# CANARA ENGINEERING COLLEGE,

## Benjanapadavu, Bantwal

## Department of Mechanical Engineering

# Introduction to Mechanical Engineering

## BESCK104D/204D

**Semester:** $I^{st}$

**Module No.:** 4

**Module Title:** Engineering Materials

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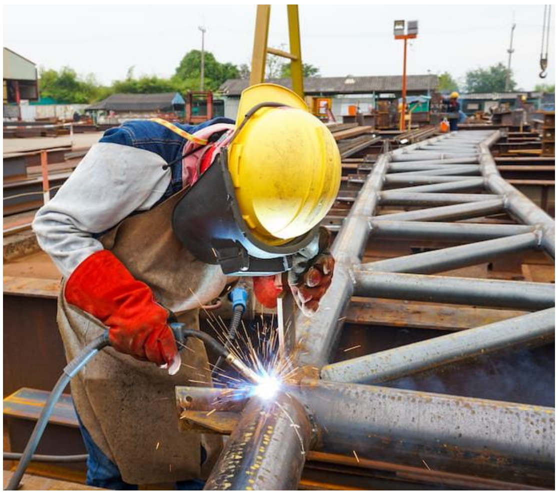


# MODULE 3

## Engineering Materials

**Syllabus of the module**

Engineering materials: Introduction, Classification, Ferrous and Non-Ferrous metals: Types, Properties and their applications.

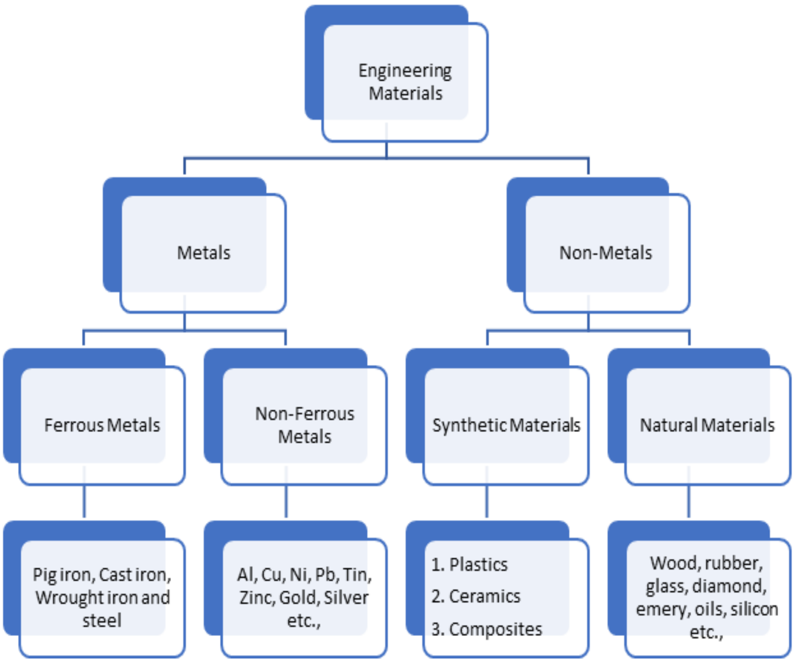
Composite materials: Introduction, Constituents of a composite, Classification, Types of Matrix and Reinforcement materials, Advantages, Disadvantages and Applications of composite materials.

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

## Engineering Material

Engineering materials refers to the group of materials that are used in the construction of manmade structures and components. The primary function of an engineering material is to withstand applied loading without breaking and without exhibiting excessive deflection. The major classifications of engineering materials include metals, polymers, ceramics, and composites.

## Classification of Engineering Materials:




## Metal

A metal is a material that, when freshly prepared, polished, or fractured, shows a lustrous appearance, and conducts electricity and heat relatively well. Metals are typically ductile (can be drawn into wires) and malleable (they can be hammered into thin sheets). These properties are the result of the metallic bond between the atoms or molecules of the metal.

Engineering materials are generally grouped into two parts i.e., Metals & Non-Metals. Metals include Ferrous, Non-Ferrous, and Non-Metals include Glass, Rubber, Plastic, etc. However, there are many other engineering materials which are Ceramics, Polymers,

### Ferrous Metals

Iron and Carbon are the main constituents of Ferrous metals and due to the presence of Iron, ferrous metals are having magnetic properties. For example, Cast Iron, Wrought Iron, Steel, etc.,

### Non-Ferrous Metals

Non-Ferrous metals do not have Iron content and thus these are non-magnetic and rust resistant. For example, Aluminium, Copper, Lead, Brass, Bronze, Gold, Zinc, etc.

### Pig iron:

Composition- C: 3.5 – 4.5%; Si: 0.5 – 3%; S: 0.04 to 0.2%; Mn: 0.5 – 2.5%; P: 0.04 – 1%
Properties- Brittle

Application- used for making wrought iron, cast iron or steel.

**Cast iron**:
Composition- C: 2 – 4.5%; Si: 1 – 3%; small amounts of S, Mn, and P.
Properties- strong, brittle, low melting point, wear resistance, good fluidity, good machinability.
Application- machine frames, beds and plates, housing, flywheels, automotive parts such as engine block, cylinder head, gear box case.

## Steel:

Steel is an alloy of iron and carbon. Steel generally contains C: 0.5 – 1.5%; small amounts of Si, S, P and Mn.
Classification of steels:

1. Carbon steels
2. Alloy steels
3. Tool steels

**Carbon Steel:**

i. **Low carbon steel or Mild steel:**

Composition- C: 0.05 – 0.3%; rest is iron.
Properties- soft and ductile, good weldability, good formability, good machinability, good toughness. Generally low strength.
Application-

i. In lightly stressed parts, nails, chains, rivets, bolts, keys, plain washers etc.,
ii. In structural sections like angles, channels, girders, beams etc.,
iii. In small forgings.
iv. In boiler plates, making shafts, camshafts, gears, and axles for low loads.

ii. **Medium carbon steel:**

Composition- C: 0.3 – 0.6%; rest is iron.
Properties- high toughness, high tensile strength, high hardness, good bending strength, wear resistance, good torsion strength and good machinability.
Application- transmission shafts, axles, gears, connecting rods, spindles, couplings, springs, washers, forging dies, rotor shafts, crane hook, torque tubes, loco wheels, keys, hand tools etc.,

iii. **High carbon steel:**

Composition- C: 0.6 – 1.5%; Fe: 96 – 97%.
Properties- high hardness, brittle, resistance to wear and tear, surface abrasion resistant, large torque capacity, high tensile strength, high yield strength. Low impact strength, less ductility.

Application- hammers, chisels, screws, punches, knives, saws, drills, taps, reamers, lathe tools, ball races and ball bearings, leaf springs, scrapers, bandsaws, circular saws, wrenches, forming dies, banking dies, shearing dies, shaper tools, planer tools and milling cutters etc.,

### Alloy Steel:

Alloy steels are the steels produced by adding elements other than carbon in calculated amounts to provide specific properties. Common types of alloy steels are:

**i. Chromium steel:**

Chromium is the alloying element.

Chromium improves corrosion resistance, hardenability, toughness, resistance to abrasion, resistance to heat.

Application- in balls, rollers and racers for bearings, armor plate, cutting tools.

**ii. Nickel steel:** Ni: 3% and C: 0.2 – 0.35%.

Application- locomotive forgings, axles, piston rods, parts of ship and components subjected to shocks and fatigue.

An alloy of 36% Ni and 64% Fe has very less coefficient of expansion is used in measuring instruments.

**iii. Manganese steel:** Mn: 1.5%; C: 0.4 – 0.55%.

Properties- improves strength, hardness, and toughness.

Application- axles, gears, shafts etc.,

**iv. Molybdenum steel:** Molybdenum is an alloying element.

Properties- increases tensile strength and creep strength at high temperature. Increases wear resistance, heat resistance and corrosion resistance.

Application- used in high temperature heating elements, forging dies, extrusions, radiation shields etc.,

**v. Tungsten steel:** Tungsten is an alloying element.

Properties- increases strength, hardness, toughness, provides shock resistance at high temperature and wear resistance.

Application- in industrial cutting tools, rocket nozzles etc., Hastelloy and Satellite which are superalloys containing tungsten is used in the blades of turbine.

**vi. Stainless steel:** Cr: 18%; Ni: 8%; C: 0.03%. Rest in majorly Iron and small amounts of Mn, Si, Mo, P, S and N etc.,

Properties- corrosion resistant.

Application- used in kitchen equipment, cutlery, springs, circlips, chemical handling equipment's, surgical equipment's, shaving blades etc.,

**vii. Tool steel:** are special steels with carbon content is in the range of 0.8 to 1.2%. Common example of tools steel is High Speed Steel (HSS). It contains 0.7 to 0.8% C, 12 to 20% tungsten, 3 to 5% chromium, 1 to 2% vanadium and 5 to 10% cobalt.

Properties- very hard and exhibit good wear and abrasion resistance. Withstand hardness at elevated temperatures.

Application- in drill bits, lathe tools, milling cutters, reamers etc., They can cut at high speeds without any loss in the hardness.

## Non-Ferrous Metals

Non-Ferrous metals do not have Iron content and thus these are non-magnetic and rust resistant. For example, Aluminium, Copper, Lead, Brass, Bronze, Gold, Zinc, etc.

**Aluminium:**

Aluminium is a silvery white, soft, and ductile material. In its ore form, aluminium is found as hydrated aluminium oxide or Bauxite.

Properties-

i. Light weight and easy workability.
ii. Corrosion resistance.
iii. Non-magnetic and good reflector of heat.
iv. Highly ductile.
v. Good electrical and thermal conductivity.

Application-

i. Metallurgical application: as de-oxidizer in the production of iron and steels. Used for alloying steels.
ii. Electrical industry: used to make bus bars, cables, induction motors, conductors, rotors, windings etc.,
iii. Aircraft industry: used in making aircraft parts.
iv. Automotive applications: used in making cylinder blocks, panels, suspension, chassis, and other engine components.
v. Packaging industry: to make foils and drinking cans. Beer containers.
vi. Domestic: cooking utensils, ladders, furnishing, lighting fixtures, household electrical appliances.
vii. Construction industry: to make windows, doors, frames, fencing, shutters, curtain walls, insect screens, gates etc.,

**Duralumin:**

Composition- Al: 92%; Cu: 3.5 to 4.5%; Mg: 0.4 to 7%; Mn, Fe and Si maximum 0.7%.

Properties- Duralumin can be highly strengthened by heat treatment. It is strong Duralumin can be spun, presses, riveted, machined etc., Low resistance to corrosion hence coated with pure aluminium.

Application- connecting rod of aero engines and automobiles, aircraft structures.

**Y-alloy:**
Composition- Al: 93%; Cu: 4%; Ni: 1%; Mg: 1%.
Properties- good conductor of heat. Maintains strength at elevated temperatures.
Application- used to make pistons, cylinder head of IC engines. Also used to make connecting rods and blades of propeller.

**Copper:**
Copper is a soft, malleable, and ductile metal with the atomic number 29 and the symbol **Cu**. Its key characteristics are excellent electrical and thermal conductivity, high corrosion resistance, and a reddish-orange color. Due to these properties, copper is widely used in electrical wiring, plumbing, heat exchangers, and various alloys like brass and bronze for coins, tools, and cookware.
**Composition**
**Pure copper:** In its pure form, it is a chemical element with the symbol Cu and atomic number 29.
**Alloys:** Copper is often mixed with other metals to create alloys that have enhanced or different properties.
Brass**:** An alloy of copper and zinc.
Bronze**:** An alloy of copper and tin.
**Other alloys:** Include cupronickel and constantan, used for specific applications like marine hardware and thermocouples
**Characteristics**
Electrical and thermal conductivity: Copper has the highest electrical and thermal conductivity of all common metals, second only to silver.
Mechanical properties: It is soft, malleable, and ductile, making it easy to form into wires, tubes, and other shapes.
Corrosion resistance: Copper forms a protective layer (patina) that prevents further corrosion in many environments, such as in the presence of water and air.
Color: A freshly exposed surface of pure copper has a distinct pinkish-orange color.
Non-magnetic: Pure copper is non-magnetic and non-sparking.
**Applications**
Electrical and electronic:
Wiring and cables for power generation and distribution
Integrated circuits and printed circuit boards
Motors, appliances, and telecommunications equipment
Construction:
Pipes for water and heating
Roofs and wall cladding
Ornaments and fixtures
Industrial and commercial:
Heat exchangers and radiators
Marine hardware and coinage
Tools and cookware (often as alloys like brass and bronze)
Alloy-specific:
Brass: Used for musical instruments, fittings, and decorative items

Bronze: Used for statues, sculptures, and bearings
Cupronickel: Used for marine hardware and coins
Constantan: Used in thermocouples and strain gauges

**Non Metals**

**Silica**

silica, also called silicon dioxide, compound of the two most abundant elements in Earth's crust, silicon and oxygen, $SiO_2$. The mass of Earth's crust is 59% silica, the main constituent of more than 95 percent of the known rocks.

Silica sand is used in buildings and roads in the form of portland cement, concrete, and mortar, as well as sandstone.

Silica also is used in grinding and polishing glass and stone in foundry molds in the manufacture of glass, ceramics, silicon carbide, ferrosilicon, and silicones; as a refractory material; and as gemstones.

**Ceramics:** Ceramic is an inorganic, non-metallic solid manufactured by baking naturally occurring clays at high temperatures after moulding to shape.

A ceramic is any of the various hard, brittle, heat-resistant and corrosion-resistant materials made by shaping and then firing an inorganic, nonmetallic material, such as clay, at a high temperature. Common examples are earthenware and brick.

Application- used in the manufacture of knives, high- voltage insulators, high temperature resistant cutting tool tips, dies, engine parts, pottery, tiles, structural and refractory bricks.

**Glass** is made from natural and abundant raw materials (**sand, soda ash and limestone**) that are melted at very high temperature to form a new material: glass. At high temperature glass is structurally similar to liquids, however at ambient temperature it behaves like solids. As a result, glass can be poured, blown, press and moulded into plenty of shapes.

Glass is an amorphous solid material which is non-crystalline in nature. It is smooth with non-porous surface and is abrasion resistant, a good insulator, good resistant to chemical attacks. Glasses are generally brittle and optically transparent.

Additional materials such as iron oxide or cobalt can be added to the mix to give a green or blue colour to the glass.

Application- used in food containers, laboratory apparatus, doors, furniture, utensils, vehicle windows, mirrors, as lenses for spectacles, telescopes or magnifying glasses.

**Graphite** is a crystalline form of the **element carbon**. It consists of stacked layers of graphene.

Graphite occurs naturally and is the most stable form of carbon under standard conditions.

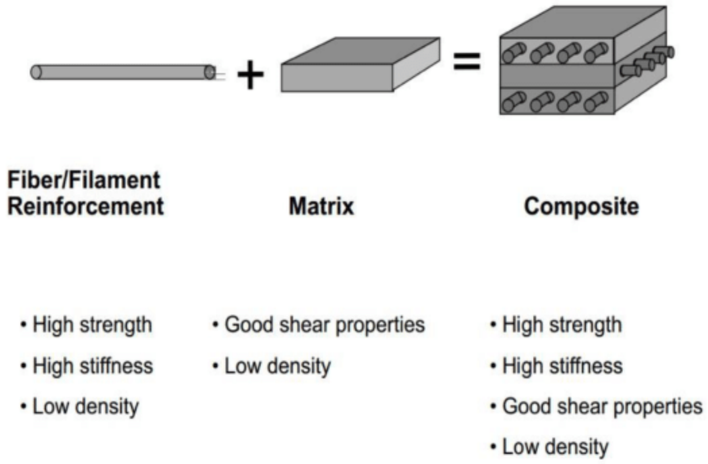
Synthetic and natural graphite are consumed on large scale for uses in pencils, lubricants, and electrodes.

Under high pressures and temperatures, it converts to diamond.

It is a weak conductor of heat and electricity.

**Diamond** is a solid form of the element carbon with its atoms arranged in a crystal structure called diamond cubic.
Another solid form of carbon known as graphite is the chemically stable form of carbon at room temperature and pressure,
Diamond has the highest hardness and thermal conductivity of any natural material, properties that are used in major industrial applications such as cutting and polishing tools, Because the arrangement of atoms in diamond is extremely rigid,
Diamond also has a very high refractive index and a relatively high optical dispersion.
A **polymer** is a substance or material consisting of very large molecules called macromolecules, composed of many repeating subunits. Synthetic and natural polymers play essential roles in everyday life.
Polymers, both natural and synthetic, are created via polymerization of many small molecules, known as monomers. Polymers unique physical properties including toughness, high elasticity, viscoelasticity.
Natural polymeric materials such as hemp, shellac, amber, wool, silk,
Synthetic polymers, roughly in order of worldwide demand, Includes polyethylene, polypropylene, polystyrene, polyvinyl chloride, synthetic rubber, phenol formaldehyde resin (or Bakelite), neoprene, nylon, polyacrylonitrile, PVB, silicone.

**Composites:** A composite is defined as a material which is a combination of two or more materials which have different interfaces between them, and the resulting material properties are enhanced compared to the individual constituent material.
**Constituents of a Composites:** The main constituents of composites are the reinforcements and the matrix.
In a composite material one material forms a matrix to bond together the other material called reinforcement material. The matrix and composites are chosen in such a way that their mechanical properties complement each other, at the same time their deficiencies are neutralized.
**Constituents of Composites:**
Main components of a composite
**Matrix:**
This is the binder material that holds the structure together. It can be a polymer (like epoxy or polyester), a metal, or a ceramic. The matrix protects the reinforcement from environmental damage and transfers the load between the fibers.
**Reinforcement:**
This is the material that provides the composite with its strength and stiffness. It can be in the form of fibers (like glass, carbon, or aramid), particles, or flakes.
**How they work together**
The two materials are combined without dissolving or blending into each other, so their original properties remain distinct.
The matrix transfers stress to the more resistant reinforcement, allowing the final composite to be stronger and stiffer than either component alone.
By selecting different matrices and reinforcements, engineers can create materials with tailored properties for specific applications, such as high strength-to-weight ratios for aircraft or impact resistance for bulletproof glass.




**Metal Matrix Composites:** Metal Matrix Composites are composites that contain at least two component parts one of which is metal. The other material may be a metal or ceramic or an organic compound.
Properties- Higher specific strength, stiffness, higher operating temperature, low coefficient of thermal expansion, greater wear resistance. Lower ductility and cost of fabricating is high.
Applications-

- Used is making piston for diesel engine due to good wear resistance and strength.
- Used in applications where weight saving is vital factor such as robots, high-speed machinery and high-speed rotating shafts.
- Used in automotive engine and brake parts due to good wear resistance.
- Used in lasers, precision machinery, electronic packaging, spacecraft structures, missile structures, fighter aircraft engine and structures.

**Fiber Reinforced Composites:** Fiber Reinforced Composites are composed of axial particles in the form of fibers embedded in a matrix material. Reinforcing fibers are usually of metals, ceramics, glasses or polymers that are turned into graphite. FRC has high strength and high elastic modulus for its weight.
Applications-

- Used in advanced sports equipment like a time-trail racing bicycle frame that consists carbon fibers in thermoset polymer matrix.
- Used in body parts of racing cars and few other automobiles are of composite material that is made of fiberglass in a thermoset matrix.
- A hybrid mixture of carbon fibers and Kevlar 49 fibers are used as primary material to make wings, fuselage and tail assembly components of an aircraft.

Types of matrix materials

- Polymer Matrix Composites (PMCs)**:** The most common type, used in aerospace, automotive, and marine applications.
  - **Matrix:** Thermoset (e.g., epoxy, polyester) or thermoplastic resins.
  - **Reinforcement:** Fiberglass, carbon fiber, Kevlar, or boron fiber.

- Metal Matrix Composites (MMCs): Used in applications requiring higher strength and temperature resistance, such as in the aerospace and automotive industries.
  - **Matrix:** Aluminum, magnesium, titanium, or copper alloys.
  - **Reinforcement:** Ceramic particles or fibers (e.g., silicon carbide), carbon fibers, or metallic fibers.

- Ceramic Matrix Composites (CMCs): Designed for extreme temperatures, such as in jet engines and other high-performance applications.
  - **Matrix:** High-temperature ceramics like oxides, silicon carbide, or alumina.
  - **Reinforcement:** Ceramic fibers, such as silicon carbide or carbon fibers.

Types of reinforcement materials

- Particulate Composites: Reinforcements are particles distributed throughout the matrix. **Examples:** Adding particulate silicon carbide to an aluminum matrix to improve wear resistance.
- Fiber Composites: Reinforcements are fibers, which can be continuous or discontinuous.
  - **Continuous Fiber:** Long, high-strength fibers are aligned in one or more directions to provide maximum strength in those directions. Examples include carbon fiber, glass fiber, and boron fiber.
  - **Discontinuous (Whisker) Fiber:** Short-length fibers used to improve properties like stiffness and strength.
- **Laminates:** Multiple layers of different materials are bonded together to create a composite with unique properties

**Properties of Composites:**

- Light in weight.
- Excellent specific strength and stiffness.
- High tensile strength to weight ratio.
- Excellent spring-back property with resilience.
- Non-corrosive and resistant to chemicals.
- Fire retardant and fire resistant.
- Low thermal conductivity.

**Advantages of Composite materials:**

- Less maintenance and repair cost as CM are non-corrosive and resistant to chemicals.
- Lower weight than their metal counter parts. Saving in weight and cost.
- Outstanding strength-to-weight and stiffness-to-weight ratio.
- Good resilience hence application in transport industry.
- Composite structures have good thermal properties and are very good insulators.

- In military applications, high strength composites can give good from blast and ballistic threats.
- FRCs are low in thermal conductivity and are good fire retardants.
- Innovative designs can be obtained from composites.

**Disadvantages of Composite materials:**

- Fabrication cost is high.
- More brittle than wrought metals.
- Repair of composites is not a simple process.
- Must be cleaned thoroughly before.
- Cost of raw material used for composites is high.
- The matrix of the composite is subject to environmental degradation.

**Application of Composite materials:**

- Aircraft industry: spoilers and flight controls.
- Automobile industry: car parts such as front end, tail doors, side doors, seating, hoods, fuse boxes, headlamps, engine valve cover, leaf springs, etc.,
- Sports equipment: badminton racket, tennis racket, golf stick, hockey stick, softball bat, table tennis bat, helmets, climbing ropes, high jump pole etc.,
- Construction industry: polymer composites are used in the construction industry in non-load bearing applications like trimmings, kitchenware, vanities etc.,
- Biomedical industry: in orthopaedic applications such as bone fixation plates, hip joint replacement, bone cement and bone grafts. In dental application such as preparation of crowns, repair of cavities or entire tooth replacement.
- Wind energy applications: manufacturing blades of wind turbine.
- Marine applications: construction of ships and marine structures because of their higher stiffness and strength by weight compared to other materials like steel and aluminium. It is used in marine applications in boat hulls, minesweepers, ship superstructures etc.,
- Military applications: used in submarines, armoured vehicles, bullet-proof vests and military aircraft.

## Introduction to smart materials

- **Definition**: Smart materials have one or more properties that can be significantly altered in a controlled manner by an external stimulus.
- **Characteristics**: They exhibit properties like self-adaptability, self-sensing, and self-repairing, allowing for unique applications in sensors and actuators.
- **Stimuli**: These materials respond to a range of stimuli, including temperature, light, pressure, moisture, electric fields, magnetic fields, and pH changes.

### Types of smart materials

Smart materials are often classified based on how they respond to stimuli:

- Shape Memory Alloys (SMAs): Metal alloys that can return to their original shape after being deformed, usually when heated above a specific temperature.

- Piezoelectric Materials: These materials generate an electric charge when subjected to mechanical stress, and conversely, change shape when an electric field is applied.
- Magneto-responsive Materials:
  - **Magnetostrictive Materials**: Change shape when exposed to a magnetic field.
  - **Magneto-rheological fluids**: Fluids that change viscosity from a liquid to a semi-solid when a magnetic field is applied.
- Thermo-responsive Materials: Materials that change their shape, color, or other properties in response to changes in temperature.
- Chromic Materials: Materials that change color due to an external stimulus:
  - **Thermochromic**: Change color with temperature.
  - **Photochromic**: Change color with light exposure.
  - **Electrochromic**: Change color when an electric voltage is applied.
- pH-sensitive Materials: Change their color or other properties based on the acidity of their environment.
- Electroactive Polymers (EAPs): Polymers that change shape or size when stimulated by an electric field, often called "artificial muscles".

**Piezoelectric Materials:**

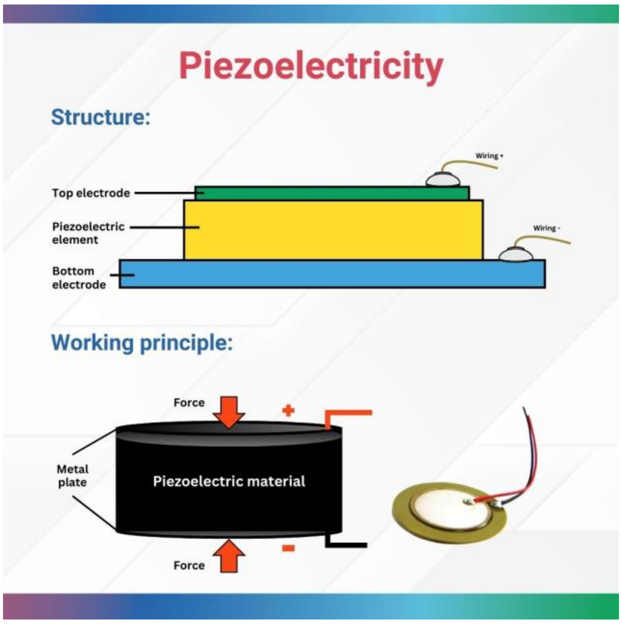
Piezoelectric materials are solids that generate an electric charge in response to mechanical stress, a phenomenon known as the piezoelectric effect. They can also deform when an electric field is applied, which is the converse piezoelectric effect. This unique ability to convert between mechanical and electrical energy makes them essential for sensors, transducers, actuators, and more, and they can be classified as crystals, ceramics, or polymers.

**Types of piezoelectric materials**

- **Crystals:** Naturally piezoelectric crystals include quartz, tourmaline, and topaz. Artificially grown crystals like lithium niobate and lithium tantalate are also used.
- **Ceramics:** These are polycrystalline materials, with common examples including lead zirconate titanate (PZT), barium titanate, and lead titanate. Ceramics are often preferred for their ease of fabrication into various shapes and sizes, though they can be less efficient than single crystals.
- **Polymers:** Materials like polyvinylidene fluoride (PVDF) are piezoelectric polymers. They offer advantages such as low density, flexibility, and low mechanical impedance, and can be manufactured into large areas.

**How they work**

- **Charge generation:** The crystal structure of piezoelectric materials lacks a center of symmetry. When mechanical stress is applied, the crystal lattice is deformed, disrupting the balance of positive and negative charges and creating a potential difference across the material.
- **Deformation:** Conversely, when an electric field is applied, the positive and negative charge centers within the crystal are shifted, causing the material to physically deform.




**Applications**

- **Sensors:** They are used in sensors for detecting pressure, acceleration, and force, including in things like accelerometers and gyroscopes.
- **Energy harvesting:** Piezoelectric materials can harvest energy from vibrations, such as from footsteps or machinery, to power small electronic devices.
- **Actuators:** They are used in applications requiring precise movement, such as in micro-positioning and inkjet printers.
- **Transducers:** A key application is in ultrasonic transducers, which are used in medical imaging and sonar.
- **Other devices:** They are found in electric lighters (for ignition triggers) and can be used for precise focusing in optical devices.

**MR fluids:**

MR fluids, or magnetorheological fluids, are smart fluids that can rapidly and reversibly change from a liquid to a semi-solid state when exposed to a magnetic field. This is because they are a suspension of tiny magnetic particles in a carrier fluid, and the particles align to form chains in response to a magnetic field, drastically increasing the fluid's viscosity and stiffness. This controllable property makes them useful in applications like vibration control, such as in shock absorbers, as well as in clutches and other damping devices.

**Composition:**
MR fluids are a suspension of tiny, magnetizable particles (like iron) in a carrier fluid, such as oil. In their "off" state, they are a free-flowing liquid. When a magnetic field is applied, the particles align along the magnetic field lines, forming structures that restrict movement and make the fluid behave like a solid. The strength of the magnetic field can be adjusted to precisely control the fluid's viscosity and yield strength, allowing for variable damping and force transmission.

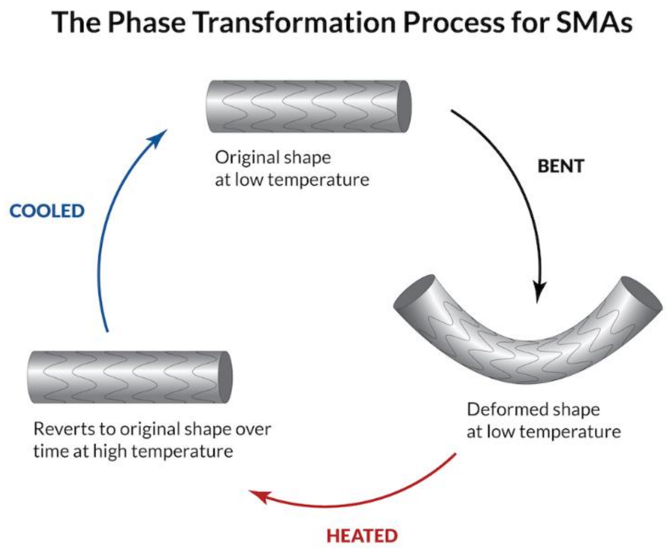
**Applications**
**Vibration control:**
Their ability to change stiffness makes them ideal for shock absorbers and other dampers that need to adapt to different conditions.
**Damping devices:**
They are used in clutches and other devices where controllable resistance is required.
**Robotics and haptics:**
The controllable nature of MR fluids allows them to be used in creating haptic feedback and in robotics, particularly where heavy loads need to be managed.
**Polishing:**
They are also used in precision optical polishing machines.

**Shape memory alloys:**
In metallurgy, a shape-memory alloy (SMA) is an alloy that can be deformed when cold but returns to its pre-deformed ("remembered") shape when heated. It may also be called memory metal, memory alloy, smart metal, smart alloy, or muscle wire.
When a shape memory alloy is in its martensitic form, it is easily deformed to a new shape. However, when the alloy is heated through its transformation temperatures, it reverts to austenite and recovers its previous shape with great force. This process is known as shape memory.
The two most prevalent shape-memory alloys are copper-aluminium-nickel and nickel-titanium (NiTi), but SMAs can also be created by alloying zinc, copper, gold and iron.
**Key properties and characteristics**
Pseudo-elasticity: Some SMAs, like nitinol, exhibit pseudo-elasticity in their high-temperature phase, meaning they can be deformed and return to their original shape without heating.
**"Training":** The memory shape is set during a process called "training" or "shape setting," where the material is heated and cooled while held in its desired shape.
**One-way vs. two-way effect:** The one-way effect is when the alloy recovers its original shape only when heated. The two-way effect involves the alloy remembering and returning to two different shapes depending on the temperature.

**Applications**

- Biomedical: Used for stents that expand in arteries due to body heat, and for surgical plates that help set bone fractures.

- Aerospace: Employed in release and restraint devices for deployable components like solar panels, and as actuators for precise movement.
- Automotive: Can be found in components like thermostats and in certain active damping systems.
- Robotics: Used in actuators, or "muscle wire," that can perform work, such as lifting or creating motion, by contracting and expanding when heated electrically.




## QUESTION BANK

1. List and explain the classification of Engineering materials
2. Classify Engineering metals and explain the composition, characteristics and application of ferrous metals
3. State and explain the composition, characteristics and application of non-ferrous metals
4. Classify and explain the composition, characteristics and application of steel.
5. State and explain the composition, characteristics and application of Aluminium
6. Explain the properties and application of glass and ceramics.
7. Illustrate with a short note on Composite materials and shape memory alloys
8. Write a short note on silica and graphite.
9. Illustrate the types of Matrix and Reinforcement Composite materials and list the merits and demerits.
10. Classify smart materials and explain Piezoelectric materials, and MR fluids
11. Explain shape memory alloys, their applications, and list their merits and demerits.

## WEB RESOCRES

1. https://mechanicalc.com/reference/engineering-materials
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## REFERENCES


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2. An Introduction to Mechanical Engineering, Jonathan Wickert and Kemper Lewis, Third Edition, 2012