There are thousands of materials available for use in engineering applications. Most materials fall into one of three classes that are based on the atomic bonding forces of a particular material. These three classifications are metallic, ceramic and polymeric. Additionally, different materials can be combined to create a composite material. Within each of these classifications, materials are often further organized into groups based on their chemical composition or certain physical or mechanical properties. Composite materials are often grouped by the types of materials combined or the way the materials are arranged together.
Classification of Engineering Materials

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Classification of Engineering Materials

- Metals
  - Brass
  - Aluminium
  - Cast Iron
  - Metal Sludge
  - Steel
  - Copper

- Polymer
  - Gloves
  - Plumbing pipes

- Ceramics
  - Tiles

- Composites
  - Aircraft
  - Boats

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Classification of Engineering Materials

Materials used in the design and manufacture of products

- Plastics
- Wood
- Composites
- Ceramics
- Metals
- Fabrics
Plastics can be further classified as:

- Thermoplastic
- Thermoset
- Elastomer

<table>
<thead>
<tr>
<th>Thermoplastics</th>
<th>Thermoset</th>
<th>Elastomers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylics</td>
<td>Epoxy resins</td>
<td>Rubbers</td>
</tr>
<tr>
<td>Nylons</td>
<td>Phenolic</td>
<td>Silicones</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>Polyesters</td>
<td>Polyurethanes</td>
</tr>
</tbody>
</table>
Wood can be further categorised as:

- Hardwood
- Softwood
- Manufactured board

<table>
<thead>
<tr>
<th>Hardwood</th>
<th>Softwood</th>
<th>Manufactured Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak</td>
<td>Pine</td>
<td>Plywood</td>
</tr>
<tr>
<td>Ash</td>
<td>Cedar</td>
<td>Block board</td>
</tr>
<tr>
<td>Beech</td>
<td>Fir</td>
<td>MDF</td>
</tr>
<tr>
<td>Sycamore</td>
<td>Spruce</td>
<td>Melamine board</td>
</tr>
</tbody>
</table>

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A composite is a combination of two or more chemically distinct materials whose characteristics are superior to its constituents acting independently. Because of their high strength to weight ratio they are widely used in:

- Aerospace industry
- Offshore structures
- Boats
- Sporting goods
Examples of composites include;
• Reinforced Plastics
• Ceramic-matrix
• Metal-Matrix
• Laminates
Ceramics are compounds of metallic and non-metallic elements, examples include:

- Oxides (alumina – insulation and abrasives, zirconia – dies for metal extrusion and abrasives)
- Carbides (tungsten-carbide tools)
- Nitrides (cubic boron nitride, 2\textsuperscript{nd} in hardness to diamond)
Metals can be further classified as Ferrous & Non-Ferrous, some examples include:

<table>
<thead>
<tr>
<th>Ferrous</th>
<th>Non-Ferrous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steels</td>
<td>Aluminium</td>
</tr>
<tr>
<td>Stainless Steels</td>
<td>Copper</td>
</tr>
<tr>
<td>High Speed Steels</td>
<td>Brass</td>
</tr>
<tr>
<td>Cast Irons</td>
<td>Titanium</td>
</tr>
</tbody>
</table>

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### Classification of Engineering Materials

#### Some *Ferrous* Metals And Properties

<table>
<thead>
<tr>
<th>NAME</th>
<th>ALLOY OF</th>
<th>PROPERTIES</th>
<th>USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel</td>
<td>Carbon 0.1 - 0.3%</td>
<td>Tough. High tensile strength. Can be case hardened. Rusts very easily</td>
<td>Used in general metal products and engineering.</td>
</tr>
<tr>
<td></td>
<td>Iron 99.9 - 99.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Steel</td>
<td>Carbon 0.6 - 1.4%</td>
<td>Tough. Can be hardened and tempered.</td>
<td>Cutting tools such as drills.</td>
</tr>
<tr>
<td></td>
<td>Iron 99.4 - 98.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stainless</td>
<td>Iron, nickel and chromium.</td>
<td>Tough, resistant to rust and stains</td>
<td>Cutlery, medical instruments.</td>
</tr>
<tr>
<td>steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cast iron</td>
<td>Carbon 2 - 6%</td>
<td>Strong but brittle. Compressive strength very high</td>
<td>Castings, manhole covers, engines</td>
</tr>
<tr>
<td></td>
<td>Iron 98 - 94%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrought iron</td>
<td>Almost 100% iron</td>
<td>Fibrous, tough, ductile, resistant to rusting.</td>
<td>Ornamental gates and railings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Classification of Engineering Materials

**Some Non-Ferrous Metals And Properties**

<table>
<thead>
<tr>
<th>NAME</th>
<th>ALLOY OF</th>
<th>PROPERTIES</th>
<th>USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>Al 95% Cu 4% Mn 1%</td>
<td>Ductile, soft, malleable, machines well. Very light.</td>
<td>Window frames, aircraft, kitchen ware.</td>
</tr>
<tr>
<td>Copper</td>
<td>Not an alloy</td>
<td>Ductile, can be beaten into shape. Conducts electricity and heat.</td>
<td>Electrical wiring, tubing, kettles, bowls, pipes.</td>
</tr>
<tr>
<td>Brass</td>
<td>Cu – Zn 65% - 35%</td>
<td>Hard. Casts and machines well. Surface tarnishes. Conducts electricity.</td>
<td>Parts for electrical fittings, ornaments</td>
</tr>
<tr>
<td>Lead</td>
<td>Not an alloy</td>
<td>Soft, heavy, ductile, loses its shape under pressure</td>
<td>Solders, pipes, batteries, roofing.</td>
</tr>
</tbody>
</table>
Classification of Engineering Materials

COMMON METALS
TYPICAL BICYCLE

FRAME
STEEL AND CHROME ALLOY OR HEAT TREATED ALUMINIUM

BRAKE LEVERS ALUMINIUM

WHEEL RIMS - STEEL

SUSPENSION SPRING TENSILE STEEL (SPRING STEEL)

BEARINGS HARDENABLE STEEL

SPOKES STEEL

GEARS BRASS BEARINGS

PEDAL ALUMINIUM

CHAIN CARBON STEEL (HARDENED)

QUICK RELEASE CAM - ALUMINIUM

By V. Ryan

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Fabrics can be further classified as natural and synthetic.

<table>
<thead>
<tr>
<th>Natural</th>
<th>Synthetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>Nylon</td>
</tr>
<tr>
<td>Canvas</td>
<td>Polyester</td>
</tr>
</tbody>
</table>

Materials used in space suits include aluminized Mylar, neoprene coated nylon, dacron, urethane coated nylon, tricot and spandex. The outer layer is a blend of Gortex, Kevlar and Nomex.
Classification of Engineering Materials

Smart Materials - Shape Memory Alloy

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INTRODUCTION

- Many materials, when in service, are subjected to forces or loads; examples include the aluminum alloy from which an airplane wing is constructed and the steel in an automobile axle.
- In such situations it is necessary to know the characteristics of the material and to design the member from which it is made such that any resulting deformation will not be excessive and fracture will not occur.
- The mechanical behavior of a material reflects the relationship between its response or deformation to an applied load or force.
- Important mechanical properties are strength, hardness, ductility, and stiffness.
Properties of Materials

Mechanical Properties

- Strength
- Ductility
- Hardness
- Toughness
- Elasticity and Plasticity

Physical Properties

- Density
- Melting point
- Conductivity
- Expansion

Chemical Properties

- Density
- Melting point
- Conductivity
- Expansion

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Mechanical Properties

Stress and strain

**Stress**

\[ R = \frac{P}{A_0} \]

**Strain**

\[ \varepsilon = \frac{d}{L_0} = \frac{\Delta L}{L} = \frac{L - L_0}{L_0} \]
Mechanical Properties

Stress – Strain curve

- Ultimate strength
- Elastic limit
- Fracture
- ‘necking’ occurs at this point
- Soft ductile steel
- Serrated yield point

Strain, elongation per unit length

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**Proportional limit**

is the highest stress at which stress is directly proportional to strain. It is obtained by observing the deviation from the straight-line portion of the stress-strain curve.

**Elastic limit**

is the greatest stress the material can withstand without any measurable permanent strain remaining on the complete release of load.

**Yield strength** is the stress required to produce a small-specified amount of plastic deformation.
Resistance of metal to plastic deformation, usually by indentation

The ability to resist being permanently, deformed (bent, broken, or have its shape changed), when a load is applied.

Hardness measurement can be defined as macro-, micro- or nano-scale according to the forces applied and displacements obtained.

**Hardness Measurement Methods**

The most common hardness test methods used in today’s technology:

- Rockwell hardness test
- Brinell hardness
- Vickers
Mechanical Properties

A

Minor load $F_0$

B

Minor load $F_0$

plus

Major load $F_1 = \text{Total load } F$

C

Minor load $F_0$

Zero Reference line

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Toughness

It is a measure of the ability of a material to absorb energy up to fracture. The area beneath a stress / strain curve produced from a tensile test is a measure of the toughness of the test piece under slow loading conditions.