farmland to be used and more food to be produced. In addition, farms did not have to maintain teams of horses, oxen, or mules specifically for use in the fields. Efficiency and crop yields rose exponentially.

Application of IC Engines in Marine Propulsion:

Propulsion means to push forward or drive an object forward. A propulsion system is a machine that produces thrust to push an object forward. Today ship propulsion is not just about successful movement of the ship in the water. It also includes using the best mode of propulsion to ensure a better safety standard for the marine ecosystem along with cost efficiency. Diesel propulsion system is the most commonly used marine propulsion system converting mechanical energy from thermal forces. Diesel propulsion systems are mainly used in almost all types of vessels along with small boats and recreational vessels. Marine engines on ships are responsible for propulsion of the vessel from one port to another. Whether it's of a small ship plying in the coastal areas or of a massive one voyaging international waters, a marine engine of either 4-stroke or 2-stroke is fitted onboard ship for the propulsion purpose. The engines used onboard ships are internal combustion engines (a type), in which, the combustion of fuel takes place inside the engine cylinder and the heat is generated post the combustion process. A 4 stroke engine can be installed on the ship to produce electrical power and also to propel the ship (usually in small size vessel). The 2 stroke engines are used for vessel propulsion and are bigger in size as compared to the 4 stroke engines.

Application of IC Engines in Aircraft Propulsion:

An internal-combustion piston engine is normally used especially for smaller planes while for larger planes jet engines are used for propulsion. Jet engines are typical IC engines which use a number of rows of fan blades to compress air which then enters a combustion chamber where it is mixed with fuel and then ignited. The burning of the fuel raises the temperature of the air which is then exhausted out of the engine creating thrust. In simplest terms, a jet engine ingests air, heats it, and ejects it at high speed. For example in a turbojet engine which is a type of jet engine which consist of rotating elements similar to that of a turbine, ambient air is taken in at the engine inlet (induction), compressed about 10 to 15 times in a compressor consisting of rotor and stator blades (compression), and introduced into a combustion chamber where igniters ignite the injected fuel (combustion). The resulting combustion produces high temperatures (760 to 1,040 °C). The expanding hot gases pass through a multistage turbine, which turns the air compressor through a coaxial shaft, and then into a discharge nozzle, thereby producing thrust from the high-velocity stream of gases being ejected to the rear (exhaust). A turbojet engine is far simpler than a reciprocating engine of equivalent power, weighs less, is more reliable, requires less maintenance, and has a far greater potential for generating power.

Application of IC Engines in Automobile:

Internal combustion engines are the most common form of heat engines, as they are used in vehicles, boats, ships, airplanes, and trains. Automobiles are the vehicles designed primarily for passenger transportation as well for transporting goods from one place to another and commonly propelled by an internal-combustion engine using a volatile fuel. Reciprocating piston engines are by far the most common power source for land and water vehicles, including motorcycles, cars, buses, trucks, ships and to a lesser extent, locomotives (some are electrical but most use diesel engines). Two stroke petrol engines are normally used for operating very light vehicles while four stroke diesel engines are widely used for driving medium to heavy vehicles. The automobiles have become an integral part of our life without which we cannot perform our day to day activities in a simple easy way.

Area of Application	Description	Key Examples / Uses
Power Generation	IC engines convert heat from fuel combustion into mechanical energy, which drives a generator to produce electricity.	Diesel generators, gas engines, gas turbines, gasoline engines.
Agriculture	IC engines power farm machinery for planting, cultivating, harvesting, irrigation, and transportation, improving efficiency and yield.	Tractors, harvesters, sprayers, water pumps, transport vehicles.
Marine Propulsion	IC engines (mainly diesel) provide thrust for ship movement; used in 2-stroke and 4-stroke marine engines.	Cargo ships, fishing vessels, boats, tankers; auxiliary generators.
Aircraft Propulsion	Small aircraft use piston IC engines; larger aircraft use jet engines that compress, ignite, and expel air to create thrust.	Piston-prop aircraft, turbojet and turbofan engines.
Automobiles	IC engines power land vehicles for transport of passengers and goods; includes 2-stroke and 4-stroke engines.	Cars, bikes, buses, trucks, trains, delivery vehicles.

Numerical on IC Engine:

A gas engine working on a four stroke cycle has a cylinder of 250mm diameter, length of stroke 450mm & is running at 180rpm.Its Mechanical efficiency is 80% When the mean effective pressure is 0.65Mpa,
Find 1. Indicated power 2. Brake power 3. Friction power 4. Break thermal efficiency if Cv = 42000 Kj/kg for fuel consumption of 3 kg/hr

Given: 4 stroke engine.

D = 250mm = 0.25m L = 450mm = 0.45m
N = 180 rpm η_{mech} = 80%
P_m = 0.65 Mpa = $0.65x10^6$ N/m^2
C_v = 42000 KJ/Kg
m = 3 Kg/hr = 3/3600….Kg/s

IP ? BP? FP? η_{Bth} ?

$$\mathbf{IP = \frac{P_m\, LAn}{60000} \ldots KW}$$

$$A = \frac{\pi\, D^2}{4} \ \ldots m^2$$

$$A = \frac{\pi 0.25^2}{4} = 0.049 \ldots m^2$$

* For 4 stroke engine: n = N/2 180/2 = 90cycles/min

$$IP = \frac{0.65x10^6 x0.45x0.049x90}{60000} = 21.5 \ldots KW$$

$$\eta_{mech} = \left(\frac{BP}{IP}100\right)\%$$

$$80 = \left(\frac{BP}{21.5}100\right)\%$$

BP = 17.2….KW

FP = IP - BP = 21.5 - 17.2 = 4.3….KW

$$\eta_{Bth} = \left(\frac{BP}{C_V.\, m}100\right)\%$$

$$\eta_{Bth} = \left(\frac{17.2}{42000x3/3600}100\right) = \mathbf{49.14}\%$$

The following observations were obtained during a trial on a four stroke diesel engine
Cylinder diameter = 25cm; Stroke of the piston = 40cm
Crankshaft speed = 250rpm; Brake load = 70kg
Brake drum diameter = 2m; Mean effective pressure = 6bar
Diesel oil consumption = 0.1 ltrs/min; Specific gravity of diesel = 0.78
Cv = 43900 Kj/kg
Find 1.BP 2. IP 3. FP 4. Mechanical efficiency 5. Brake thermal efficiency 6.Indicated thermal efficiency

Given: 4 stroke engine:

D = 25 cm = 0.25m L = 40 cm = 0.4m
N = 250 rpm W = 70 Kg
R = 2/2 = 1m P_m = 6bar = $6x10^5$ N/m^2
V = 0.1 ltr/min

$$V = \frac{0.1x10^{-3}}{60} = 1.666x10^{-6} \ldots m^3/s$$

Specific gravity of fuel = 0.78 Cv = 43900 KJ/Kg

IP ? BP? FP ? η_{mech} ? η_{Bth} ? η_{Ith} ?

$$\mathbf{IP = \frac{P_m\, LAn}{60000} \ldots KW}$$

$$A = \frac{\pi\, D^2}{4} \ \ldots m^2$$

$A = \frac{\pi 0.25^2}{4} = 0.049 \ldots . m^2$

* For 4 stroke engine: n = N/2 = 250/2 = 125 cycles/min

$IP = \frac{6x10^5 x0.4x0.049x125}{60000} = 24.5 \ldots . KW$

$\mathbf{BP = \frac{2\pi NT}{60000} \ldots . KW}$

T = 9.81 W R…..Nm

= 9.81x 70x1 = 686…. Nm

$BP = \frac{2\pi 250x686}{60000} = 17.95 \ldots . KW$

FP = IP - BP = 24.5 - 17.95 = 6.55….KW

$\boldsymbol{\eta_{mech} = \left(\frac{BP}{IP}100\right)\%}$

$\eta_{mech} = \left(\frac{17.95}{24.5}100\right) = 73.26\%$

$\boldsymbol{\eta_{Bth} = \left(\frac{BP}{C_V . m}100\right)\%}$

Mass flow rate of the Fuel: m = Volume flow rate x Density of fuel…..Kg/s

Density of Fuel = 1000 x Specific gravity of fuel

Density of Fuel = 1000 x 0.78 = 780 …. Kg/m^3

Mass flow rate of the Fuel: m = $1.666x10^{-6}x780 = 1.3x10^{-3}$….Kg/s

$\eta_{Bth} = \left(\frac{17.95}{43900x1.3x10^{-3}}100\right) = 31.45\%$

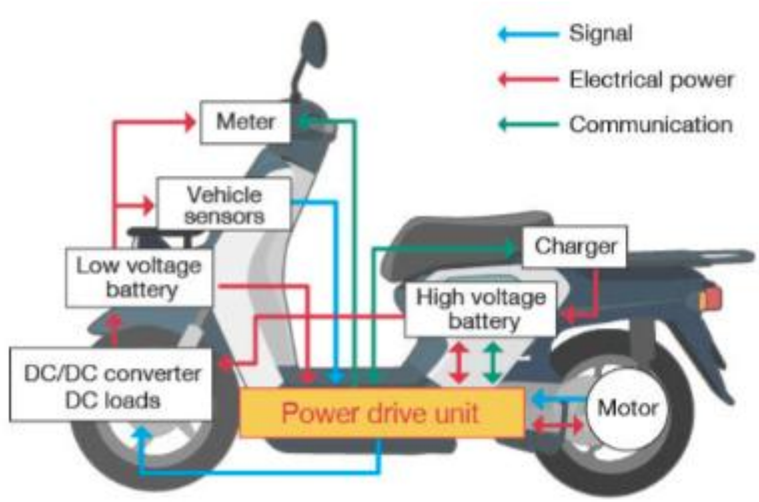
$\boldsymbol{\eta_{Ith} = \left(\frac{IP}{C_V . m}100\right)\%}$

$\eta_{Ith} = \left(\frac{24.5}{43900x1.3x10^{-3}}100\right) = \mathbf{42.92}\%$

2.4 ELECTRIC AND HYBRID VEHICLES:

Electric Vehicles (EVs) are vehicles that are either partially or fully powered on electric power. Hybrid electric vehicles (HEVs) are powered by an internal combustion engine in combination with one or more electric motors that use energy stored in batteries. A hybrid vehicle combines any two power (energy) sources. Typically, one energy source is storage, and the other is conversion of a fuel to energy. The combination of two power sources may support two separate propulsion systems.

The main difference between hybrid vehicles and an electric vehicle is that the hybrid combines an internal combustion engine and electric motor(s) to send power to its wheels while the electric vehicles draws power from a single source of the electric motor(s) to propel the vehicle



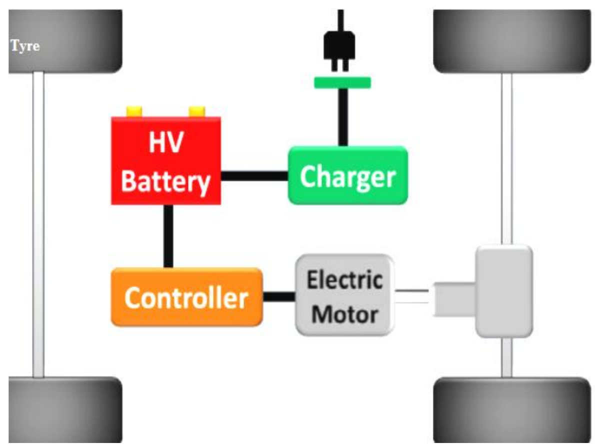
2.5 Advantages & Disadvantages of Electric Vehicles:

Advantages of EVs	Disadvantages of EVs
Low running cost	Risk of battery fire
Very low maintenance (few moving parts)	High initial purchase cost
No tailpipe emissions → eco-friendly	Limited number of charging stations
Better performance & smooth driving	Long charging time
Saves more money compared to hybrids	Charger compatibility issues
Quiet operation	Expensive charging infrastructure

2.6 Advantages & Disadvantages of Hybrid Vehicles:

Advantages of Hybrid Vehicles	Disadvantages of Hybrid Vehicles
High fuel economy	Poor acceleration performance
Lower fossil-fuel consumption	Battery degrades faster than EV batteries
Reduced CO_2 emissions	Battery replacement is expensive
Eco-friendly operation	Higher maintenance cost
Regenerative braking charges battery	Complex system → costly repairs
Higher resale value	Heavier due to dual system

2.7 Components of Electric Vehicles:



The major components of an electric vehicle consist of

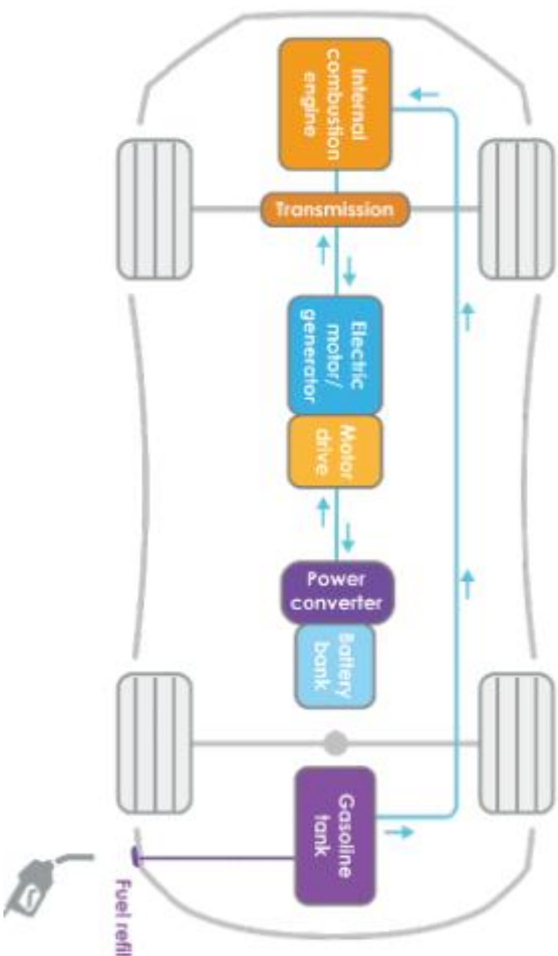
Electric motor: The motor converts electric energy into kinetic energy that moves the wheels of the vehicle. It reduces the noise and the vibration as well as a lot of space occupied by the conventional engine system to drive the crank shaft.In most of the vehicles the motor will act as a generator to produce electrical energy when the vehicle is in neutral gear which can be used to charge the battery.

Controller: It controls the flow of the electric power in the vehicle. It consists of the inverter, low voltage DC converter, Vehicle Control Unit (VCU) and reducer. The inverter converts the battery's DC into AC, which then is used to operate the motor. The device is also responsible for executing acceleration and deceleration, the low voltage DC converts the high voltage electricity from the EV's high-voltage battery into low-voltage(12V) and supplies it to the vehicle's various electronic systems. The VCU is arguably the most important component. It oversees nearly all the vehicle's power control mechanisms, including the motor control, regenerative braking control, A/C load management, and power supply for the electronic systems. The reducer reduces the speed of the motor to match the required speed of the vehicle.

Battery: The battery stores electrical energy and is the equivalent of a fuel tank in an internal combustion engine. The maximum driving distance of an EV is often determined by the battery capacity-the higher the capacity, the higher the driving distance.

Charger: It supplies the electric current required for charging the battery. It consists of converter to convert AC to DC for charging the battery in the house hold premises. In case of the charging stations it supplies direct DC for fast charging of the batteries.

Component	Function
Electric Motor	Converts electrical energy into mechanical (kinetic) energy to drive the wheels; reduces noise, vibration, and occupies less space. Also acts as a generator during neutral/regen braking to charge the battery.
Controller	Manages power flow and operation of the EV. Includes inverter, low-voltage DC converter, Vehicle Control Unit (VCU), and reducer.
Inverter	Converts DC from the battery into AC to operate the electric motor.
Low-Voltage DC Converter	Converts high-voltage battery power to low-voltage (12V) for electronics like lights, infotainment, etc.
Vehicle Control Unit (VCU)	Central control unit that manages motor control, regenerative braking, A/C loads, and power supply distribution.
Reducer	Reduces motor speed to match the wheel speed requirement.
Battery	Stores electrical energy; determines the EV range (higher capacity → longer driving distance).
Charger	Supplies electric current to charge the battery. Converts AC to DC for home charging; charging stations provide DC for fast charging.



2.8 Components of Hybrid Vehicles:

A hybrid electric vehicle uses an electric motor/generator along with an internal combustion engine-offering high fuel economy. A hybrid vehicle combines any two power (energy) sources. Typically, one energy source is storage, and the other is conversion of a fuel to energy. These two power sources may be paired in series, meaning that the fuel engine charges the batteries of an electric motor that powers the vehicle, or in parallel, with both mechanisms driving the vehicle directly.

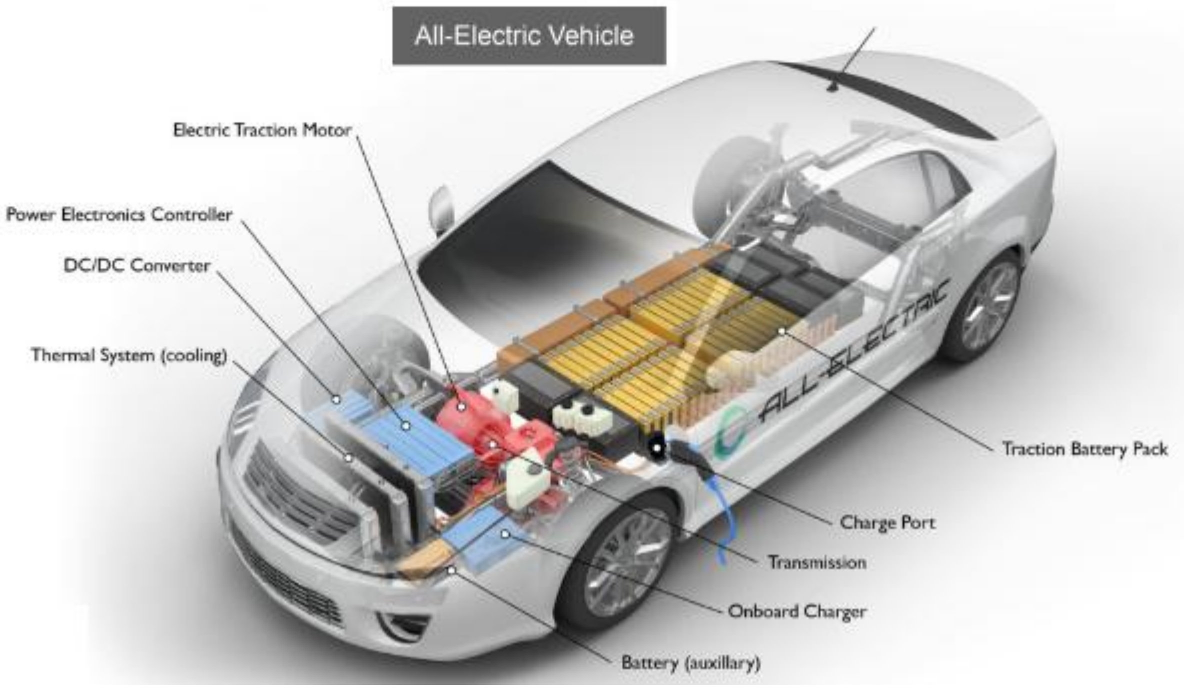
It consists of components similar to electric vehicle with additional components such as an IC engine, electric generator, control module.

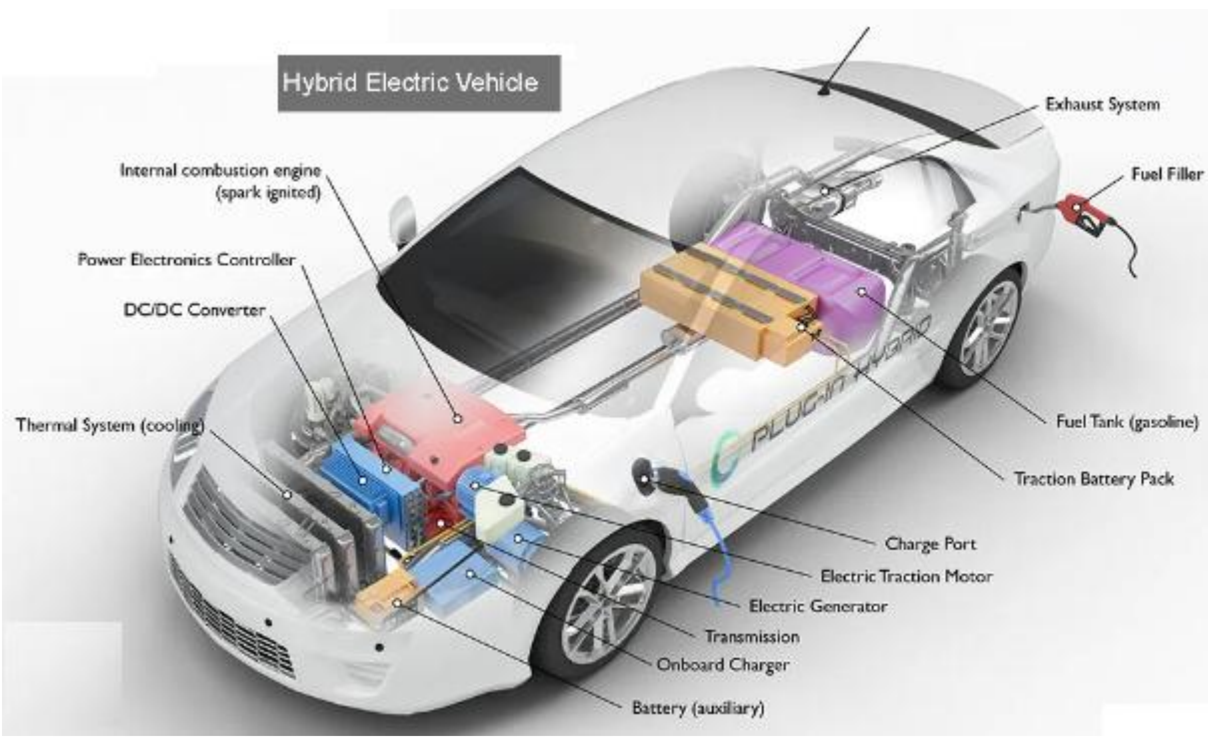
IC Engine: In most of the hybrid vehicles, IC engine acts as the main source of power. The parts of an IC engine are similar to that of the conventional IC engine.

Electric Generator: The function of an electric generator is to produce electricity when driven by an external power source (IC engine). It depends on the type of mode followed i.e., series, parallel or both.

Control Module: It is the most important component of the hybrid vehicle. It controls the entire operation of the vehicle by synchronizing all the power sources employed.

The functions of rest of the components are similar as mentioned in the above topic of electric vehicles


All-Electric Vehicle
Electric Traction Motor
Power Electronics Controller
DC/DC Converter
Thermal System (cooling)
Traction Battery Pack
Charge Port
Transmission
Onboard Charger
Battery (auxillary)
ALL-ELECTRIC


Hybrid Electric Vehicle
Exhaust System
Fuel Filler
Internal combustion engine
(spark ignited)
Power Electronics Controller
DC/DC Converter
Thermal System (cooling)
Fuel Tank (gasoline)
Traction Battery Pack
Charge Port
Electric Traction Motor
Electric Generator
Transmission
Onboard Charger
Battery (auxiliary)
PLUG-IN HYBRID

Difference Between Electric Vehicles and Hybrid Electric Vehicles

Feature	Electric Vehicle (EV)	Hybrid Electric Vehicle (HEV)
Power Source	Runs only on electricity using a battery and electric motor.	Uses both an internal combustion engine (ICE) and an electric motor.
Fuel Usage	No petrol/diesel required.	Uses petrol/diesel + electricity.
Emissions	Zero tailpipe emissions (environment-friendly).	Lower emissions than conventional vehicles but not zero.
Battery Charging	Must be charged using an external charger (AC/DC).	Battery charges automatically through regenerative braking and engine.
Range	Dependent on battery capacity; may have range anxiety.	Longer range due to dual power sources.
Maintenance	Low maintenance (fewer moving parts).	Higher maintenance (ICE + electrical system).
Cost	Higher initial cost due to large battery.	Lower cost than EV but higher than normal petrol vehicles.
Performance	Smooth, fast torque, quieter operation.	Moderate performance; acceleration usually lower.
Charging Infrastructure	Requires charging stations.	No need for external charging infrastructure.
Environmental Impact	Very eco-friendly.	Eco-friendly but still uses fossil fuel.

2.9 Power Transmission System:

The power transmission system is the set of mechanical components in a vehicle that transmits power from the engine to the wheels. Its main function is to deliver engine power at the right speed and torque required for driving, starting, climbing, and cruising. It ensures smooth power flow, speed variation, direction change, and efficient vehicle movement.

Belt, chain, and gear drives are common methods used to transmit power between shafts. A belt drive uses a flexible belt and pulleys, is simple and inexpensive, and is suitable for light loads. A chain drive uses a metal chain and sprockets, provides slip-free transmission, and is used for higher torque applications. A gear drive uses meshing gears to transmit power accurately, offering high efficiency and precise speed ratios for heavy-duty and high-speed machinery.

Gear Drives:

Gear drives are toothed wheels used to transmit considerable power over a short distance positively with a constant velocity ratio.

2.10 Classification of Gears:

The following represent different types of gears, which are classified based on the position of the axis of the shaft.

1. Spur gears
2. Helical gears
3. Bevel gears
4. Worm gears
5. Rack & pinion gears.

Spur Gears:

Spur gears are the simplest & the most commonly used gears designed to transmit motion between two parallel shafts, as shown in the following fig.

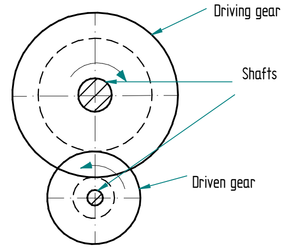


FIG : SPUR GEARS

From the fig,

- The axis of driving shaft & driven shaft are parallel to each other.
- The teeth are cut straight on the circumference of the gears & are parallel to the axis.

Application: Spur gears are used in machine tools, gear boxes , windup alarm clocks & watches, precision measuring instruments etc.,

Helical Gears:

Helical gears are similar to the spur gears except that the teeth are curved, each being helical in shape & hence the name, as shown in the following fig.

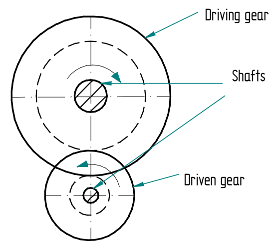


FIG : HELICAL GEARS

The helical gears are used to transmit power or motion between two parallel shafts or between non parallel but non-intersecting shafts.

Application: Compared to spur gears, helical gears are used when smooth & quiet running at higher speeds are necessary.

Bevel Gears:

Bevel gears are used for transmitting power between two intersecting shafts a shown in the following fig,

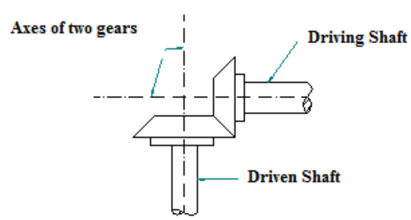


Fig: Bevel Gears

From the fig,

- The teeth of the bevel gears are cut on the conical surfaces.
- They are usually mounted on shafts that are 90^0 apart, but can be designed to work at other angles as well.

- Since the diameter of the cone is greatest at its base, the teeth will be thicker at the base.
- The size of the driving & driven bevel gears may be varied depending upon the gear ratio, but if the size of both driving & driven gears are equal & their axes are 90^0 apart, then they are called 'miter gears'.

Worm Gears:

Worm gears are used to transmit power between the driving & driven shafts having their axes at right angles & non-coplanar, as shown in the following fig.

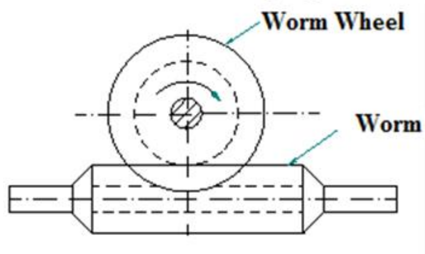


Fig: Worm Gear

From the fig, Worm gears consist of

- A worm, which is essentially a screw having one or more number of helical threads of trapezoidal shape cut on it.
- A worm wheel, with tooth profile segment consisting of a small segment of a helix, which engages with the worm.
- Applications:
- Worm gears are suitable for power transmission when a high velocity ratio as high as 60:1 is required.
- They are generally employed in machine tools like lathe, milling machine, drilling machines etc.,

Rack & Pinion Gear:

When a rotary motion is to be converted into a linear motion, rack & pinion arrangement is used, as shown in the following fig.

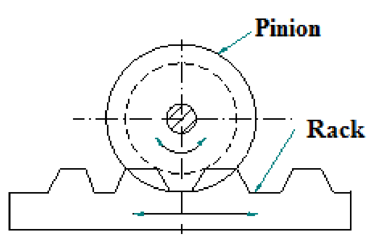


Fig: Rack & Pinion Gear

From the fig, the arrangement consist of

- A rack, which is a gear having teeth cut along a straight line
- A pinion, which is a gear with teeth cut along its periphery.

Applications: They are used in machine tools such as lathe, drilling, planning machines etc.

Velocity ratio of Gear Drives:

$$\frac{N_1}{N_2} = \frac{d_2}{d_1} = \frac{T_2}{T_1} = \frac{No.\,of\ teeth\ on\ driven\ gear}{No.\,of\ teeth\ on\ driving\ gear}$$

Where, d_1 =Diameter of the driving gear
d_2 = Diameter of the driven gear
N_1 =Speed of the driving gear in rpm
N_2 = Speed of the driven gear in rpm
T_1 = No. of teeth on driving gear.
T_2 = No. of teeth on driven gear.

Gear Train:

A grain train is an arrangement of successively meshing gear wheels through which the power can be transmitted between the driving & driven shafts.

Classification:

Depending on the arrangement of the gear wheels, Gear trains are classified into the following four types.

1. Simple gear train.
2. Compound gear train
3. Reverted gear train
4. Epicyclic gear train.

2.11 Simple Gear Train:

A series of gear wheels mounted on different shafts between the driving & driven shafts, such that each shaft carries only one gear is known as Simple gear train as shown in the following fig.

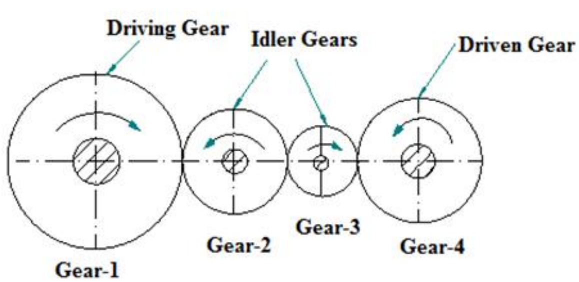


Fig: Simple Gear Train

From the fig,

- $Gear_1$ is the driving gear, while $gear_4$ is the driven gear.
- $Gear_2$ & $gear_3$ are intermediate gears which are called idler gears.
- The idler gears does not effect the ‘velocity ratio’ but only serves to fill up the space between the driving gear & driven gear .Hence the velocity ratio depends only upon the number of teeth on the driving & driven gears.
- The idler gears change the direction of rotation of the driven gear. Even no of idler gears will rotate the driven gear in the direction opposite to that of the driving gear, while odd no of idler gears will rotate driven gear in same direction of the driving gear.

$$\text{Velocity Ratio} = \frac{N_1}{N_4} = \frac{T_4}{T_1}$$

Train value = 1/velocity ratio.

Where, N_1 =Speed of the driving gear in rpm

N_4 = Speed of the driven gear in rpm

T_1 = No. of teeth on driving gear.

T_4 = No. of teeth on driven gear.

2.12 Compound Gear Train:

To obtain a very high velocity ratio with a small center distance, Compound gear train is used.

In a compound gear train, the intermediate shaft carries two gears, which are keyed to it, as shown in the following fig.

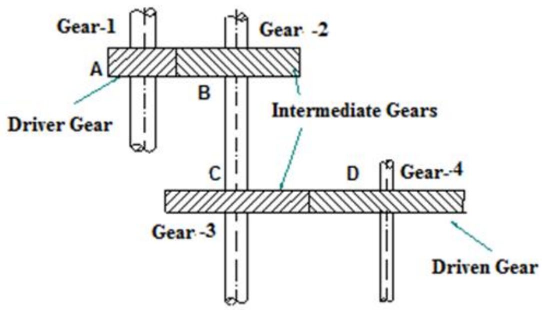


Fig: Compound Gear Train

From the fig,

- $Gear_1$ is the driving gear while $gear_4$ is the driven gear.
- $Gear_2$ & $gear_3$ are intermediate gears called idler gears, which are keyed to the same shaft. Hence they rotate at the same speed.

$$\text{Velocity Ratio} = \frac{N_1}{N_4} = \frac{T_4 x T_2}{T_1\, x T_3}$$

Train value = 1/velocity ratio.

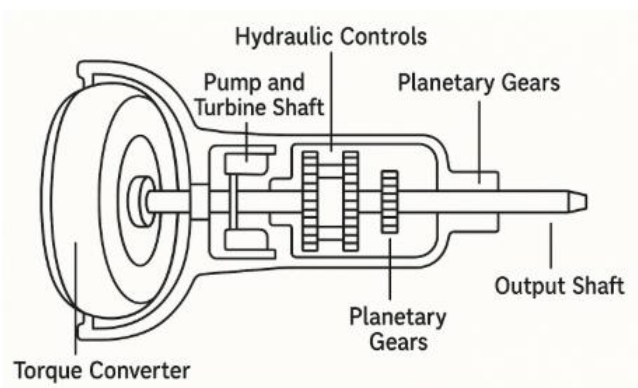
Where, T_2 & T_3 are No of teeth on idler gears.

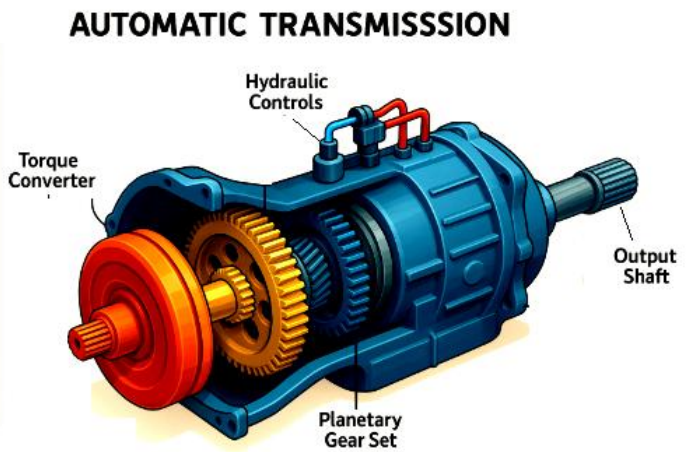
2.13 Automatic Transmission System:

An automatic transmission is a vehicle transmission system that automatically changes gear ratios without driver input using a torque converter, planetary gears, and hydraulic/electronic controls.

Construction Details:

Part	Function
Torque Converter	Replaces the clutch; transfers engine power to the transmission using fluid coupling and multiplies torque during acceleration.
Pump & Turbine Shaft	Part of the torque converter; pump pushes transmission fluid, turbine receives fluid energy to rotate the input shaft.
Planetary Gear Set	Provides different gear ratios (1st, 2nd, Reverse, etc.) through the interaction of sun gear, planet gears, and ring gear.
Hydraulic Controls / Valve Body	Directs transmission fluid to clutches and bands to engage or disengage gears based on driving conditions.
Output Shaft	Delivers the final rotational power from the gear sets to the drive shaft and wheels.
Clutches and Bands (Internal)	Lock and unlock specific gears in the planetary gear set to achieve different gear ratios.



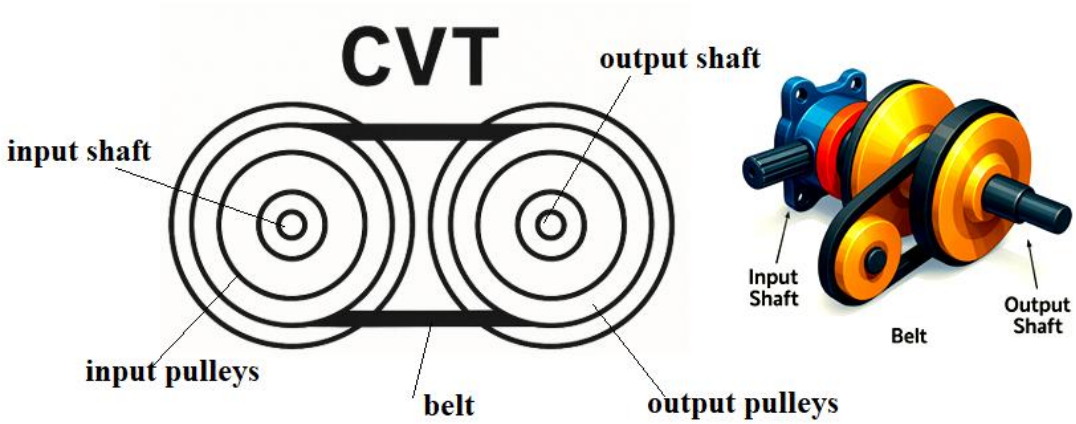


Operating Principle:

The automatic transmission works by combining hydraulic pressure, fluid coupling, and mechanical gearing. When the engine runs, the torque converter uses transmission fluid to transfer and multiply torque to the input shaft**,** eliminating the need for a clutch. The hydraulic control unit (valve body) senses vehicle speed, load, and throttle position and sends pressurized fluid to engage the appropriate clutches and bands. These elements lock and unlock parts of the planetary gear set**,** automatically selecting different gear ratios such as low gear for acceleration and higher gears for cruising. Finally, the output shaft delivers controlled power to the wheels, enabling smooth and automatic gear shifting without driver intervention.

2.14 CVT (Continuously Variable Transmission):

A Continuously Variable Transmission (CVT) is a transmission system that provides infinite gear ratios using a belt and variable-diameter pulleys to deliver smooth and efficient power transfer.



Construction details:

Part	Description
Input Shaft	Receives power from the engine and transfers it to the input pulley.
Input Pulleys (Primary Pulley)	A pair of cones whose spacing varies to change effective pulley diameter for the belt.
Output Pulleys (Secondary Pulley)	Receives motion from the belt; its width also varies to adjust transmission ratio.
Belt	A strong flexible belt that transfers power between the input and output pulleys while changing its position based on pulley diameters.
Output Shaft	Carries final power from the output pulley to the wheels.

Operating principle:

In a CVT system, power from the engine enters through the input shaft and rotates the input pulleys**.** The belt rides between two sets of pulleys—input and output—whose widths are continuously adjusted. When the input pulleys move closer, their effective diameter increases**,** pushing the belt outward; simultaneously the output pulleys move apart, decreasing their diameter. This change varies the speed ratio smoothly. At low speed, the input pulley diameter is small and output is large (more torque). At high speed, the input diameter increases and output decreases (more speed). Thus, the CVT provides a smooth, stepless variation of speed ratio, ensuring efficient power transmission to the output shaft as shown in the figure.

Difference between Automatic Transmission vs CVT (Continuously Variable Transmission):

Feature	Automatic Transmission	CVT (Continuously Variable Transmission)
Type of Gear System	Uses fixed gear ratios with planetary gears	No fixed gears; uses pulleys and a belt/chain
Gear Shifting	Shifts in steps (1st, 2nd, 3rd…)	Smooth continuous ratio change
Main Components	Torque converter, planetary gear sets, hydraulic control	Primary & secondary pulleys, metal belt/chain
Driving Feel	Noticeable gear shifts	No shift shock; very smooth
Fuel Efficiency	Moderate	Higher due to optimal RPM control
Acceleration	Strong & responsive	Smooth but often slower initial pickup
Complexity	Mechanically complex	Mechanically simple, electronically controlled
Common Usage	Cars, SUVs, trucks	Scooters, small cars, hybrids

Question Bank:

5 Marks:

1. Define an IC engine and list the major parts of a 4-stroke IC engine.
2. Explain the working of the suction and compression strokes in a 4-stroke petrol engine.
3. Compare petrol and diesel engines (any five differences).
4. Write a short note on applications of IC engines in automobiles.
5. Explain the construction and working of the spark-ignition (SI) engine.
6. Describe the role of the flywheel and crankshaft in IC engines.
7. What are electric vehicles (EVs)? List any four major components of an EV.
8. List advantages and disadvantages of hybrid vehicles (any four each).
9. What is a gear drive? Name five types of gears used in power transmission.
10. Explain spur gear with a neat diagram and mention two applications.
11. Explain simple gear train with the help of a diagram.
12. Define automatic transmission and list the major components.
13. What is CVT? State any four components of CVT transmission.
14. Write a short note on the torque converter in automatic transmission.
15. Explain regenerative braking in electric and hybrid vehicles.

10-MARK QUESTIONS (Long Answer / Descriptive)

1. Explain in detail the construction and working of a 4-stroke petrol (SI) engine with neat diagrams.
2. Describe the working of a 4-stroke diesel (CI) engine with PV diagram. Compare CI and SI engines.
3. Discuss the applications of IC engines in: (a) Power generation, (b) Agriculture, (c) Marine propulsion, (d) Aircraft propulsion, and (e) Automobiles.
4. Explain the components of Electric Vehicles with their functions. Draw a block diagram of an EV.
5. Explain the construction and working of Hybrid Electric Vehicles (HEV). Compare EVs and HEVs.
6. Describe the power transmission system in detail. Explain different types of gear drives with neat sketches.
7. Explain simple gear train and compound gear train with diagrams and derive the velocity ratio.
8. Explain the construction and working of an automatic transmission system with neat labelled diagram.
9. Describe the construction and operating principle of a CVT (Continuously Variable Transmission).
10. With neat diagrams, compare Automatic Transmission and CVT Transmission. Explain their applications and advantages.

GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN

Department of Mechanical Engineering

Near Dairy Circle, Hosur Road, Bengaluru , Karnataka 560029

INTRODUCTION TO MECHANICAL ENGINEERING (1BESC104D/204D)

As per New Syllabus Prescribed by V.T.U. (2025 CBCS System)

For

FIRST / SECOND SEMESTER

(Bachelor of Engineering)

MODULE-03
Engineering Materials

Dr.NAVEED M.Tech., PhD.
Assistant Professor
Department of Mechanical Engineering

MODULE-03 **ENGINEERING MATERIALS**

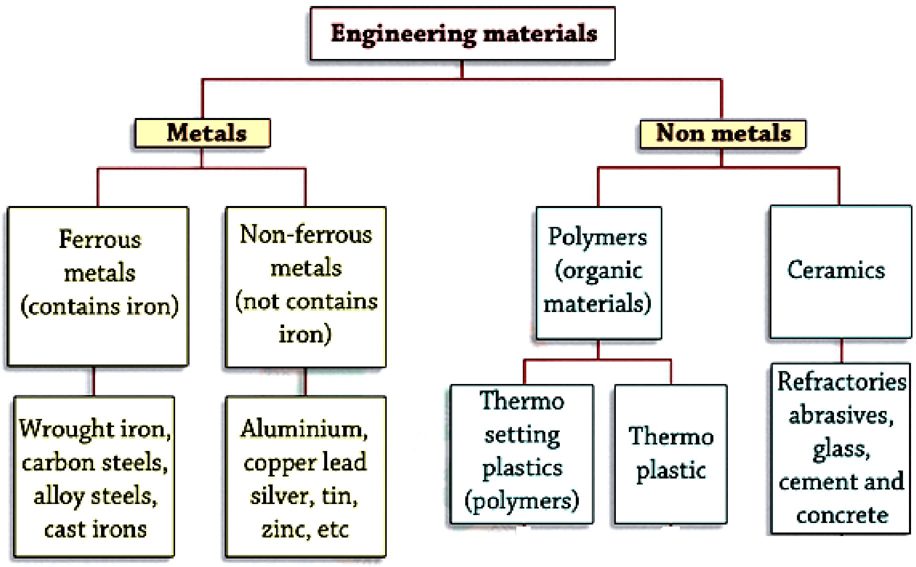
Syllabus:

Engineering Materials: Introduction, Classification, Ferrous and Non-Ferrous metals: Types, Properties and their applications. **Composite materials:** Introduction, Constituents of a composite, Classification, Types of Matrix and Reinforcement materials, Advantages, Disadvantages and Applications of composite materials. **Smart materials:** Introduction, Types - Piezoelectric materials, MR fluids, Shape memory alloys and Advantages, Disadvantages and Applications.

ENGINEERING MATERIALS

3.1 Introduction & Classification

Materials which are used in the engineering practice are called engineering materials. These have physical, mechanical and chemical properties. Engineering materials can be broadly classified into metals & non-metals, while metals are further sub-classified as ferrous and non-ferrous metals as shown in fig



Engineering materials	Description
Metals	Metals are materials which are in solid form at room temperature except mercury which is in liquid form. They are opaque and good conductors of heat and electricity. They also possess high density, high melting temperature and most of them are elastic up to a limit. A metal can also exist in liquid and gaseous forms.
Non Metals	All materials which are not metals belong to this category. These may be in the form of liquids, gases or solids such as Wood, Stone, Rubber, Plastic, Ceramic, Concrete, Asbestos etc.
Ferrous Metals	Metals containing iron, such as pig Iron, wrought Iron, Cast Iron, Steel, Carbon Steel, nickel steel etc, are called Ferrous metals, these can be attracted by magnets and are susceptible to rusting. They are very widely used in engineering.
Non-Ferrous Metals	Metals like gold, silver, Copper, Aluminium, Tin, Platinum, Zinc, Manganese, Nickle, Antimony etc. which do not contain iron are non-Ferrous metals. These can neither rust nor can be attracted by magnets.

3.2 Basic Types of Ferrous Materials.

Ferrous materials	Description
Pig Iron	The metallic product coming out of blast furnace is known as pig iron.
Wrought Iron (Pure Iron)	99.8% Pure iron, 0.01 – 0.02% carbon with traces of phosphorus, sulphur, Silicon and Slag left behind is known as wrought iron.
Cast Iron	Remelting of pig iron and refining it gives cast iron. In grey cast iron carbon is present in the form of graphite flakes, in white cast iron in the form of iron carbides, while in the form of nodules in nodular cast iron. The heat treatment of white cast iron for about 900^0C for several days gives malleable cast iron. Products of cast iron obtained from chilling process(rapid cooling) gives chilled cast iron.
Steel	It contains various alloying elements to enhance its properties. In addition to carbon it contains silicon, sulphur, manganese, phosphorous, nickel , chromium, tungsten . Steel with all these alloying elements is known as alloy steel, while ***tool steels*** exhibit good wear & abrasion resistance & can withstand hardness at elevated temperatures. ***Stainless steel*** is a type of steel with very good corrosive wear resistance unlike the ordinary steel.

Chemical composition of basic ferrous materials with their applications

Ferrous materials	Chemical composition	Applications
Pig iron	3.5-4.5% of C, 0.5-3% silicon, 0.04-0.2% sulphur, 0.5-2.5%manganese, 0.04-1% phosphorous.	For making wrought iron, cast iron, steel.
Wrought iron	99.8% iron, 0.02% C, 0.12% silicon, 0.018% sulphur, 0.02% phosphorous.	For making steam & water pipes, engine bolts, rivets, chain links, crane hooks etc.
Cast iron	90%iron, 2-4.5% C, 1-3% silicon, small amount of sulphur, manganese, phosphorous.	For making machine frames, columns, beds, plates flywheels, engine block, cylinder head etc.,
Steel	0.5-1.5% C, small amount of silicon, sulphur, manganese, phosphorous, nickel, chromium, tungsten.	Low carbon steel is used for making shafts, camshafts, gears and axles. Medium carbon steel is used for making connecting rods, couplings, spindles etc. High carbon steel is used for making hammers, chisels, knives, punches drills etc.
Tool Steel	0.8 to 1.2 % C, small amount of tungsten, vanadium, chromium, molybdenum.	Suited for machine tools such as High Speed Steel (HSS).
Stainless Steel	18% chromium, 8% nickel, 0.03% carbon with rest iron along with some small traces of manganese, silicon, molybdenum, sulphur, phosphorous, nitrogen	For making cutting tools and dies for machining & forming operations.

3.3 Non-ferrous materials with their chemical composition and applications

Non-ferrous materials	Chemical composition	Applications
Copper & its alloys.		
Brass	51-81% Cu, 19-49% Zn, small amount of aluminium, tin, manganeses, lead.	For making ornaments, electrical fittings, gears, pinions and other moving parts of a clock etc.,
Bronze	5-10% of tin with rest of Cu in addition to small amount of Al, Si, Mn, Ni.	For making marine fittings, pumps, valves, bearings etc.,
Aluminium		
Al casting and its composites	With different reinforcements like SiC, Gr, TiO_2, Al_2O_3	For making bumpers, car body, connecting rod, golf clubs, tennis racket etc.,
Wrought Al alloy (duralumin)	4% Cu, 0.5% of Mg, Mn, Si & iron each.	For making aircraft structures, connecting rod of aero engines.
Lead & its alloys		
Nickel	Cu, iron, chromium, Si, molybdenum, Mn, Al	For making heat resistant alloy for electrical heaters, as catalyst in many reactions, measuring instruments.

COMPOSITE MATERIALS

3.4 Introduction: Composite materials are defined as material systems consisting of mixture of (or combination of) two or more micro constituents insoluble in each other and differing in form and or material composition. These materials may have a hard phase (reinforcement) in soft matrix and vice-versa. In most cases a hard phase is embedded in a soft matrix, which increases the modulus or strength of the matrix. A soft phase embedded in hard matrix increases the shock resistance of the materials.

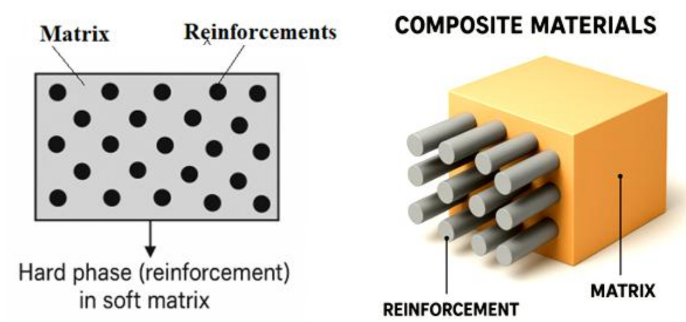
Composite materials are becoming increasingly important because they provide a unique combination of properties that cannot be achieved with traditional materials like metals, ceramics, or polymers alone. They offer high strength-to-weight ratio, excellent stiffness, corrosion and wear resistance, and improved fatigue life, making them ideal for aerospace, automotive, marine, construction, defense, and sports industries. Their scope is expanding rapidly as modern engineering demands materials that are lightweight yet strong, durable yet economical, and capable of withstanding extreme environments. With advancements in manufacturing technologies such as additive manufacturing, automation, and smart materials, composites continue to replace conventional materials, opening new possibilities in design, performance, and sustainability.

3.5 Constituents of a Composite:

Composites are made up of two main constituents**:** Matrix and Reinforcement.

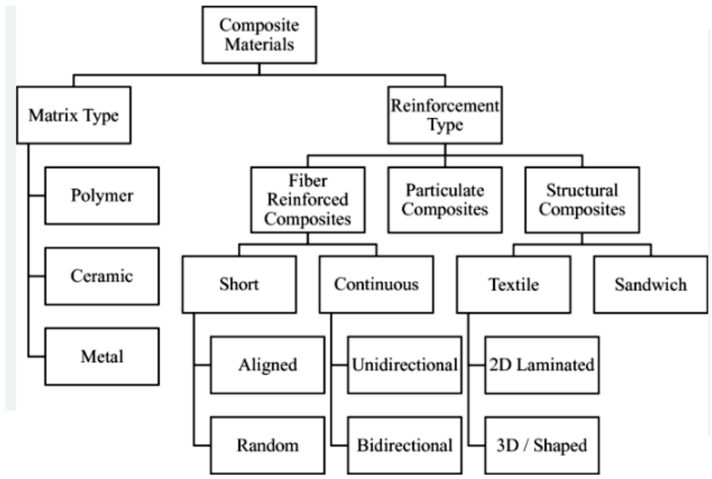
Matrix: The matrix is the *continuous phase* that holds everything together. It surrounds the reinforcement, keeps it in place, transfers loads, and protects it from environmental damage. Matrices can be polymers, metals, or ceramics.

Reinforcement: The reinforcement is the *dispersed phase* added to improve the mechanical, thermal, or electrical properties of the matrix. It carries most of the load and provides strength and stiffness. Reinforcements may be in the form of fibers, particles, whiskers, platelets, or flakes as shown in the following fig.



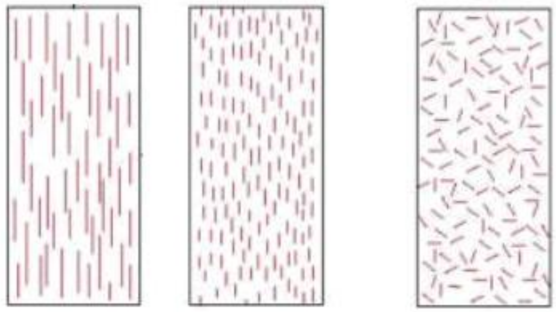
3.6 Classification of composite materials

Composite materials are classified into various types based on matrix phase and reinforcement phase. Matrix phase serves two paramount purposes viz., binding the reinforcement phases in place and deforming to distribute the stresses among the constituent reinforcement materials under an applied force while, reinforcement phase provide adequate stiffness and strength to the matrix phase. It enhances the life of the matrix material by improving thermal, electrical conductivity and mechanical properties.



3.7 Classification of Composite Materials

Based on matrix phase	
Metal Matrix Composites (MMCs)	In this the matrix material is made up of usually light weight .Metals are very rigid and strong. Metals can be easily plastically deformed and strengthened through various types of technologies. The various metal matrices that have been tried are nickel based alloys, magnesium alloys, copper and its alloys, titanium alloys, aluminium alloys etc. All these matrices are suitable for high temperature applications (300 to 500^{0}C.).They are used in making piston for diesel engine, high speed rotating shafts, brake pads, in spacecraft structures, missile structures, fighter aircraft engines etc.,
Polymer Matrix Composites (PMCs)	Polymers are non metals made up of large number of molecules called monomers. These molecules are interconnected together in the form of a chain. Polymers are abundantly available in nature and are produced by chemical reactions. Chain growth and condensation polymerization are two such chemical reactions.
Ceramic Matrix Composites (CMCs)	Ceramics are highly brittle non metals fabricated at extremely high temperature. It posses excellent chemical resistance, high hardness, non conducting properties, high refractoriness. The various types of ceramics which have been tried are titanium oxide, silicon carbide, titanium nitride, silicon nitride, aluminium oxide etc.
Based on reinforcement phase	
Fibers (Fiber Reinforced Composites)	Fibers are substances characterized with longer axis in the longitudinal direction. It has an outstanding strength property in the longitudinal direction. These are available in many diameters and lengths including continuous, which can be used as it is, or chopped to the desired length. These can be polycrystalline or amorphous and forms the principal constituents in a fiber-reinforced composite with polymer or ceramic or metal matrices. They occupy the largest volume fraction in a composite and share the major portion of the load acting. They are available in the form of natural fibers and synthetic fibers. Some of the natural fibers available in the nature are vegetable fibers, jute fibers, animal fibers etc. Some of the important fibers are glass, carbon, kevlar, boron, SiC and Al_2O_3.Fiber reinforced composites have resulted in a better type of high strength material. It has a very good load withstanding property. They are used in advanced sports equipments, body parts of racing car, wings, fuselage and tail assembly components of an aircraft. They are classified into continuous, discontinuous with either aligned arrangement or randomly distributed arrangements as shown in
Whiskers	Whiskers are single crystals which have diameter ranging from 0.01 micron to 10 microns with an aspect ratio of more than 10. It has high surface to volume ratio and are available in various forms like rhombohedral, hexagonal, triangular etc. Ceramic matrix with whiskers posses excellent properties like wear resistance, fracture toughness, stiffness, creep resistance etc.
Flakes	Flakes are attractive reinforcements when used with ceramic matrix. Some of the examples are mica, silicon carbide, boron carbide, copper, aluminum etc.
Particulates	Particulates are small microscopic material in the form of a powder and have low aspect ratio. They may be in the form of cubes, spherical, plate like or irregular or regular geometry. Size, geometry, distribution, and volume fraction are the factors on which the efficiency of the particulate reinforcement depends. Particulates may be metallic or non metallic types. Some of the particulates which are used as reinforcements in composites are aluminium oxide, silicon carbide, graphite, titanium oxide, tungsten carbide, zirconium oxide etc.



1. Continous 2. Discontinous & Aligned 3. Discontinous & Random Orientation

3.8 Types of Matrix Materials:

Matrix Type	Description	Examples	Key Advantages
Polymer Matrix (PMC)	Uses polymers as the continuous phase; most common type of matrix.	Epoxy, Polyester, Vinyl ester, Polyethylene	Lightweight, easy to process, low cost, good corrosion resistance
Metal Matrix (MMC)	Uses metals as the matrix to hold reinforcements; used for high-strength and high-temperature applications.	Aluminium and its alloys, Magnesium alloys, Titanium alloys, Copper alloys	High strength, good thermal conductivity, withstands high temperatures
Ceramic Matrix (CMC)	Uses ceramics as the matrix; suitable for very high-temperature and wear-resistant applications.	Alumina, Silicon carbide, Silicon nitride, Zirconia	Excellent hardness, high melting point, good corrosion and wear resistance

3.9 Types of Reinforcement Materials:

Reinforcement Type	Description	Examples	Key Advantages
Fibers	Long, high-aspect-ratio reinforcements that carry most of the load in composites.	Glass fibers, Carbon fibers, Kevlar, Boron fibers, SiC fibers	Very high strength & stiffness, lightweight, excellent fatigue resistance
Whiskers	Very thin, single-crystal needle-like reinforcements with extremely high strength.	SiC whiskers, Al_2O_3 whiskers, Si_3N_4 whiskers, TiC whiskers	Extremely strong, high stiffness, excellent wear & creep resistance
Platelets / Flakes	Flat reinforcements with moderate aspect ratio; reduce anisotropy and improve dimensional stability.	Mica flakes, SiC platelets, Boron carbide flakes	Good toughness, stability, improved thermal & barrier properties
Particulates	Equiaxed particles with low aspect ratio distributed within the matrix.	Al_2O_3, SiC, BN, Graphite, TiC, ZrO_2 particles	Cost-effective, increases wear resistance, improves stiffness & hardness

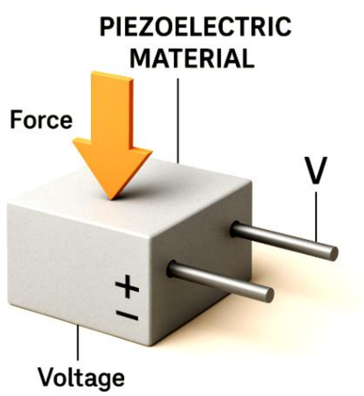
3.10 Advantages, Disadvantages, and Applications of Composite Materials

Aspect	Summary
Advantages	• High strength-to-weight ratio • High stiffness and tailored mechanical properties • Excellent corrosion and wear resistance • Good fatigue performance • Low thermal expansion (in many composites) • Design flexibility (fibers can be oriented as needed) • Long service life with low maintenance
Disadvantages	• High manufacturing and material cost • Difficult to repair once damaged • Complex fabrication processes • Low transverse strength compared to longitudinal strength • Sensitive to temperature and moisture (especially polymers) • Recycling is difficult due to multi-material nature
Applications	• Aerospace components (wings, fuselage, radomes) • Automotive parts (body panels, driveshafts) • Marine structures (boat hulls, propellers) • Sporting goods (bats, rackets, bicycles) • Civil structures (bridges, reinforcement bars, panels) • Electrical and electronics (circuit boards, insulators) • Defense and military (armor, helmets, missile parts)

3.11 SMART MATERIALS:

Smart materials, which are also known as intelligent or responsive materials are those materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli, such as stress, temperature, moisture, pH, electric or magnetic fields, light, or chemical compounds. Smart materials are the basis of many applications, including sensors and actuators. Examples: Piezoelectric materials, shape memory alloys, MR fluids, photovoltaic materials, electroactive polymers etc.

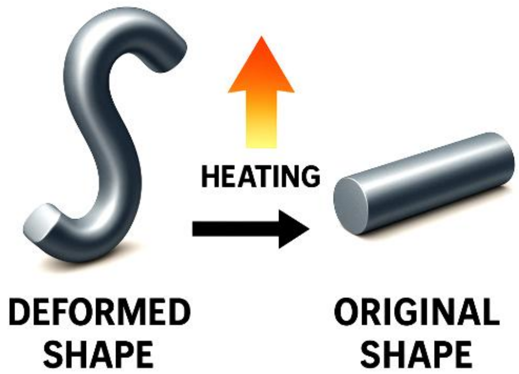
3.12 Piezoelectric Materials: A piezoelectric material is a smart material that generates an electric voltage when subjected to mechanical stress and produces mechanical deformation when an electric field is applied.



Piezoelectric materials are special smart materials that exhibit a reversible coupling between mechanical and electrical energy. When an external force, pressure, or vibration is applied, they generate an electrical voltage—this is known as the direct piezoelectric effect. Conversely, when an electric field is applied, they undergo mechanical deformation, known as the inverse piezoelectric effect. These materials are highly sensitive, have fast response times, and can operate over a wide frequency range, making them suitable for precise sensing and actuation. They are also capable of converting very small mechanical changes into measurable electrical signals, which makes them valuable in high-accuracy applications.

Naturally occurring piezoelectric materials include bone, tendons, silk, dentin, and collagen, whereas artificially engineered materials include quartz, barium titanate ($BaTiO_3$), lead titanate ($PbTiO_3$), and lead zirconate titanate (PZT). Because of their unique characteristics, piezoelectric materials are used in sonar systems, microphones, pressure sensors, medical ultrasound devices, actuators, and ignition sources.

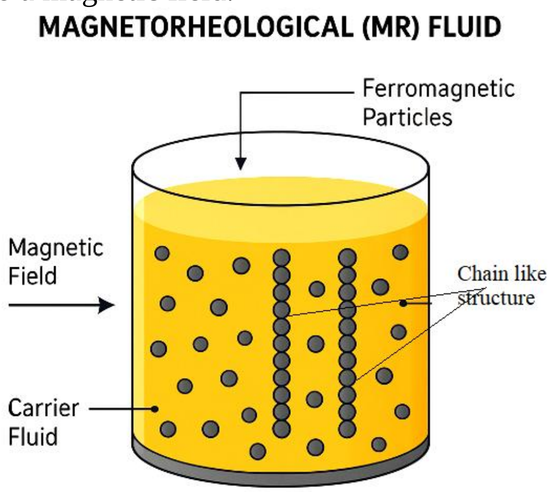
3.13 Shape Memory Alloys (SMAs): A shape memory alloy is a smart material that can be deformed at low temperatures and return to its original shape upon heating due to a reversible solid-state phase transformation.



Shape Memory Alloys (SMAs) are unique smart materials that possess the remarkable ability to "remember" and recover their original shape after being deformed, when they are heated above a specific transformation temperature. This behavior is due to a reversible change between two crystal phases—martensite (low-temperature, easily deformable phase) and austenite (high-temperature, stronger phase). Their key characteristics include high strength, excellent corrosion resistance, good biocompatibility, and the ability to undergo large recoverable strains. SMAs also exhibit properties such as *shape memory effect* and *superelasticity*, making them suitable for applications requiring adaptive responses.

Common examples of SMAs include Nickel–Titanium (NiTi or Nitinol) and Copper–Aluminium–Nickel (Cu–Al–Ni) alloys, while other SMAs may be produced by alloying materials such as zinc, gold, iron, and copper. SMAs are widely used in medical stents, orthodontic wires, vibration dampers, actuators, aerospace couplings, and safety devices due to their distinctive mechanical and thermal behavior.

3.14 MR Fluids: A Magnetorheological (MR) fluid is a smart fluid whose viscosity changes rapidly and reversibly when exposed to a magnetic field.



Magnetorheological (MR) fluids are advanced smart materials composed of micron-sized ferromagnetic particles, such as iron, suspended in a carrier liquid like oil, water, or synthetic fluids. Their key characteristic is that they behave like a normal liquid in the absence of a magnetic field but instantly transform into a semi-solid or highly viscous fluid when a magnetic field is applied. This happens because the magnetic particles align into chain-like structures along the direction of the field, resisting flow and increasing the fluid's apparent yield stress. MR fluids exhibit fast response time, reversibility, controllability, and require very low power to operate, making them ideal for adaptive systems. Common applications include MR dampers, automotive suspension systems, vibration control devices, prosthetics, clutches, and brakes. Examples of MR fluids include carbonyl iron–based MR fluids and synthetic oil-based MR fluids used in commercial damping systems.

3.15 Advantages, Disadvantages & Applications of Smart Materials:

Smart Material	Advantages	Disadvantages	Applications
Piezoelectric Materials	• Very fast response time • High sensitivity to mechanical/pressure changes • Capable of converting mechanical energy to electrical energy and vice versa • Precise control and actuation	• Limited strain capability • Brittle and can crack under high loads • Temperature-sensitive performance	• Sensors (pressure, vibration, force) • Actuators and micro-positioning devices • Ultrasonic transducers • Energy harvesting devices
Shape Memory Alloys (SMA)	• Unique ability to return to original shape upon heating • High strength and good corrosion resistance • Large recoverable strain • Biocompatibility (suitable for medical use)	• Expensive material and processing • Slow response compared to piezoelectrics • Limited fatigue life under repeated cycles	• Medical stents, orthodontic wires • Actuators and robotic components • Aerospace couplings and fasteners • Temperature-sensitive switches
Magnetorheological (MR) Fluids	• Rapid, reversible change in viscosity under magnetic field • High controllability and adaptability • Good damping performance • Low power requirement	• Particle sedimentation over time • Possible wear due to particles • Higher cost than conventional fluids	• MR dampers and shock absorbers • Automotive suspension systems • Vibration control devices • Clutches and brakes

QUESTION BANK:

5-Marks Questions (Short Descriptive)

1. Define composite materials and explain their constituents with neat sketches.
2. Classify engineering materials and briefly explain ferrous and non-ferrous materials with examples.
3. Write a note on Polymer Matrix, Metal Matrix and Ceramic Matrix Composites.
4. Explain different types of reinforcement materials used in composites.
5. Describe Piezoelectric materials with characteristics and applications.
6. What are Shape Memory Alloys? Explain their characteristics and two applications.
7. Define MR fluids and explain their working principle briefly.
8. List advantages and disadvantages of composite materials.
9. Explain the classification of composites based on matrix material.
10. Write short notes on any two smart materials: Piezoelectric, SMA, MR fluids.

10-Marks Questions (Long, Detailed, Full-Marks)

1. Explain composite materials in detail with:
(a) Definition, (b) Constituents, (c) Classification, (d) Advantages, disadvantages & applications.
2. Discuss the following in detail:
(a) Types of matrix materials
(b) Types of reinforcement materials
(c) Their examples and key advantages.
3. With neat diagrams, explain the behavior of Piezoelectric materials, Shape Memory Alloys and MR Fluids, including characteristics and applications.
4. Classify engineering materials. Explain ferrous and non-ferrous metals along with their composition and applications.
5. What are smart materials? Explain Piezoelectric materials, SMAs and MR fluids with working principles, advantages, disadvantages, and applications.
6. Explain the classification of composite materials based on:
(a) Matrix phase
(b) Reinforcement phase. Illustrate with diagrams and examples.
7. Describe in detail the properties, composition, uses and significance of ferrous materials (pig iron, cast iron, wrought iron, steel).
8. Explain non-ferrous metals (Al, Cu alloys, Brass, Bronze, Nickel alloys) with their chemical composition and applications.
9. Write a detailed note on smart materials and their role in modern engineering applications.
10. Compare PMCs, MMCs, and CMCs along with their characteristics, advantages, limitations and example applications.

GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN

Department of Mechanical Engineering

Near Dairy Circle, Hosur Road, Bengaluru , Karnataka 560029

INTRODUCTION TO MECHANICAL ENGINEERING

(1BESC104D/204D)

As per New Syllabus Prescribed by V.T.U. (2025 CBCS System)

For

FIRST / SECOND SEMESTER

(Bachelor of Engineering)

MODULE-04

Manufacturing

Dr.NAVEED M.Tech., PhD.

Assistant Professor

MODULE-04 MANUFACTURING

Syllabus:

Manufacturing overview: classification of manufacturing processes, process selection criterion. Principles of Welding, soldering, brazing. **Introduction to machine tools** – lathe, drilling and milling machine. Lathe operations: Turning, facing, knurling, Drilling machine operations: Drilling, reaming, tapping. Milling machine operations: End milling, face milling. **Introduction to CNC** components, advantages and applications. Basic principles of 3D printing.

Manufacturing Overview:

Manufacturing is the process of converting raw materials into finished products through physical, chemical, or mechanical means. It involves systematic operations, tools, and technologies to achieve products with desired shape, size, and functionality.

4.1 Classification of Manufacturing Processes:

1. Casting Technology

Casting is a manufacturing process where molten metal is poured into a prepared mold and allowed to solidify into a desired shape. It is widely used for producing complex shapes, large components, and parts that would be difficult or uneconomical to make by other methods. Common examples include engine blocks, pipes, and machine housings.

2. Forming Technology

Forming involves shaping materials—usually metals—through deformation without removing material. Processes like forging, rolling, extrusion, and sheet-metal forming use force, pressure, or heat to change the shape while maintaining the original volume. Formed parts are generally strong and used in applications such as automotive components, structural sections, and fasteners.

3. Machining Technology

Machining is a subtractive manufacturing process where excess material is removed from a workpiece using cutting tools to achieve precise dimensions and superior surface finish. Processes such as turning, milling, drilling, and grinding fall under machining. It is essential for producing accurate, high-quality parts used in mechanical, aerospace, and precision industries.

4. Joining Technology

Joining refers to processes that assemble two or more parts into a single unit using methods like welding, soldering, brazing, riveting, or adhesive bonding. Joining is crucial for constructing complex assemblies such as frames, structures, machinery, and electronic circuits. It provides strength, stability, and functionality to final products.

Summary with selection criteria:

Type of Manufacturing Process	Description	Purpose	Selection Criteria	Examples
Casting Technology	Pouring molten metal into a mold and letting it solidify	Used to make complex or large shapes easily	Choosen when parts have complex shapes, large sizes, or when molten metal can easily fill molds	Engine blocks, pipes, housings
Forming Technology	Shaping material by applying force without removing material	Increases strength and changes shape by deformation	Choosen when high strength, good mechanical properties, and material conservation are required	Forging, rolling, extrusion
Machining Technology	Removing unwanted material from a workpiece using cutting tools	Achieves high accuracy and smooth surface finish	Choosen when precision, tight tolerances, and detailed features are needed	Turning, milling, drilling, grinding
Joining Technology	Connecting two or more parts into a single unit	Used for assembling structures or components	Choosen when components must be assembled, repaired, or when large structures need to be built	Welding, brazing, riveting, adhesives

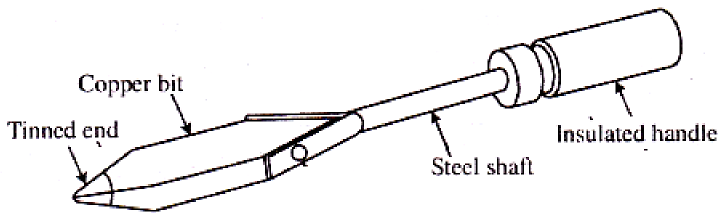
SOLDERING, BRAZING AND WELDING:

Introduction: There are various processes by which two or more parts can be joined together. The joints obtained by joining processes may be temporary or permanent. Among all the various joining processes, welding, brazing and soldering are different from the others in the sense that, in these processes, the parts are joined by the application of heat.

Soldering: Soldering is a method of joining similar or dissimilar metals by means of a filler metal whose melting temperature is below 450^{o}C. The filler metal usually called, solder is an alloy of tin and lead in various proportions.

4.2 Construction & operating principle of soldering iron method

It is the common and widely used method of soldering. The construction details & operating principle of soldering iron method is discussed in table and shown in fig .

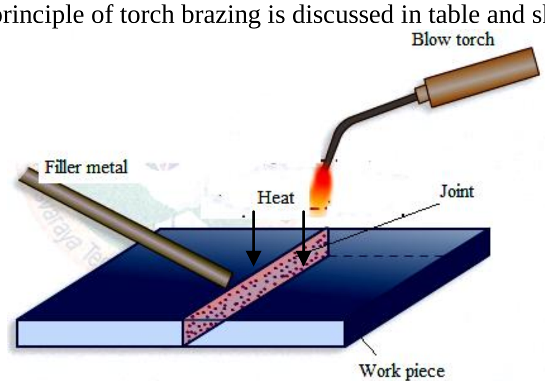


Construction details	Description
Tinned end	It is the tip of the copper bit. It receives & stores heat from the copper bit. It conducts heat from the copper bit to the components being joined.
Copper bit	It is heated electrically or by oil or gas flame & supplies heat energy to the tinned end.
Steel shaft	It is connected to the copper bit through rivets & provides support to the copper bit.
Insulated handle	It is gripped by the operator & helps the operator to carry on soldering.
Flux material	The function of the flux is to wet the surface of the workpiece and to permit the molten solder to flow easily into the joint. It also prevents oxides from separating the solder from the surface. Zinc chloride & hydrochloric acid are some of the fluxes used in soldering.
In operation, the surface of the parts to be joined are first cleaned in order to remove dirt, grease and other oxides which is followed by application of 'flux' at the edges of the parts to be joined. The solder is heated by an electric source, usually a soldering iron and the molten solder is deposited at the joint. The solder is allowed to cool for some time and then the soldered joint is cleaned to remove any flux residues in order to avoid corrosion.	

BRAZING: Brazing is a method of joining similar or dissimilar metals by means of a filler metal whose melting temperature is above 450^{0}C but below the melting point of the base metal. The filler metal used is called 'spelter'- a non-ferrous metal or alloy. Usually copper and copper alloys, silver and silver alloys and aluminum alloys are most commonly used spelters. Further the use of flux increases both the flow of filler metal and its ability to stick to the base metal. It also prevents the formation of oxides that are formed during the process. Borax, boric acid, fluorides or chlorides are the commonly used flux materials.

4.3 Construction & operating principle of torch brazing

The construction details & operating principle of torch brazing is discussed in table and shown in fig.



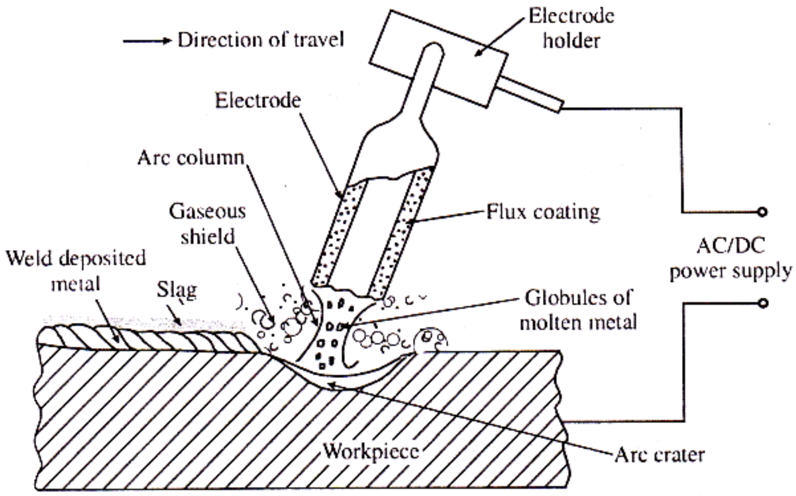
Construction details	Description
Blow torch	It provides source of heat energy for carrying out brazing operation. It is operated through oxy-acetylene gas cylinders. It provides carburizing flame with excess acetylene for heating the components to be joined.

Filler metal	It is similar in chemical composition to that of the components to be joined. It is an additional material which provides sufficient molten metal to obtain the joint.
Flux material	The function of the flux is to wet the surface of the workpiece and to permit the molten solder to flow easily into the joint. It also prevents oxides from separating the solder from the surface. Zinc chloride & hydrochloric acid are some of the fluxes used.
In operation, the surface of the parts to be joined are first cleaned in order to remove dirt, grease and other oxides which is followed by application of 'flux' at the edges of the parts to be joined. The base metals are heated by an oxy-acetylene welding torch. The filler metal is then placed at the joint & is heated with a carburizing flame, which makes it to melt. The molten metal fills the joint by capillary action, forming a strong metallurgical bond between the two base metals	

WELDING: Welding is a metallurgical process in which the parts to be joined are heated to a suitable temperature and then fused together either with or without the application of pressure. Since a slight gap usually exists between the work pieces, a 'filler metal' can be used to supply additional material to fill the gap.

4.4 Construction & Operating Principle of Arc Welding

Arc welding process is fusion method of welding that utilizes the high intensity of the arc generated by the flow of current to melt the workpieces. The construction details & operating principle of arc welding is discussed in table and shown in fig.



Construction details	Description
Electrode holder	It provides source of heat energy for carrying out welding operation. It is connected to either AC or DC transformer and helps in transferring electric current to the electrode which is connected to it.
Electrode	It is similar in chemical composition to that of the components to be joined. It is an additional material which provides sufficient molten metal to obtain the joint. One of its end is left uncoated with flux material & it connected to the electrode holder for passage of electric current. An electric circuit is formed between the electrode & workpiece to generate heat energy for welding. It can be consumable electrode or non-consumable electrode. In case of non-consumable electrode a separate filler material is used.
Flux material	The function of the flux is to provide a safer zone for welding operation. It removes impurities from the workpiece material in the form of slag.
In operation, an electric arc is produced by striking the electrode on the work piece. The electrode is momentarily separated from the work piece by a small gap such that the arc is still maintained between the workpiece and the electrode. The electrical energy is thus converted into heat energy & results in molten pool of electrode & the joint surface of the base metals. The tip of the electrode melts and combines with the molten metal of the workpiece thereby forming a homogenous joint as shown in the fig. Arc welding process is used for fabrication work, repair and maintenance work. Examples: Boiler and Pressure vessel fabrication, Ship building, Joining of large pipes and penstock, Building and Bridge constructions, Automotive and Aircraft industries etc.	

Video: https://drive.google.com/file/d/1SpABigmSxeTiFcgw20zSWV8a4yRYNzj7/view?usp=drive_link

Comparison of joining processes

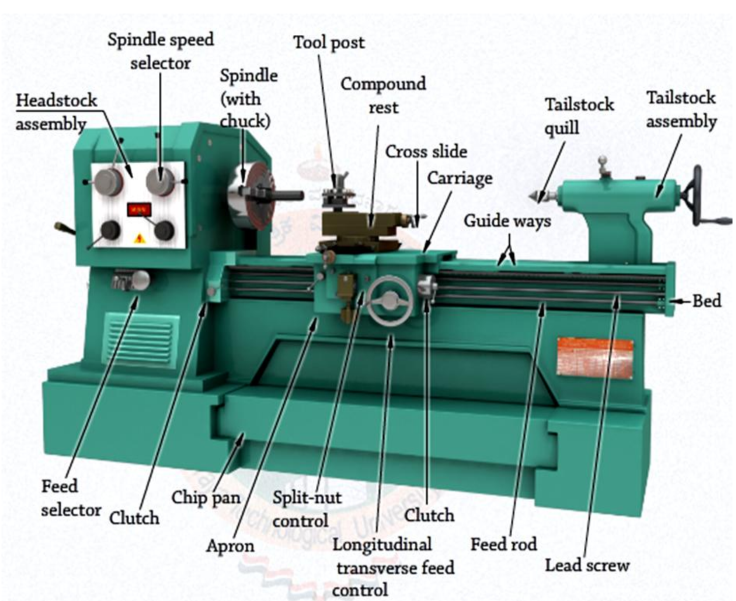
Some comparisons of the joining processes are discussed in table

Parameters	Welding	Soldering	Brazing
Heating temperature	Base metals are heated above their melting point.	They are heated below their melting point.	They are also heated below their melting point.
Filler material	It is made up of same material as that of the base metals	It is not as same as that of the base metals	It is not as same as that of the base metals
Joint formation	It is formed by solidification of both molten filler metal and base metal.	It is obtained by diffusion of filler metal into the base metal.	It is obtained by diffusion of filler metal into the base metal.
Strength of the joint	It is much stronger than the base metal due to modification in grain structure.	It is weaker than that of brazing & welding.	It is stronger than soldering but weaker than welding.
Heat affected zone	It is affected to larger extent	It is almost negligible.	It is affected but not to the level of welding.
Finishing operations	It requires certain finishing operations like grinding, filing etc.,	It doesn't require & the joint can be used as it is.	In some cases finishing operations are needed.
Applications	In fabrication & structural applications	For joining thin sheet metals, pipes, wires, circuit board etc.,	In arts, jewelry & also in industries.

Introduction to Machine Tools: Machine tools are power-driven machines used to shape, cut, or finish materials by removing unwanted material with high precision and accuracy. They are essential in manufacturing for producing components with exact dimensions and smooth surfaces.

Types of Machine Tools:

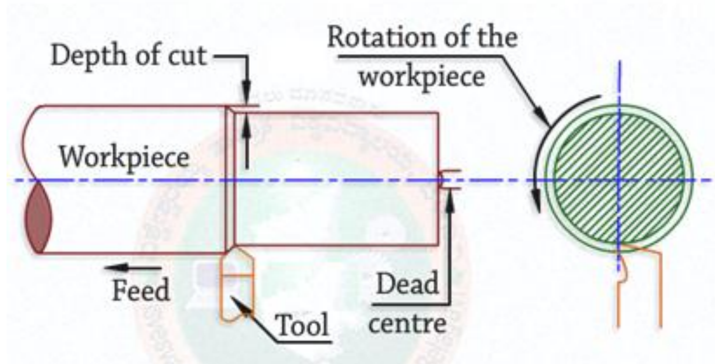
- ✓ Lathe – Used for turning, facing, and threading operations.
- ✓ Milling Machine – Used to remove material using a rotating cutter for slots, grooves, and profiles.
- ✓ Drilling Machine – Used for making holes in materials.
- ✓ Grinding Machine – Used for fine finishing and achieving high surface accuracy.
- ✓ Shaper and Planer – Used for producing flat surfaces.
- ✓ CNC Machines – Computer-controlled machines for automated and precise operations.

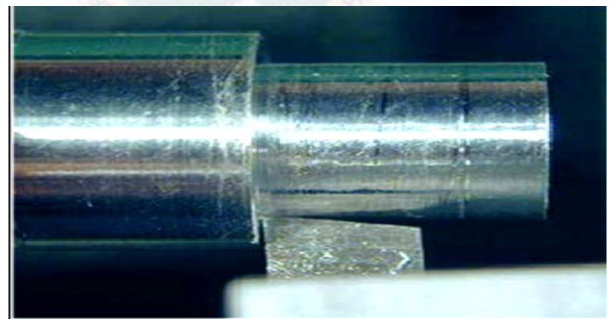


Lathe Machine: A lathe is a machine tool employed generally to produce circular objects. It is one of the oldest, most common, most basic, most versatile and most widely used machine tool. Engine lathe is the most commonly used general purpose lathe, it is small in size, inexpensive and can perform many operations. Engine Lathe is so called because the lathe of this type was driven by a steam engine. Today these lathes are equipped with the motor for the lathe driven mechanism, it is also called as center lathe or simply Lathe.

4.5 Principle of Working of a Center Lathe:

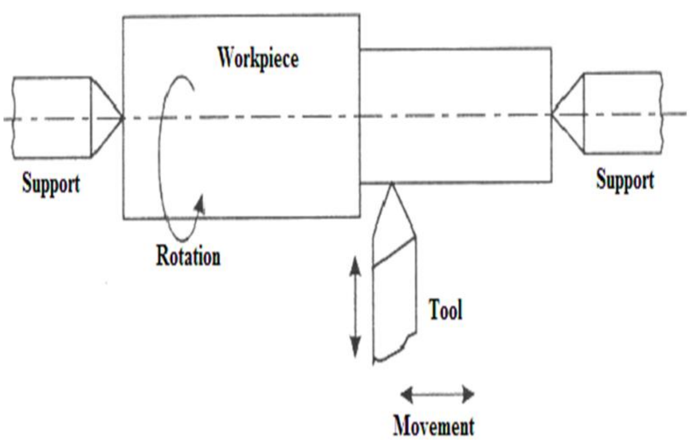
A lathe, basically turning machine works on the principle that, when a cutting tool is moved against a rotating work piece, the excess material is removed in the form chips. The figure illustrates principle of working of a center lathe.





In operation, the work piece is placed between the two centers of the lathe, that is the live center (head stock) and the dead center (tail stock). The cutting tool is mounted on the tool post at the compound rest. As the work piece is turned or rotated on the lathe, the cutting tool is moved on the work piece and the desired amount of material is removed in the form of chips. Based on the operation, the cutting tool can be selected, the most commonly used tool in the lathe are High Speed Steel (HSS), Cemented Carbide, Cemented Oxide, Diamond, etc.

In lathe the amount of cut given to the job is termed as depth of cut where as the direction in which the tool is traveling is called feed. The cutting tool is usually made up of material which is harder than the work piece.



Lathe Operations: These are the various operations which can be carried out on the cylindrical work piece using the lathe machine with different types of cutting tools. Examples: Turning operation, facing operation, knurling operations , thread cutting operation, taper turning etc.,

4.6 Turning Operation:

Turning is an operation on a lathe in which the work piece is reduced to the cylindrical section of required diameter as shown in the fig.

From the fig, the work piece is supported in between the two centers which permit the rotation of the work piece.

A single point cutting tool is moved perpendicular to the axis of the work piece to a known predetermined depth of cut& is then moved parallel to the axis of the work piece. The excess material is removed in the form of chips. With this operation the diameter of the work piece can be reduced to the required dimension.

4.7 Facing Operation:

Facing is an operation on lathe for generating flat surfaces at the ends of the work piece as shown in the fig.

In this operation, the cutting tool is moved perpendicular to the axis of rotating work piece. It removes excess material on the face of the work piece. It is very helpful in removing the burrs present on the face of the work piece which if not removed may be harmful to the operator. It is also carried out to reduce/cut the work piece to the required length.

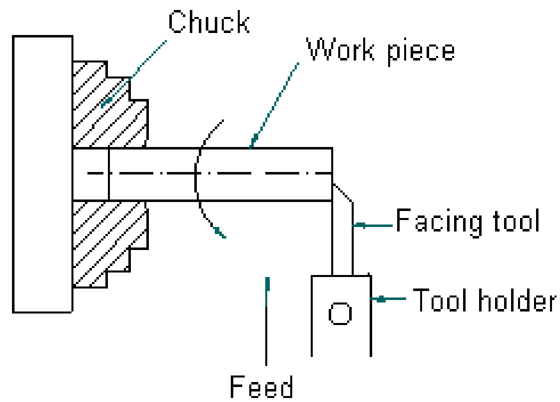


Fig: Facing operation

Video: **https://drive.google.com/file/d/1ksmjq_r033k98sUaYqAwFMvAs2KPTi4c/view?usp=drive_link**

4.8 Knurling Operation:

Knurling is an operation on the lathe to generate serrated surfaces on work pieces by using special tool called knurling tool, which impresses its pattern on the work piece as shown in the fig.

From the fig, in operation, the work piece is rotated at a low speed. The knurling tool is pressed against the rotating work piece and pressure is slowly increased until the knurling tool produces a pattern on the surface of the work piece. Knurling operation is preferred where grip is required which will increase the friction to hold the work piece.

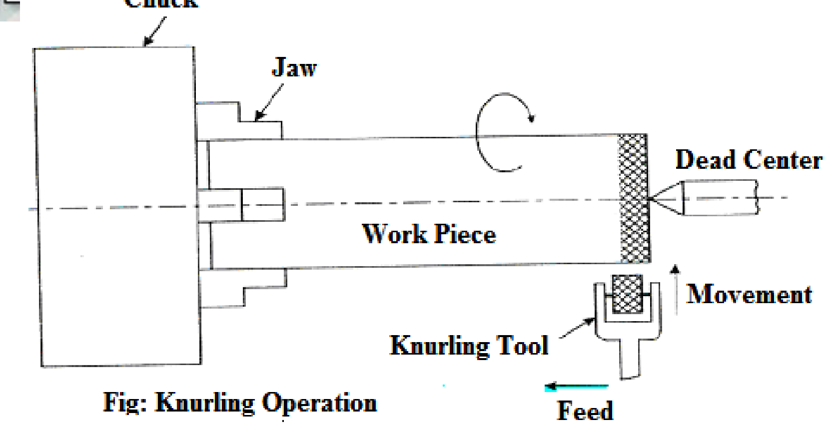
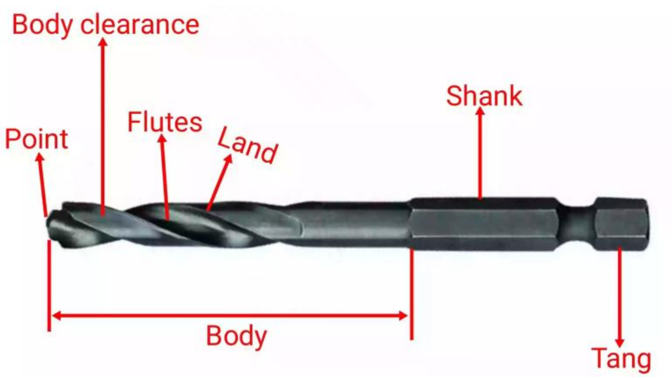


Fig: Knurling Operation

4.9 Drilling:

Drilling is a metal cutting process carried out by a rotating cutting tool to make circular holes in solid materials. The cutting tool is also called 'twist drill', since it has sharp twisted edges formed around a cylindrical body.

Drilling machine is a power operated machine tool, which holds the twist drill bit in its spindle, rotating at high speeds & when manually actuated to move linearly against the work piece produces a circular hole.



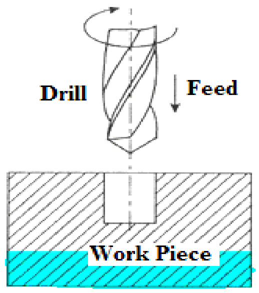


Fig: Principle of Drilling Operation

4.10 Working Principle of Drilling Machine/Drilling Operation

In drilling machine the drill bit is rotated while the stationary work piece is brought in contact with the rotating drill bit to carry out drilling operation as shown in the fig.

In operation the work piece is rigidly clamped & the rotating drill bit is brought closer to it. The hole is generated by the sharp edges of the rotating drill bit, which is forced to move against the rigidly clamped work piece. The excess material is removed in the form of chips which get curled and escapes through the helical grooves provided in the drill bit. In drilling, while cutting action takes place inside the work piece a lot of heat is generated during the operation which is carried away by the use of coolants.

Drilling operation is carried out to drill holes on metal, wood or concrete surface of different diameter depending on the size of the drill bit.

4.11 Tapping Operation:

Tapping is the operation of cutting internal threads in a previously drilled hole as shown in the following fig.

From the fig,

The tool used for the operation is called 'Tap', which is a fluted threaded tool used for cutting internal threads. Before tapping, a hole which is slightly smaller than the size of the tap is drilled. The internal threads are cut in the same way as drilling, but the spindle is rotated at slow speeds compared to drilling.

Generally tapping is carried out on a drilling machine when identical threading is required on large number of parts.

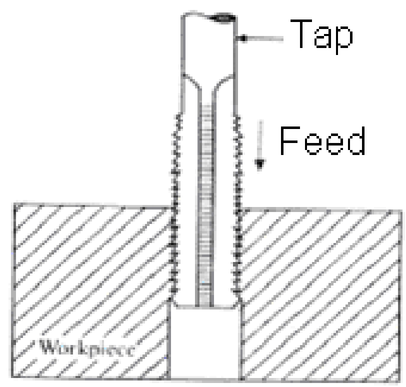


Fig: Tapping operation

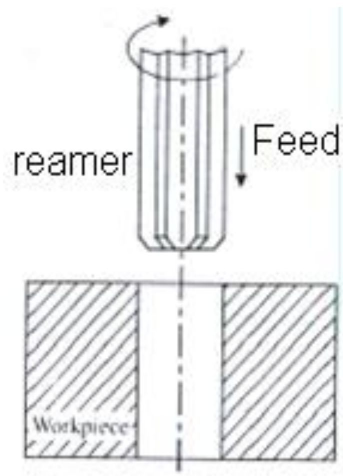


Fig: reaming operation

4.12 Reaming Operation:

Reaming is the process of smoothing the surface of the drilled holes using a reamer tool as shown in the fig.

From the fig, reaming operation is carried out by means of a multi tooth revolving tool called 'reamer' which is similar to the twist drill, but has straight flutes.

While reaming, the speed of the spindle is reduced to half of that of the drilling.

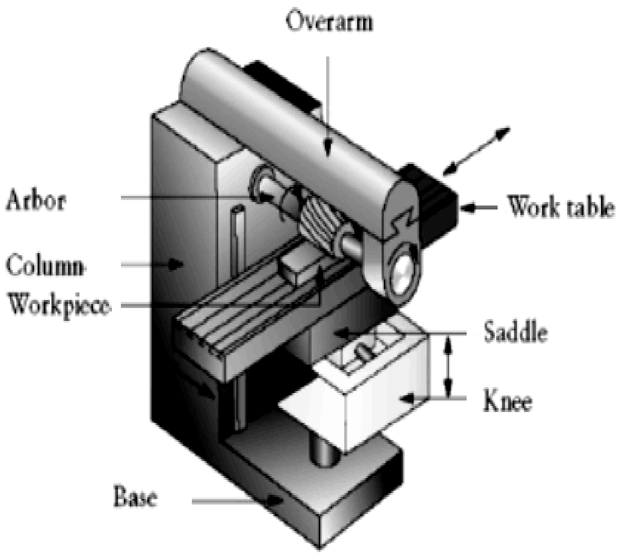
The material removed is very less and hence the drilled hole surfaces are finished with high accuracy.

Applications of Drilling Machine Tool:

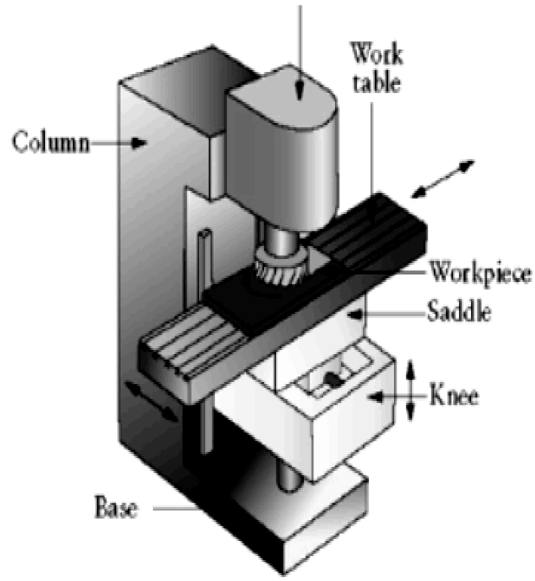
- Drill is a machine tool used for drilling the holes in solid equipment like metal, wood or concrete with drill bit or driver bit.
- Drills are used in wide variety of applications in metal working, constructions and wood working industries.
- Drilling machine is widely being used in different industries including construction, medical equipment, transportation and electronic equipment.
- Different kinds of drills are using in particular applications that can construct holes in numerous sizes in various kinds of materials.
- Drills powered by electricity are the most common tools in wood working and machining shops
- Drills are also used in surgery to remove or create holes in bone.

Milling Machine:

Milling is a process of removing excess material from the work piece in which the operating tool is called as milling cutter or just cutter. The milling cutter is a multipoint cutting tool having cutting teeth formed on its periphery. In milling, the work piece is fed against a revolving milling cutter. A milling machine is a power operated machine tool in which the milling operation is carried out. It can be horizontal type /universal or vertical/radial type.

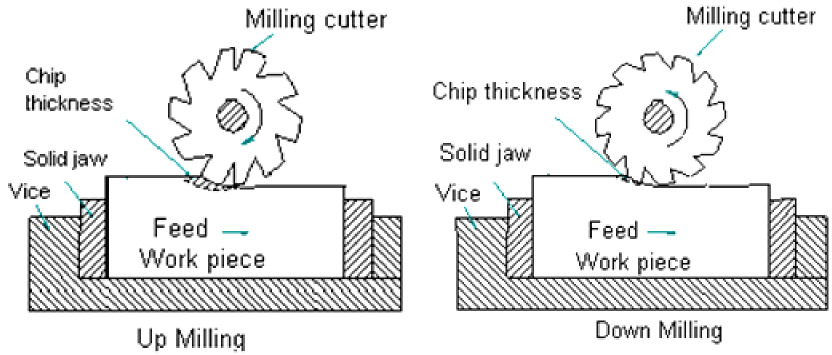


Universal milling machine

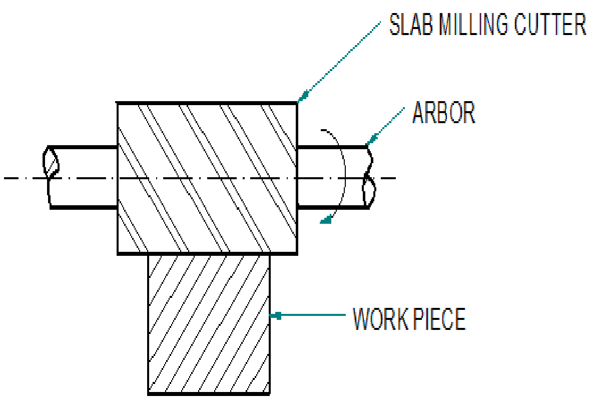


Vertical milling machine

4.13 Principle of Milling: Milling is carried out in two basic ways namely, Up Milling & Down Milling as shown in fig & explained in table



Up Milling	Down Milling
The work piece is fed in the direction opposite to that of the rotating cutter	The work piece is fed in the same direction as that of the rotating cutter.
Thickness of chip is minimum at the beginning of cut and reaches to the maximum when the cut ends.	Thickness of chip is maximum at the beginning of cut and reaches to the minimum when the cut ends.
The cutting force is directed upwards and this tends to lift the work piece from the table. Hence greater clamping force is necessary	The cutting force acts downwards that tends to keep the work piece firmly on the table, thereby permitting lesser clamping forces.
During up milling, the chip gets accumulated at the cutting zone. These chips interfere with the revolving cutter, thereby impairing the surface finish.	The chips do not interfere with the revolving cutter as they are disposed easily by the cutter. Hence there is no damage to the surface finish.
Difficult for efficient cooling since the cutter rotates in the upward direction carrying away the coolant from the cutting zone	Efficient cooling can be achieved since the coolant can easily reach the cutting edge
Used for machining hard surfaces such as castings and forgings	Used for finishing operations and small works



4.14 Face Milling/Plain Milling / Slab Milling:

Slab/Plain milling is a process used to mill flat surfaces of work pieces in such a way that the milling cutter axis is made parallel to the surface of the work piece that is being milled as shown in the fig.

The operation is carried out in a horizontal/universal milling machine with the milling cutter mounted on the standard milling arbor.

The milling cutter has straight or helical teeth on its periphery.

When the work piece is brought in contact with the rotating milling slab cutter and moved horizontally, the excess material from the flat work piece is removed.

4.15 End Milling:

End milling is a process used to mill slots, pockets and keyways in such a way that the axis of the milling cutter is perpendicular to the surface of the work piece as shown in the following fig.

The end milling cutter, although similar in appearance to that of the twist drill is distinguished from the latter in its geometry, application and manufacture.

The end milling has teeth on the bottom face (end face) as well as the periphery and may have straight or helical flutes.

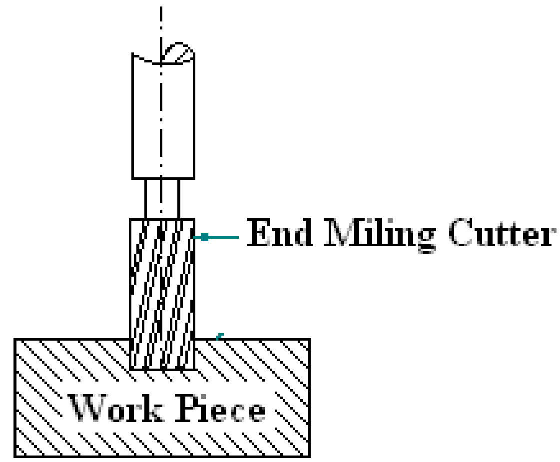


Fig: End Milling Operation.

Applications of Milling Machines:

- The milling machine is used for making various types of gears.
- It is generally used to produce slot or groove in work pieces.
- It can able to machine flat surface and irregular surfaces too.
- It is used in industries to produce complex shapes.
- Milling machines can be used for a variety of complicated cutting operations – from slot cutting, threading, and rabbeting to routing, planning, and drilling.
- They are also used in die sinking, which involves shaping a steel block so that it can be used for various functions, such as moulding plastics or coining.
- Milling machines are used mainly for shaping and cutting solid materials such as metal, wood, plastics or even brass.

Introduction to Advanced Manufacturing System:

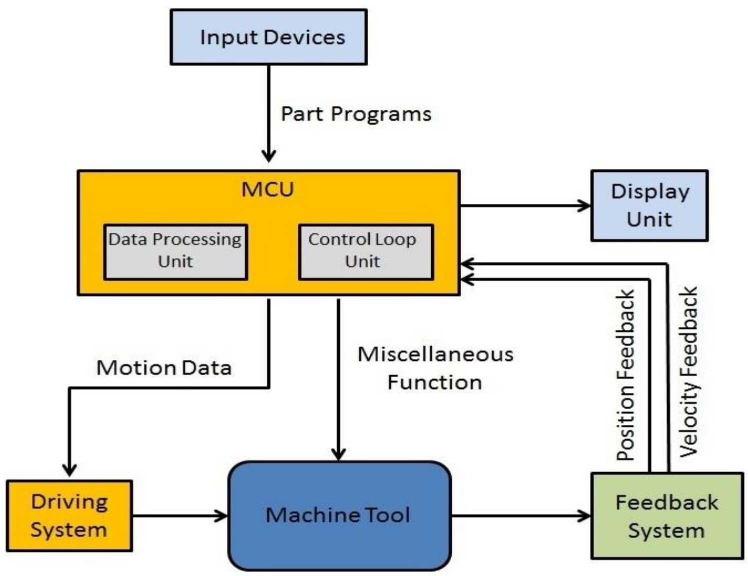
Advanced manufacturing is the use of innovative technology to improve products or processes. It is also referred as Smart Manufacturing. Automation is one of the key elements of Advanced Manufacturing.

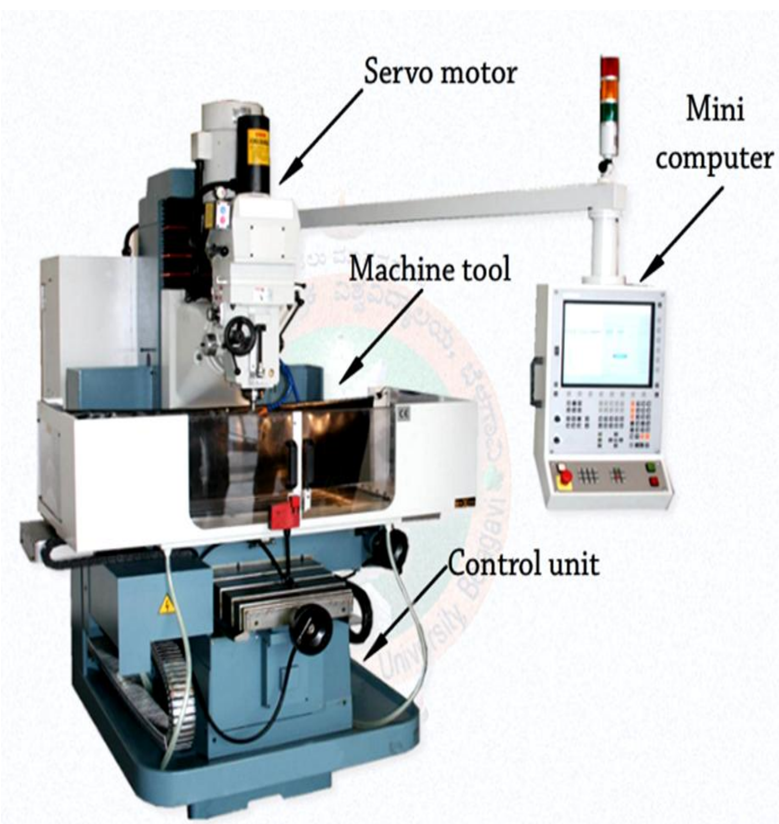
Automation from the point of industrial context may be defined as “A technology that is concerned with the use of mechanical, electrical/electronics and computer based system to control the various production processes in a systematic manner”.

Examples: Numerically controlled machines (NC Machines), Computer Numerical Control (CNC), Transfer lines, Mechanized assembly machines, Feedback control systems etc. Robots & Automation are two closely related technologies. Robots assist in industrial automation.

4.16 Components of CNC Machines:

Computer Numerical Control (CNC) is a system in which a microcomputer or microprocessor is made an integral part of the control panel of a machine or equipment. It may also defined as "An NC system with a microcomputer or microprocessor using software to implement control algorithms". The basic elements of CNC machine are shown in fig .





Input Devices: These are the devices which are used to input the part program in the CNC machine.

Machine Control Unit (MCU): It is the heart of the CNC machine. It is just like CPU of a computer. It involves several actions to perform in a CNC machine. Then, it helps to send the proper instruction to every part of the machine. It can recognize interpolations (circular, straight, and helical) to form axis transfer commands. In this part programming is typed & entered into the computer memory. It can be used again and again. A typical CNC may need only the drawing specifications of a part to be manufactured and the computer automatically generates the part program for the loaded part. The CNC machines have the facility for proving the part program without actually running it on the machine tool. It is connected to Display Unit which acts just like monitor of a computer.

Driving System: Basic function of a CNC machine is to provide automatic and precise motion control to its elements such work table, tool spindle etc for this driving systems are used to provide such kinds of controlled motion to the elements of a CNC machine tool. It consists of drive motors and ball lead-screws.

Machine Tool: Depending on the type of machining carried out, a specific machine tool like lathe, milling etc with be interconnected to the MCU and feedback system. Based on the programming the part will be finished inside the machine tool.

Position feedback package: CNC control unit allows compensation for any changes in the dimensions of the cutting tool. With CNC control systems, it is possible to obtain information on machine utilization which is useful to the managements. It uses feedback providing components like sensors.

Advantages of CNC Machines:

- Greater flexibility
- Reduced data reading error
- Conversion of units possible
- CNC machines can diagnose program and can detect the machine malfunctioning even before the part is produced.
- High repeatability & precision manufacturing
- High volume of production
- Complex contours & surfaces can be easily obtained
- Flexibility in job change, automatic tool settings, less scrap
- Less paper work, more safe & better quality products

Disadvantages of CNC Machines:

- Higher investment cost
- Unsuitable for long run applications
- Requires planned support facilities
- Setup is expensive
- Requires skilled operators with knowledge of computer programming
- High maintenance & service required

Applications of CNC Machines:

- CNC machining prototype productions are not tied to any single sector. People use it virtually everywhere. It helps to create everything from aircraft parts to surgical tools.
- The aerospace industry has a long-shared history with CNC machining. The machining of metal aircraft components occurs at the highest level of precision. Some of the machinable aerospace components include engine mounts, fuel flow components, landing gear components, and fuel access panels.
- The automotive industry regularly enjoys the uses of CNC milling machine for both prototyping and production. Extruded metal can be machined into cylinder blocks, gearboxes, valves, axels, and various other components. On the other hand, CNC machines plastics into components like dashboard panels and gas gauges.
- CNC machining also helps in the prototyping and production of consumer electronics. These electronics include laptops, smart phones, and many others.
- The military sector frequently turns to CNC machining for the prototyping of rugged and reliable parts.
- CNC machining offers its use on various medically safe materials. CNC machinable medical parts include surgical instruments, electronic enclosures, orthotics, and implants.

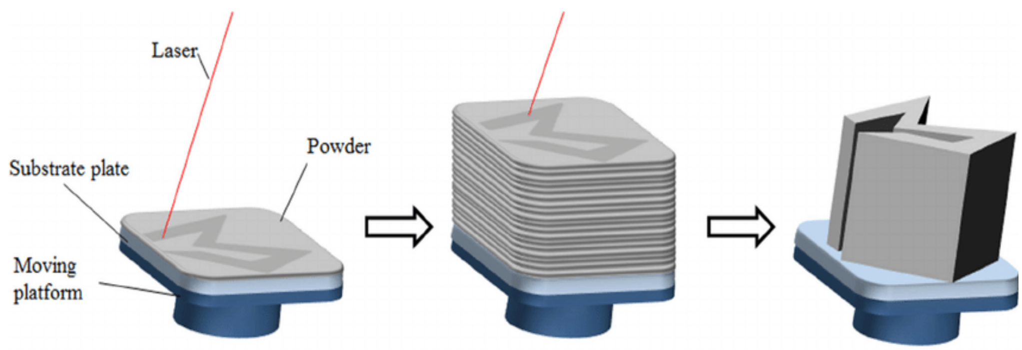
Video:
https://drive.google.com/file/d/1btQ1TKwPd1PiiD41Bb9JTE3R0Ohh4biS/view?usp=drive_link

4.17 : 3D Printing/Additive Manufacturing:

Additive Manufacturing (AM) is an appropriate name to describe the technologies that build 3D objects by adding layer-upon-layer of material, whether the material is plastic, metal, concrete or one day even it may be human tissue.

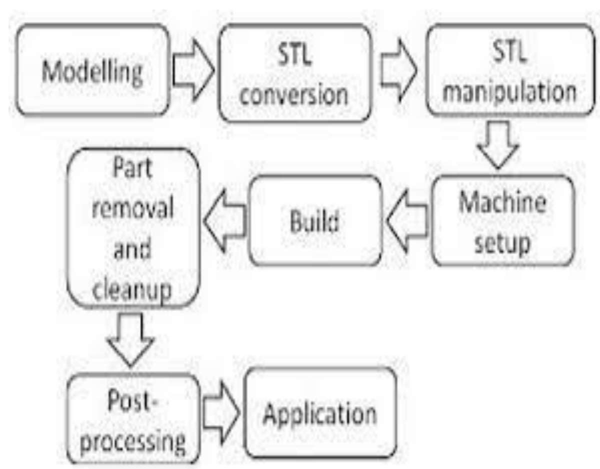
It is also referred by other words such as rapid prototyping, direct digital manufacturing and additive manufacturing.

The raw material used may be in the form of liquid, powder, semi solid etc.,



i. First layer. ii. n^{th} layer. iii. Loose powder removed, finished part revealed.

Stages in 3D Printing:



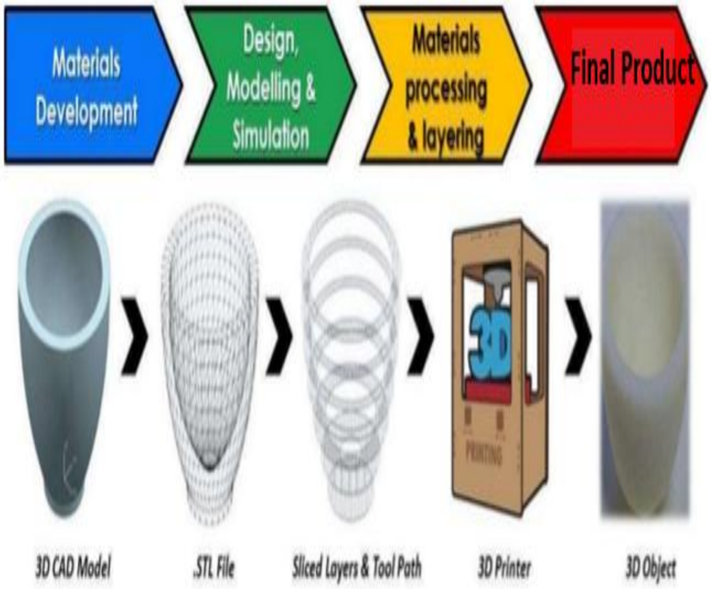
1. 3D CAD Modelling :
All AM parts must start from a software model that fully describes the external geometry. This can involve the use of almost any professional CAD solid modeling software, but the out put must be a 3D solid or surface representation.

2. STL convertion:
Nearly every AM machine accepts the .STL file format, which has become a defacto standard, and nearly every CAD system can output such a file format. This file describes the external closed surfaces of the original CAD model and forms the basis for calculation of the slices.

3. STL manipulation:
The STL file describing the part before it is transferred to the AM machine can also be manipulated for any changes

4. Machine setup:
The AM machine must be properly set up prior to the build process. Such settings would relate to the build parameters like the material constraints, energy source, layer thickness, timings, etc.

5. Build:
Building the part is mainly an automated process and the machine can largely carry on without supervision. Only superficial monitoring of the machine needs to take place at this time to ensure no errors have taken place like running out of material, power or software glitches,etc.



6. Part removal & clean up:

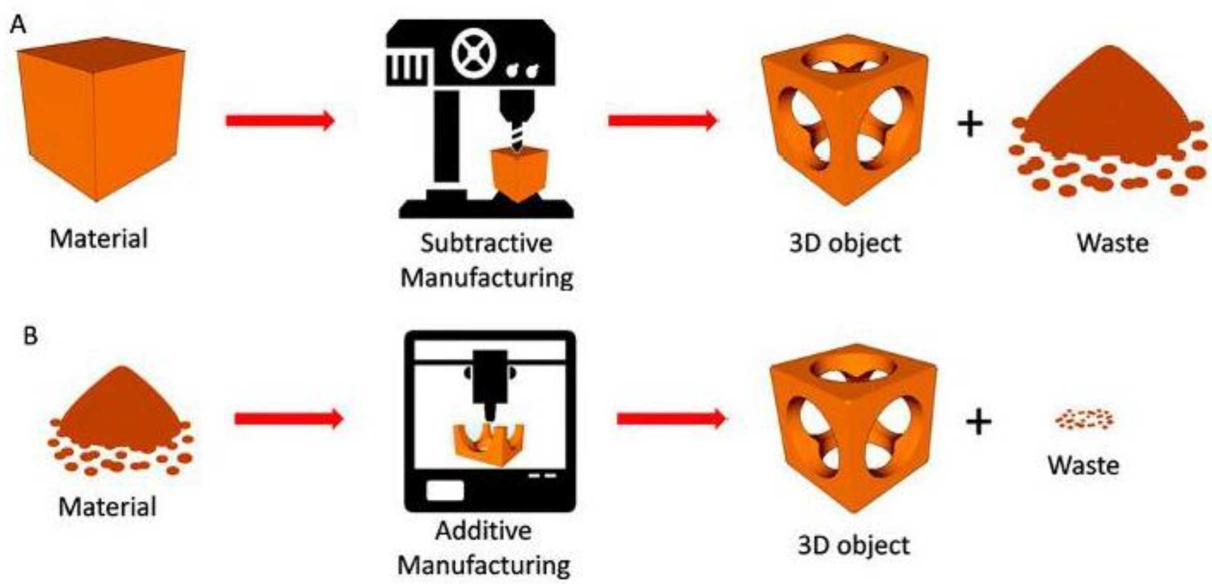
Once the AM machine has completed the build, the parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure for example that the operating temperatures are sufficiently low or that there are no actively moving parts.

7. Post-process:

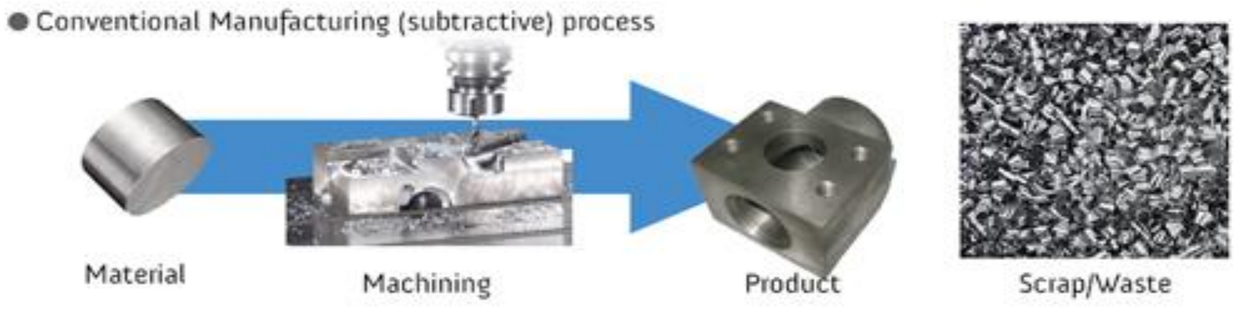
Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. Parts may be weak at this stage or they may have supporting features that must be removed. This therefore often requires time and careful, experienced manual manipulation. Parts may now be ready to be used. However, they may also require additional treatment before they are acceptable for use.

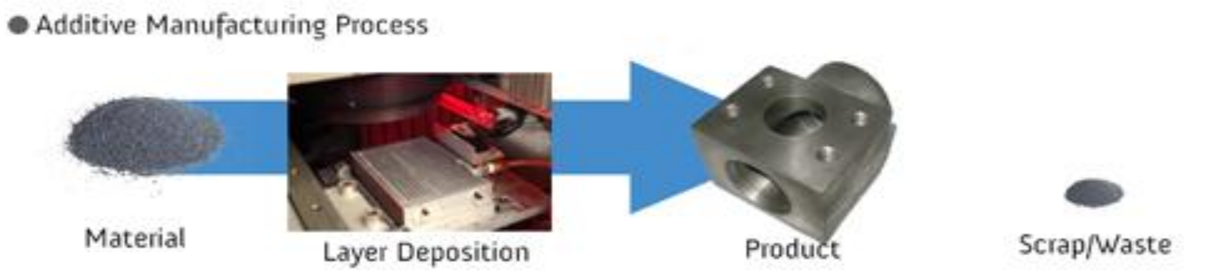
For example, they may require priming and painting to give an acceptable surface texture and finish. Treatments may be laborious and lengthy if the finishing requirements are very demanding

Difference between 3D printing and CNC Machines



- The key difference between 3D printing and CNC machining is that 3D printing is a form of additive manufacturing, while the CNC machining is subtractive manufacturing.
- This means CNC machining starts with a block of material (called a blank), and cuts away material to create the finished part. To do this, cutting tools are used to shape the piece.
- Both 3D printing and CNC machining are compatible with a wide variety of materials, including both plastics and metals.





Advantages of AM

- Freedom of design
- Complexity for free
- Potential elimination of tooling
- Lightweight design
- Elimination of production steps

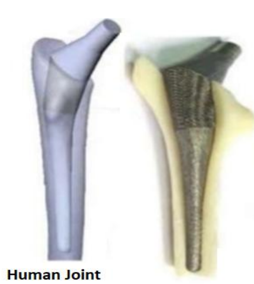
Disadvantages of AM:

- Slow build rates
- High production cost
- Limited component size
- Considerable effort required for design of model

Applications of AM

AM has been used across a diverse array of industries, including;

- Automotive
- Aerospace
- Biomedical
- Consumer goods and many others



Classification of 3D Printing: Based on the type of raw materials used, 3D printing may be classified into the following four types.

1. Liquid Polymer System (Stereo Lithography)
2. Discrete Particle System (Selective Laser Sintering & Direct Metal Laser Sintering)
3. Molten Material System (Fused Deposition Modeling, FDM)
4. Solid Sheet System

Liquid Polymer System (Stereo Lithography): A polymer is a large molecule composed of many repeated subunits called monomers. They are prepared by polymerization reactions, in which simple molecules are chemically combined into a long chain molecules or three-dimensional structures. They have low specific gravity and good strength. Plastics & synthetic rubbers are termed as organic polymers. There are two important classes of organic polymers such as thermoplastics & thermosetting plastics.
Stereo Lithography is a type of most commonly used Liquid Polymer System. It was the first process ever developed in Additive Manufacturing during 1986. It builds plastic parts or plastic objects layer by layer with the help of laser beam. It uses those plastic materials which get quickly solidified when it comes in contact with laser beam.

Discrete Particle Systems: Discrete particle systems are also known as Powder Based Systems. In this the raw material is used in POWDER FORM of very fine size in terms of microns. It uses high power LASER light for melting raw material. It builds up the part layer by layer.
The TWO major types of Discrete Systems are:

1. Selective Laser Sintering (SLS) and
2. Direct Metal Laser Sintering (DMLS)

Selective Laser Sintering is an additive manufacturing technique that uses a high power laser to fuse small particles of plastic, metal, ceramics, or glass powders into a mass that has a desired 3D shape. While Direct Metal Laser Sintering uses the same above process for powdered metal.

Molten Material System: Molten material systems are characterized by a pre-heating chamber that raises the material temperature to melting point so that it can flow through a delivery system. The most well-known method for doing this is the Fused Deposition Modeling (FDM) material extrusion technology developed by the US company Stratasys. This approach extrudes the material through a nozzle in a controlled manner. Two extrusion heads are often used so that support structures can be fabricated from a different material to facilitate part cleanup and removal.

Solid Sheet System: One of the earliest AM technologies was the Solid Sheet System which used a laser to cut out profiles from sheet paper, supplied from a continuous roll, which formed the layers of the final part. Layers were bonded together using a heat-activated resin that was coated on one surface of the paper. Once all the layers were bonded together the result was very much like a wooden block.

Video-1: https://drive.google.com/file/d/1-p8kapDW-8FpGoQrfn_Uaiu1zWRO0OHd/view?usp=drive_link

Video-2: https://drive.google.com/file/d/1-Vh_k273_Q7VrgOByzXog541qcWAg89c/view?usp=drive_link

Video-3: https://drive.google.com/file/d/1-T9UXy23IFUl7cwryA_anZ7bwnz7SIKh/view?usp=drive_link

QUESTION BANK

5 MARK QUESTIONS

1. Define manufacturing and explain the classification of manufacturing processes.
2. Write a short note on casting, forming, machining, and joining processes.
3. Explain the criteria for selection of manufacturing processes with examples.
4. State the differences between casting, forming, machining, and joining processes.
5. Define soldering. Explain the construction and working of the soldering iron method.
6. Define brazing. Explain the construction and working of torch brazing.
7. Define welding. Explain the arc welding process with a neat sketch.
8. Compare welding, soldering, and brazing (any five points).
9. Explain the working principle of a center lathe.
10. Write short notes on:
    a) Turning
    b) Facing
    c) Knurling
11. Describe turning operation with a neat sketch.
12. Describe facing operation with a neat sketch.
13. Describe knurling operation with a neat sketch.
14. Explain the working principle of drilling machine.
15. Write short notes on:
    a) Drilling
    b) Reaming
    c) Tapping
16. State the applications of drilling machine.
17. Explain up milling and down milling with differences.
18. Explain slab/face milling operation.
19. Explain end milling with a neat sketch.
20. List the applications of milling machines.
21. Explain the components of CNC machine.
22. Write the advantages and disadvantages of CNC machines.
23. Write the applications of CNC machines.
24. Explain stages in 3D printing.
25. Write the advantages and disadvantages of additive manufacturing.
26. Compare CNC machining and 3D printing.
27. Classify 3D printing technologies.

10 MARK QUESTIONS

1. Explain in detail the classification of manufacturing processes with neat diagrams and examples.
2. Discuss the selection criteria for manufacturing processes with suitable examples.
3. With neat sketches, explain the construction and working of:
   - Soldering iron
   - Torch brazing
   - Arc welding
4. Compare welding, soldering and brazing in detail. Explain their applications.
5. Explain the construction and working principle of a center lathe. Describe turning, facing and knurling operations with neat sketches.
6. Explain any five lathe operations in detail with diagrams.

7. Explain the construction, working, and operations of a drilling machine with neat sketches.
8. Explain the principle of milling. Distinguish between up milling and down milling. Describe face milling and end milling with diagrams.
9. Explain the components of a CNC machine with a block diagram. Discuss the advantages, disadvantages, and applications of CNC machines.
10. Explain the role of input devices, MCU, driving system, feedback system, and machine tool in CNC machines with a neat block diagram.
11. Explain in detail the 7 stages of 3D printing with neat diagrams.
12. Explain the classification of 3D printing processes (Liquid polymer, Powder-based, Molten material, Solid sheet systems).
13. Compare conventional manufacturing, CNC machining, and additive manufacturing.
14. Explain the advantages, disadvantages, and applications of additive manufacturing in detail.

GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN

Department of Mechanical Engineering

Near Dairy Circle, Hosur Road, Bengaluru , Karnataka 560029

INTRODUCTION TO MECHANICAL ENGINEERING

(1BESC104D/204D)

As per New Syllabus Prescribed by V.T.U. (2025 CBCS System)

For

FIRST / SECOND SEMESTER

(Bachelor of Engineering)

MODULE-05

Advances in Mechanical Engineering

Dr.NAVEED M.Tech., PhD.
Assistant Professor

MODULE-05 ADVANCES IN MECHANICAL ENGINEERING

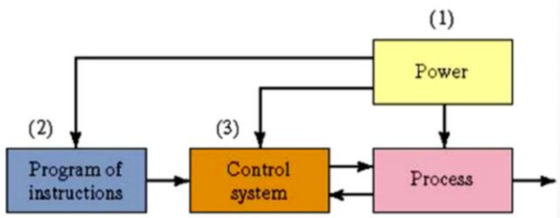
Syllabus:

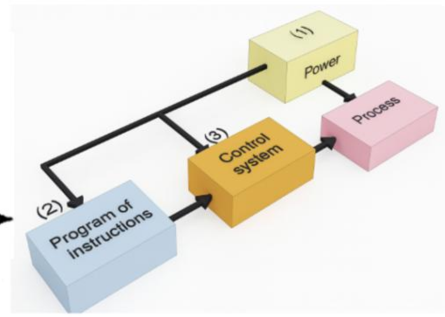
Automation Technology: Definition of automation, types of automation, basic elements of automation. Mechatronic systems: Definition of mechatronics, elements of mechatronics systems, examples. Elementary sensors: Working principle and applications of Potentiometer, capacitive sensor and optical encoders. Integrated system: Need for integration of technologies, ADAS (Advanced Driver Assistance System).

5.1 AUTOMATION: Automation can be defined as a technology concerned with performing a process by means of programmed commands combined with automatic feedback control to ensure proper execution of the instructions. The resulting system is capable of operating without human intervention. It may also be defined as A technology concerned with the application of mechanical, electrical , electronics and computer based system to execute the process without human interference.

5.2 Basic Elements of Automated System:

An automated sysytem consist of some of the major elements as shown in the following flow chart.





Power: The principal source of power in automated systems is electricity. Electric power has many advantages in automated as well as non automated processes. Electrical power can be readily converted to alternative energy forms: mechanical, thermal, light, acoustic, hydraulic, and pneumatic. Electrical power at low levels can be used to accomplish functions such as signal transmission, information processing, and data storage and communication. Electrical energy can be stored in long life batteries for use in locations where an external source of electrical power is not conveniently available. Alternative power sources include fossil fuels, solar energy, water, and wind. However, their exclusive use is rare in automated systems. In many cases when alternative power sources are used to drive the process itself, electrical power is used for the controls that automate the operation.

Program of Instructions: The actions performed by an automated process are defined by a program of instructions Whether the manufacturing operation involves low, medium, or high production each part or product style made in the operation requires one or more processing steps that are unique to that style, These processing steps are performed during a work cycle. The particular processing steps for the work cycle are specified in a work cycle program. Work cycle programs are called part programs in numerical control.

Control Systems: The control element of the automated system executes the program of instructions. The control system causes the process to accomplish its defined function. The control system in an automated system can be either closed loop or open loop. A closed loop control system also known as a feedback control system is one in which the output variable is compared with an input parameter and any difference between the two is found , it will be redirected back for modification. While in an open loop control system operates without the feedback loop. In this case, the process is executed without measuring the output variable. So no comparison is made between the actual value of the output and the desired input parameter. The controller completely relies on the actuator.

Component	Description	Key Points
Power	The energy needed to run machines and controls.	- Mostly uses electricity. - Can be changed into other forms (mechanical, heat, light, sound, hydraulic, pneumatic). - Can be stored in batteries. - Other sources (solar, water, wind) are rarely used alone.
Program of Instructions	A set of steps that tells the machine what to do.	- Defines the actions of the process. - Each product needs its own sequence of steps. - These steps are called a work cycle program. - In CNC/NC machines, it is called a part program.
Control System	The part that reads the program and makes the machine follow it.	- Executes the instructions. - Ensures the process works correctly. - Closed loop: checks output and corrects errors (feedback). - Open loop: no feedback; runs without checking output.

5.3 Types of Automation:

Automation systems are classed into three different types of automation:

- ✓ Fixed automation
- ✓ Programmable automation
- ✓ Flexible automation

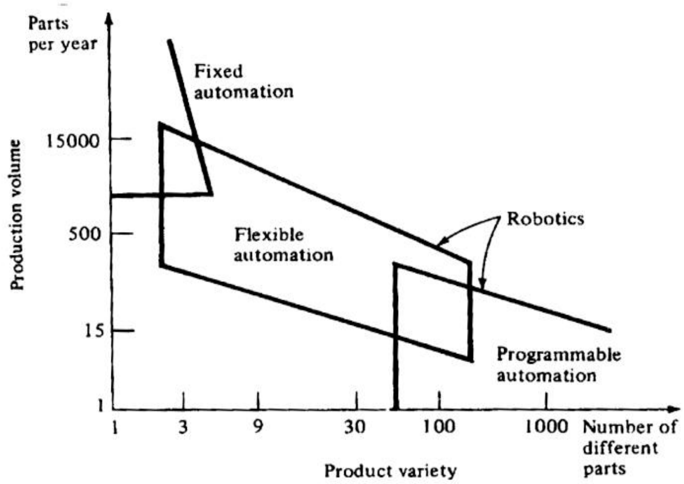
Fixed Automation: Fixed automation is a type of automation where the process of manufacturing stays fixed by the way it is configured, following a fixed sequence of automated processes. An example of this is flow production, where products are continuously being made. This is often also known as “hard automation”. Fixed automation can be expensive to set up initially due to the equipment required, but in return, it provides high production rates. This is relatively useful for many companies who use automation to create food products of one type and variant. It allows them to effectively produce that item and package it in bulk.

Programmable Automation: Programmable automation allows the production equipment and automation to be altered to changing needs. This is done by controlling the automation through a program, which can be coded in certain ways for the automation to change the sequence of automation.
It’s used more commonly in low to medium levels of production, often being most suitable for batch production. Programmable automation will often be used by factories who make different variants of foods. This allows them to make batches, from a few dozen to potentially thousands at a time, of one product. If the product needs changing, it simply needs to be reprogrammed.

Flexible automation: Flexible automation also known as “soft automation”, is an extension of programmable automation. The disadvantage with programmable automation is the time required to reprogram and change over the production equipment for each batch of new product. This is lost production time, which is expensive. In flexible automation, the variety of products is sufficiently limited so that the changeover of the equipment can be done very quickly and automatically. The reprogramming of the equipment in flexible automation is done off-line; that is, the programming is accomplished at a computer terminal without using the production equipment itself. Accordingly, there is no need to group identical products into batches; instead, a mixture of different products can be produced one right after another.

Type of Automation	Description	Where It Is Used	Key Features
Fixed Automation (Hard Automation)	The machine follows one fixed sequence and cannot be changed easily.	High-volume, continuous production (e.g., one type of food product).	- Very high production rate - Expensive to set up - Not flexible (only one product design)
Programmable Automation	Machines can be changed for different products by reprogramming.	Batch production (small to medium quantities).	- Programmable for different products - Suitable for several product variants - Changeover takes some time
Flexible Automation (Soft Automation)	Machines change automatically and quickly for different products without stopping production.	Mixed-production environments where many products are made continuously.	- Very fast changeover - No need for batches - Programming done offline (without stopping the machine) - Produces different products one after another

Comparison of the above three is best illustrated by the following fig.



Automation	Consideration	Advantages	Disadvantages
Fixed / Hard	• High demand volume • Long product life cycle	• Maximum efficiency • Low unit cost • Automated material handling – fast and efficient movement of parts	• Large initial investment • Inflexibility
Programmable	• Batch production • Products with different options	• Flexibility to deal with changes in product • Low unit cost for large batches	• New product requires long set-up time • High unit cost relative to fixed automation
Flexible/Soft	• Low production rates • Varying demand • Short product life cycle	• Flexibility to deal with design variations • Customized products	• Large initial investment • High unit cost relative to fixed or programmable automation

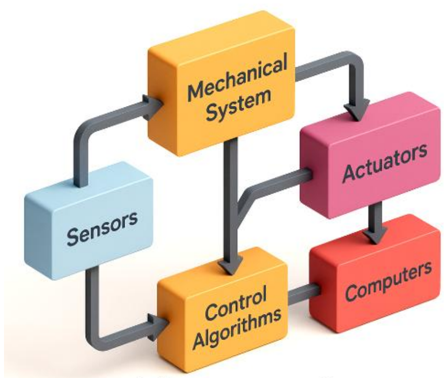
5.4 Mechatronic Systems: Definition of Mechatronics:

Mechatronics is an interdisciplinary field of engineering that integrates mechanical engineering, electronics, computer science, control engineering, and electrical engineering into a unified system. It focuses on designing and developing intelligent systems and products that combine mechanical structure, sensors, actuators, control algorithms, and embedded computing to achieve automated and optimized performance.

In mechatronic systems, mechanical components provide the physical structure and motion; electronic circuits enable sensing, power management, and signal flow; control systems ensure feedback-based decision-making; and computer programs allow logical operation, data processing, and communication. This harmonious integration results in systems that are more efficient, reliable, adaptable, and capable of self-regulation compared to conventional mechanical systems.

Mechatronics is therefore considered as an advanced approach to modern engineering, enabling the creation of intelligent products such as robots, CNC machines, automated manufacturing systems, drones, smart appliances, biomedical devices, and automotive mechatronic subsystems (ABS, airbags, fuel injection systems, etc.).

5.5 Elements of Mechatronics Systems: A mechatronic system is an integrated engineering system that combines mechanical components, electronics, sensors, actuators, and computer control to perform intelligent and automated functions. It consist of the following basic elements.



Elements of Mechatronic Systems

Element	Definition	Functions
Sensors	Devices that detect physical parameters (temperature, pressure, speed, position, etc.) and convert them into electrical signals for monitoring and feedback.	They provide real-time data to the controller, enabling automatic decisions, accurate monitoring, feedback control, and overall system intelligence.
Mechanical System	The physical structure of a mechatronic device consisting of mechanisms like gears, linkages, and frames that perform motion and mechanical work.	It performs the actual physical tasks—movement, force transmission, and interaction with the environment—making it the core working part of the system.
Actuators	Components that convert electrical control signals into mechanical motion or force for performing system actions.	They execute the controller's commands through motion or force, enabling automation and allowing the system to physically respond.

Element	Definition	Functions
Control Algorithms	Logical or mathematical rules used by the controller to process sensor data and generate commands for accurate and stable system operation.	They optimize system performance by making decisions, correcting errors, ensuring stability, and coordinating actions through feedback.
Computers / Microcontrollers	Computational units that execute control algorithms, process sensor signals, store programs, and coordinate all system functions.	They act as the "brain" of the system by managing data, running programs, controlling timing, and integrating all components into an intelligent automated system.

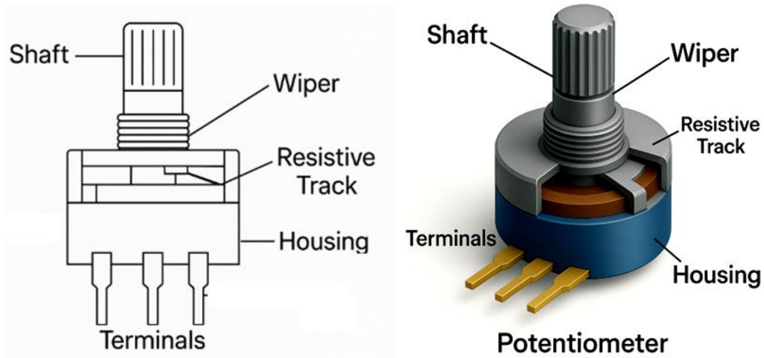
5.6 Examples of Mechatronic Systems:

Example	Explanation
1. Home Appliances (Washing Machines)	Use sensors, controllers, and programs to measure load, control water, adjust temperature, and perform wash, rinse, and spin cycles automatically.
2. ABS & Automotive Systems	Anti-lock braking systems prevent wheel locking during sudden braking; ECUs control engine functions using sensors and electronics.
3. Elevators & Escalators	Use sensors to detect position and speed, and actuators like motors for movement; safety features ensure safe transport of people.
4. Mobile Robots & Manipulator Arms	Used for tasks that are difficult, dangerous, or repetitive; rely on sensors, actuators, and control systems to perform precise movements.
5. Sorting & Packaging Systems	Automate factory production lines by identifying, sorting, and packaging items quickly and accurately.
6. CNC Machines	Computer-controlled machines that manufacture parts directly from digital models with high accuracy and consistency.
7. Aeroplanes & Helicopters	Complex systems with many subsystems controlled by sensors, actuators, and onboard computers.
8. Tank Fluid Level & Temperature Control Systems	Maintain and regulate fluid levels and temperature in industrial processes like bio-fuel production.
9. Industrial Oven Temperature Control	Control heating and cooling precisely in processes that require consistent temperature over long periods.

5.7 Elementary Sensors :

Elementary sensors are basic sensing devices used to detect simple physical quantities such as temperature, pressure, light, motion, or distance. They convert these physical or environmental changes into electrical signals that can be interpreted by a controller or processing unit. As the first layer of sensing in any automated or mechatronic system, they provide essential real-time information about the surroundings. Their design is simple, reliable, and cost-effective, making them suitable for widespread use in household appliances, industrial machines, and safety systems. Overall, elementary sensors play a crucial role in monitoring conditions and enabling feedback-based control in modern engineering systems.

5.8 Working principle and applications of Potentiometer: A potentiometer is a variable resistor used to adjust or measure voltage by moving a wiper along a resistive track.



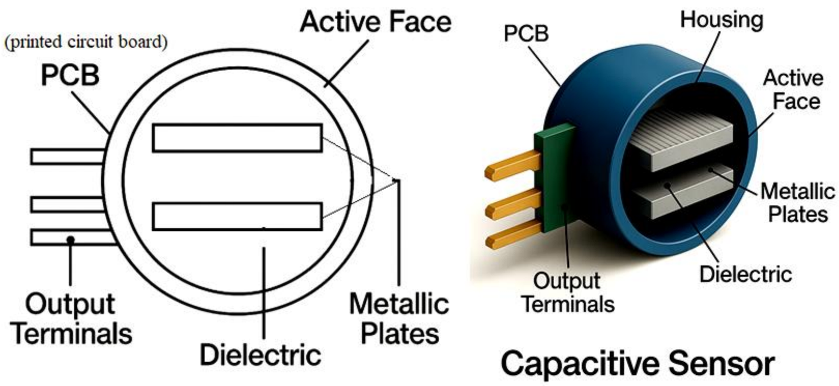
Part	Description
Shaft / Knob	The rotating part that the user turns to vary the resistance.
Wiper	A sliding contact that moves over the resistive track to pick off the output voltage.
Resistive Track	A semicircular strip of carbon or metal film that provides varying resistance.
Terminals(3 Pins)	Two terminals connect to the ends of the resistive track, and the middle terminal connects to the wiper for variable output.
Housing / Body	Covers and supports the internal components, holding everything in place.

5.9 Operating Principle: A potentiometer works on the principle of a variable voltage divider. Inside the device, a resistive track is connected to two terminals at its ends, and a movable wiper connected to the middle terminal slides across the track. When the shaft or knob is rotated, the wiper moves along this resistive path, changing the resistance ratio between the wiper and each end of the track. This results in a smooth change in the output voltage. Thus, by varying the wiper position, the potentiometer can control signal levels, adjust volume, set reference voltages, or provide position feedback in electronic and mechatronic systems.

5.10 Applications:

Application Area	How the Potentiometer Is Used
Audio Systems (Volume Control)	Adjusts sound level by varying output voltage.
Light Dimmers / LED Brightness Control	Controls brightness by changing resistance and current flow.
Robotic Arms (Position Feedback)	Measures joint angle or movement for accurate control.
Joysticks (Gaming & Control Panels)	Detects direction and movement through variable resistance.
DC Motor Speed Control	Varies input voltage to increase or decrease motor speed.
Temperature Controllers (Ovens, Heaters)	Sets desired temperature by adjusting reference voltage.
Radio Tuners (Analog Radios)	Selects frequency by varying the tuning circuit resistance.
Automotive Throttle Position Sensor (TPS)	Measures accelerator pedal or throttle valve position.
CNC & Servo Systems	Provides feedback for precise positioning.
Household Appliances (Fans, Mixers, Washers)	Adjusts settings like speed, mode, or intensity.

5.11 Working principle and applications of capacitive sensor : A capacitive sensor is an electronic device that detects changes in capacitance caused by the presence or movement of an object near its sensing plates.



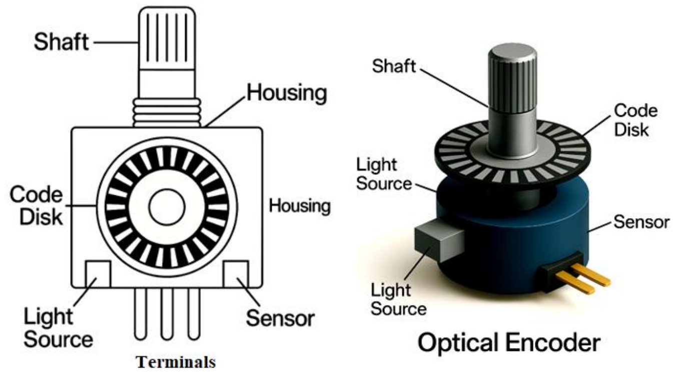
Part	Description
Active Face	The sensing surface where the electric field interacts with the object being detected.
Metallic Plates	Two conductive plates that create an electric field and form a capacitor.
Dielectric	The insulating material (air, plastic, or object) between the plates that changes capacitance.
PCB (Printed Circuit Board)	Holds the electronic circuitry and connects the sensor plates to the output terminals.
Output Terminals	Pins that carry the electrical signal to external circuits or controllers.
Housing	The protective outer casing that covers and supports internal components.

5.12 Operating Principle: A capacitive sensor operates on the principle of **capacitance change** between two metallic plates separated by a dielectric. Under normal conditions, the capacitance remains constant. When an object—conductive or non-conductive—approaches or moves near the active face, it changes the dielectric constant or the effective distance between the plates. This alters the capacitance value. The PCB electronics detect this change and convert it into an electrical output signal that indicates the presence, position, or movement of the object. Because the sensor does not require physical contact, it is highly reliable, fast, and suitable for a wide range of industrial and consumer applications.

5.13 Applications:

Application Area	How the Sensor Is Used
Touchscreens (Mobile Phones, Tablets)	Detects finger touches using changes in capacitance.
Proximity Detection in Automation	Senses the presence of objects without physical contact.
Liquid Level Detection	Measures fluid levels in tanks by sensing dielectric changes.
Humidity Measurement	Uses capacitive changes caused by moisture levels.
Material Sorting (Plastic, Paper, Glass)	Differentiates materials based on dielectric properties.
Car Seat Occupancy Sensors	Detects if a passenger is seated for airbag control.
Food & Packaging Industry	Monitors plastic bottle presence, caps, and labels.
Smart Home Devices (Touch Switches)	Replaces mechanical buttons with touch-based control.

5.14 Working principle and applications of Optical Encoders. An optical encoder is a sensor that converts the rotational or linear movement of a shaft into digital signals by detecting interruptions of light through a coded disk.



Part	Description
Shaft	The rotating input that drives the code disk.
Code Disk (Encoder Disk)	A circular disk with alternating transparent and opaque segments used to generate light pulses.
Light Source (LED)	Emits light that passes through the transparent parts of the code disk.
Sensor / Photodetector	Detects the light pulses and converts them into electrical signals.
Housing	Outer casing that protects internal components and provides mounting support.
Terminals / Output Pins	Carry electrical output signals to controllers or microprocessors.

5.15 Operating Principle: An optical encoder works based on light interruption or modulation. A code disk with alternating transparent and opaque segments is attached to the rotating shaft. As the shaft rotates, the code disk also rotates between a light source (usually an LED) and a photodetector sensor. When the transparent segments pass through the optical path, light reaches the sensor; when opaque segments pass, the light is blocked. This produces a sequence of light and dark pulses. The sensor converts these pulses into electrical signals, which correspond to rotational position, direction, or speed. These signals are then processed by a controller or microcontroller for precise motion control in mechatronic and automation systems.

5.16 Applications:

Application Area	How It Is Used
Robotics	Measures joint angles, wheel rotation, and robot arm positioning.
CNC Machines	Provides precise feedback for spindle and axis movement.
3D Printers	Ensures accurate stepper motor control and layer positioning.
Industrial Motors & Servo Systems	Monitors motor speed and direction for closed-loop control.
Computer Mice (Old Generation)	Uses optical disk to detect ball movement.
Elevators & Conveyor Belts	Tracks position and speed for safe movement.
Automatic Gates & Turnstiles	Measures rotation to detect entry/exit.
Aerospace Systems	Used in control surfaces and navigation mechanisms.

5.17 Integrated system: Need for integration of technologies:

An integrated system is a coordinated arrangement where multiple technologies, components, or subsystems—such as sensors, actuators, controllers, software, communication units, and mechanical elements—work together as one unified solution. Instead of functioning independently, each part shares information and collaborates to achieve higher efficiency, intelligence, and performance. This approach is essential in fields like automation, robotics, manufacturing, and modern automotive technologies such as ADAS (Advanced Driver Assistance Systems), where real-time interaction between multiple subsystems is critical.

Requirement of Integrated Systems

Integrated systems are required because modern engineering tasks have become too complex for standalone components to handle. Advanced applications demand precise control, real-time monitoring, reliable communication, and coordinated decision-making. For example, ADAS requires radar, cameras, ultrasonic sensors, LiDAR, and braking systems to work together to detect obstacles and ensure safe driving. Without integration, these technologies cannot exchange data quickly enough or perform complex tasks efficiently. Therefore, integration is required to achieve accurate results, synchronized actions, and smooth overall system operation.

Necessity of Integrated Systems

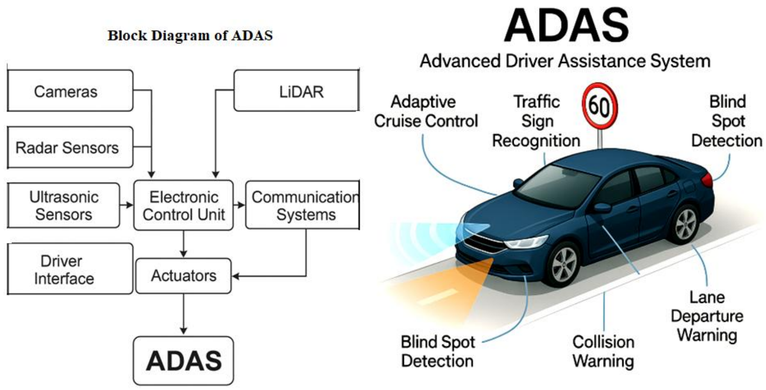
The necessity for integrated systems emerges from the growing emphasis on safety, automation, efficiency, and intelligent behavior in machines and vehicles. As systems become smarter, they must process large amounts of data, adapt to changing conditions, and make decisions instantly. ADAS, for example, cannot function unless multiple sensing and control technologies operate cohesively. The system must merge data from different sensors, interpret it using algorithms, and control vehicle functions like braking and steering. This level of coordinated intelligence makes integrated systems absolutely necessary to achieve modern technological goals.

Advantages of Integrated Systems

Integrated systems offer numerous advantages, including improved performance, faster response, and enhanced accuracy because all subsystems communicate and support each other. They reduce human error and increase safety—critical in ADAS and automation. Integration also simplifies operation and maintenance, as the entire system behaves as one coordinated unit rather than several disconnected parts. Additionally, integrated systems enable advanced functionalities such as autonomous decision-making, predictive diagnostics, and real-time optimization, making them more efficient, reliable, and capable of meeting the demands of modern technology.

Aspect	Summary
Concept of Integrated System	Multiple technologies and subsystems work together as one coordinated unit to achieve intelligent, efficient, and real-time operation.
Requirement	Needed because modern tasks involve complex sensing, processing, control, and communication that cannot be performed by isolated components.
Necessity	Essential for achieving automation, safety, accuracy, and data fusion—especially in systems like ADAS where sensors and controllers must work simultaneously.
Advantages	Provides higher efficiency, faster response, reduced errors, improved safety, easier maintenance, and enables advanced smart features.

5.18 ADAS (Advanced Driver Assistance System): ADAS is an advanced automotive system that uses sensors, cameras, and intelligent algorithms to assist drivers by enhancing safety, control, and driving comfort.



ADAS Component	Description
Cameras	Capture visual information such as lanes, traffic signs, pedestrians, and vehicles.
Radar Sensors	Detect distance and speed of objects ahead, behind, or to the sides.
LiDAR (in some vehicles)	Provides 3D mapping and precise distance measurements of surroundings.
Ultrasonic Sensors	Used for close-range detection (parking, blind spot alerts).
ECU (Electronic Control Unit)	The "brain" that processes data from all sensors and makes decisions.
Communication Systems	Connect subsystems and share real-time data across the vehicle.
Driver Interface	Alerts, warnings, sounds, dashboard icons, and steering/braking interventions.
Actuators	Perform automatic actions like braking, steering, lane correction, and acceleration.

5.19 Operating Principle: ADAS operates by continuously collecting real-time data from multiple sensors such as cameras, radar, ultrasonic units, and LiDAR. These sensors monitor the vehicle's surroundings, including road markings, nearby vehicles, pedestrians, obstacles, and driving conditions. The sensor data is sent to the Electronic Control Unit (ECU), where advanced algorithms analyze the information, detect potential hazards, and predict possible collisions or lane deviations. Based on this analysis, the ADAS system provides warnings to the driver or automatically intervenes with corrective actions such as braking, steering, or adjusting speed. This coordinated sensing, processing, and actuation improves safety, reduces human error, and enhances driving comfort.

5.20 Applications:

ADAS Feature / Application	How It Helps
Adaptive Cruise Control	Automatically maintains safe distance from the vehicle ahead.
Lane Departure Warning	Alerts when the vehicle unintentionally drifts out of its lane.
Lane Keeping Assist	Gently steers the vehicle back into the correct lane.
Automatic Emergency Braking	Applies brakes to prevent or reduce collision.
Blind Spot Detection	Warns when another vehicle is in the blind spot area.
Traffic Sign Recognition	Reads and displays road signs like speed limits.
Parking Assist	Helps with automatic parking using ultrasonic sensors.
Driver Drowsiness Detection	Monitors driver attention and alerts during fatigue.
Pedestrian & Cyclist Detection	Identifies vulnerable road users and prevents impact.
Rear Cross-Traffic Alert	Warns of approaching vehicles while reversing.

QUESTION BANK:

5-MARK QUESTIONS

1. Define automation and explain the basic elements of an automated system.
2. Explain the three types of automation: Fixed, Programmable, and Flexible.
3. Define mechatronics. Explain any two elements of a mechatronic system.
4. Describe the working principle of a potentiometer and list any four applications.
5. Explain the construction and working principle of a capacitive sensor.
6. What is an optical encoder? Explain its working with a neat sketch.
7. State the need and necessity of integrated systems in modern engineering.
8. List the components of ADAS and explain any two.

10-MARK QUESTIONS

1. Explain in detail the basic elements of an automated system with a neat block diagram. Discuss their significance in automation.
2. Describe fixed, programmable, and flexible automation. Compare them based on flexibility, production rate, cost, and changeover time.
3. Define mechatronics. Explain the five major elements of a mechatronic system with functions and suitable examples.
4. Explain the working principles, construction, and applications of the following elementary sensors:
(a) Potentiometer
(b) Capacitive sensor
(c) Optical encoder
5. What is an integrated system? Explain its requirement, necessity, and advantages with respect to modern technologies such as ADAS.
6. Explain the components, working principle, and applications of ADAS (Advanced Driver Assistance System) with a neat block diagram.
7. Discuss the role of elementary sensors in mechatronic systems. Explain how potentiometers, capacitive sensors, and optical encoders support automation.

GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN

Near Dairy Circle, Hosur Road, Bengaluru-560029, KARNATAKA

Affiliated to VTU., Belagavi, Recognized by Government of Karnataka & A.I.C.T.E., New Delhi

Contact

9986343109 / 9845954481
080 – 25536527

www.gitw.in

B.E Programs Offered

- Computer Science & Engineering
- Information Science & Engineering
- Electronics & Communication Engineering.

It was established in the year 2023, affiliated with Visvesvaraya Technological University (VTU), Belagavi, Karnataka. Recognized by AICTE, New Delhi, and the Government of Karnataka. It is one among the two engineering colleges for women in the state. The college provides hostel facilities and organizes diverse programs enhancing students' overall personality.