1 Engineering Materials and their Properties

Non-negotiable Knowledge (What you need to know)
- Material properties

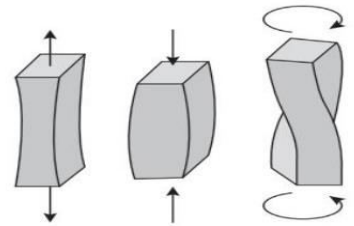
Key words/ terminology	
Materials Properties	Characteristics and traits of materials
Ferrous	metals that contain **iron**.
Non Ferrous	Metals that do not contain iron
Alloys	Combination of two or more metal materials
Ores	**Metals** are made from metal **ores** – these are rocks or minerals mined from the ground.
Thermo plastics	Plastics that can be softened with the use of heat and moulded into shape. This can be repeated.
Thermosetting polymers	Plastics that can only b e molded once.
Composites	Two or more materials combined to combine their properties
Reinforcement	Fibres in a comooste that improve steength
Timber	General term for processed wood materials
Hardwood	From trees that loos leaves in winter. Grow slow
Softwood	Comes from coniferous (evergreen) trees. Trees have needles rather than leaves
Ceramic	typically an oxide, nitride or carbide of a metal. Non organic and non metallic

Strength
The ability of a material to resist applied force

Tensile strength- pull

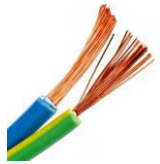
Compressive strength- push

Torsional strength- twist



Malleability
the ability of a material to be deformed without rupturing. Example- Aluminium
Use- Cans

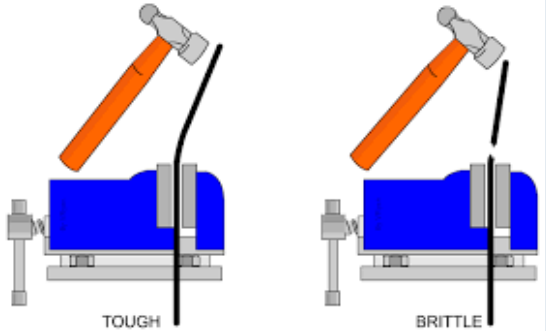
Ductility
the amount a material can be deformed/ stretched



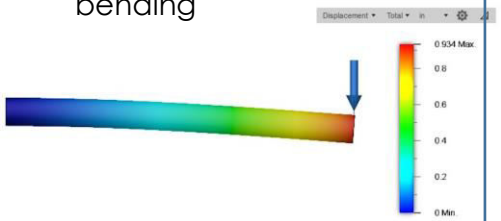
Hardness
ability of a material to resist wear and abrasion

Toughness
Ability of a material to resist bending and shattering

Brittleness
The opposite to toughness; the potential for a material to shatter when it experiences an impact

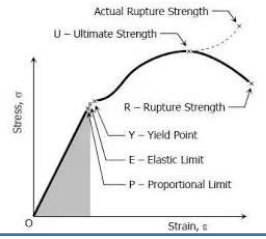


Stiffness
The ability of a material to resist bending



Yield strength
Yield strength is the amount of stress needed to start permanently deforming the material

UTS
Ultimate tensile strength is the stress at which the material eventually fails



Young's Modulus
The ratio of stress to strain of a material, showing how stiff it is.

Further knowledge/ reading
http://www.technologystudent.com/joints/matprop1.htm

1 Engineering Materials and their Properties: Metal

Non-negotiable Knowledge (What you need to know)

- Sources and origins of metals
- Metal materials and their properties

Metal bearing rocks are called ORES, these are mined or quarried from the earth's surface. Metals are obtained from raw ores by a process called smelting. Raw ore is mixed with charcoal and other chemicals, and air is blown into a furnace. The molten metal trickles from the bottom of the furnace and this can be cast or extruded into shapes.

The more the reactive the metal the higher the temperature needed to extract it from its ore. Copper needs 1100°C but iron requires 1500°C.

A metal like aluminium cannot be extracted by smelting. It is dissolved in a 'cryolite solution' and electrolysed (electricity is passed through) at a temperature of around 650°C.

A few metals can be mined from the earth as pure metals. These include gold and some small amounts of copper and silver

Ferrous metals

Ferrous metals usually also contain a small percentage of carbon – the more carbon found in the metal, the harder and less malleable the metal becomes.
Generally, ferrous metals are:
- Magnetic
- Prone to corrosion (rust) when exposed to oxygen and moisture.

Non-ferrous metals

Non- ferrous metals do not contain iron
Generally non-ferrous metals are:
-malleable
-resistant to corrosion
-not magnetic.
Examples include....
Aluminium, copper, lead and zinc are examples of non-ferrous metals

Alloys

Most metals are mixed with other metals to improve their properties.
A mixture of two or more metals is called an **alloy**.

Example of a ferrous alloy: Stainless Steel
Composition- Steel, chromium and nickel
Strong, hard, good corrosion resistance, difficult to machine, can be expensive
Cutlery, medical equipment, sinks

Examples of Non-ferrous alloys
Brass- Composition- Copper and zinc
Properties- Good machinability, however can be difficult to cast. It can be machined to a high finish
Door knobs, musical instruments

Bronze Properties- Ductile, good corrosion resistance, good electrical conductivity
Typical uses/ applications- Statues and other cast products

Ferrous Metal materials and their properties

Cast iron
Contains 3.2-3.5% carbon
Weak in tension but strong and tough in compression, very fluid when molten. Some of carbon content visible as graphite makes it self-lubricating
Machine beds, brake drums, engine cylinder blocks and cylinder heads, valve bodies, manhole covers, vices

Low-carbon steel
0.1 – 0.3 per-cent carbon
Strong, fairly malleable and ductile
Wire, rivets, nuts and bolts, pressings, girders – used as a general workshop material

High carbon steel
0.7 – 1.4 percent Carbon
Strong and hard – can be made very hard by heat treatment
Wood chisels, lathe tools, drills, screw-cutting taps and dies, springs – wide variety of sharp-edged cutting tools

Non-ferrous Metal materials and their properties

Aluminium
Lightweight, soft, ductile, malleable, good electrical and thermal conductivity, resistant to corrosion
Aluminium can be used for soft drinks cans as it is malleable and ductile, so it can be made into thin sheets.

Lead
Very soft, Very malleable, ductile, resistant to corrosion, dense
Roof flashing, weights for diving belts

Zinc
Soft, ductile, malleable, low melting point, resistant to corrosion
Die cast products (car door handles, camera bodies

Copper
Ductile, malleable, good electrical and thermal conductivity, resistant to corrosion
Plumbing, electrical wire

Further knowledge/ reading http://www.technologystudent.com/designpro/metals1.htm

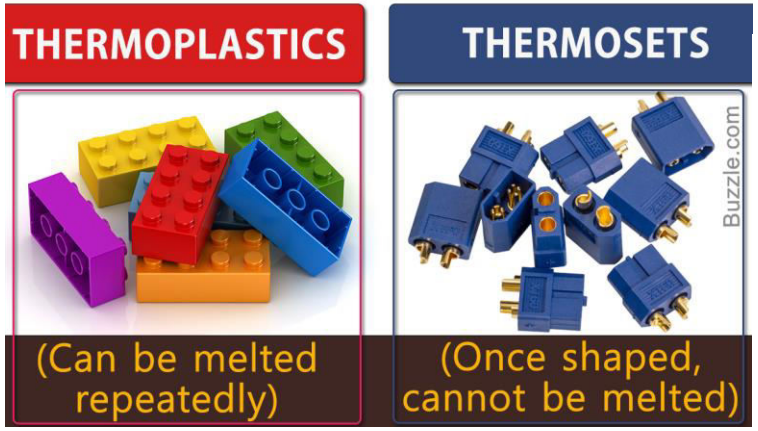
1 Engineering Materials and their Properties: Polymers

Non-negotiable Knowledge (What you need to know)

- Sources and origins of Polymers
- Polymers and their properties

Polymers and their general characteristics

- Polymers are mainly produced from crude oil.
- Most thermoplastics are recyclable.
- Most thermosetting polymers are not recyclable.
- Generally, polymers have good resistance to corrosion/degradation.
- Polymers can be relatively easily moulded into shape.
- Polymers are self coloured.
- In sheet form, polymers have a flat, smooth and shiny surface.



Thermo plastics

Thermoplastics can be softened with the use of heat and moulded into shape.

Thermosetting polymers

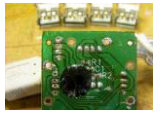
Thermosetting polymers, once moulded into shape, cannot be remoulded with the use of heat.

Further knowledge/ reading
http://www.technologystudent.com/designpro/plastic1.htm

Thermo plastic materials and their properties

Type	Properties	Uses/ applications
ABS 	Strong, rigid, hard and tough	Children's toys, plastic pipes
Acrylic (PMMA) 	Hard, shiny and flat surface, scratches easily. Can be transparent, translucent or opaque.	Illuminated shop signs, bath tubs, machine guards.
Nylon	Ductile, durable, good resistance to wear	Gear wheels, bearings
Polystyrene	Tough, good resistance to impact, lightweight, can be vacuum formed, extruded or injection moulded.	Packaging, foam cups

Thermosetting polymers

Type	Properties	Uses/ Application
Epoxy 	Easily moulded, hard, good insulating properties	Adhesive, casing electrical components, printed circuit boards
Polyester resin 	Easily moulded, hard but brittle	Producing glass-fibre reinforced polymer (GRP) boat hulls and car body panels
Melamine resin 	Stiff, hardwearing, good resistance to heat and staining	Kitchen work surfaces, plastic plates
Polyurethane 	Hard, strong, tough, flexible, low thermal conductivity	Hoses, surface coatings and sealants
Vulcanised rubber 	Good tensile strength, abrasion resistant	Tyres, shoe soles

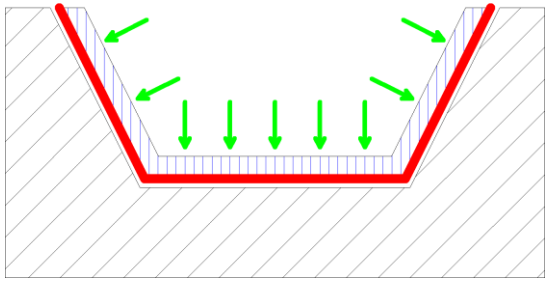
1 Engineering Materials and their Properties: Composites, Composite lay up, Reinforcement

Non-negotiable Knowledge (What you need to know)

- how new materials can be created by combining two or more materials
- the mechanical properties of a range of composite materials and how they can change through reinforcement.

How are the composites GRP and CRP made?

Both the processes of GRP and CRP follow a very similar process:
The stainless steel mould is coated with the gel coat/first resin layer (red layer)
Glass fibre or carbon fibre matting is laid on top of the gel coat
Another coat of resin is applied to the gel coat and worked into the structure (green arrows)
Another coat of resin is applied to the gel coat and worked into the structure (green arrows)
This is repeated until the thickness and strength of material is created.



How are composite materials formed?

Composite materials are formed when two or more distinctly different materials are combined together to make a new material with improved properties.

Carbon fibre and glass-reinforced fibre plastics are examples of composite materials – a thermosetting plastic is combined with a matted or woven material to produce very lightweight and strong composites. The fibres provide **reinforcement** to increase the strength and the polymer creates a matrix around the fibres to hold them in place.

Glass fibre reinforced plastic

Glass fibre matting covered with smooth plastic resin sets hard with a high gloss finish.
It is easy to manufacture complex shapes with a mould.
GRP is lightweight, corrosion resistant and chemical resistant.
It is labour intensive to produce.

Uses/ Applications

It is used to make boat hulls, car body parts, storage tanks, seating, helmets etc.

Carbon fibre reinforced plastic.

CRP is formed from a cloth woven from individual strands. The interlacing provides an interesting and modern aesthetic.
Vinyl decals can be added for decoration.
CRP has a very high strength to weight ratio.
It has good tensile strength but not good compressive strength.
It is very expensive.
The manufacture is labour intensive and is a skilled process.

Uses/ Applications

It is used in supercars and sports cars, top-end sports equipment, and is being developed for prosthetic uses.

Plywood, MDF and OSB.

Fibres are not the only form of reinforcement used in composites.

- Plywood uses layers of timber (plies or laminates) bonded together using an adhesive
- Medium Density Fibreboard (MDF) uses wood fibres and an adhesive matrix
- Oriented Strand Board (OSB) uses strands of wood compressed in an adhesive matrix.

Further knowledge/ reading

https://www.bbc.co.uk/bitesize/guides/ztxnsbk/revision/3

1 Engineering Materials and their Properties: Timbers and Ceramics

Non-negotiable Knowledge (What you need to know)

- the properties of structural grade timber and how it is used in engineering applications
- the properties of ceramics and how they are used in engineering.

Timber

Timber is wood from trees.
Natural timber is classified into two groups: **softwoods** and **hardwoods**.

In engineering we mostly use structural grade timber, which is usually softwood.

Softwood	Hardwoods
Comes from coniferous (evergreen) trees Trees have needles rather than leaves Quick growing Extensively used in joinery Generally less expensive than hardwood	Sometimes called broad-leaf trees. Lose their leaves seasonally, in winter. Hardwoods tend to be harder than softwoods (with the exception of Balsa Wood). They have a wider variety of colour and texture than softwoods. Hard woods tend to be more expensive than softwoods and take longer to mature.

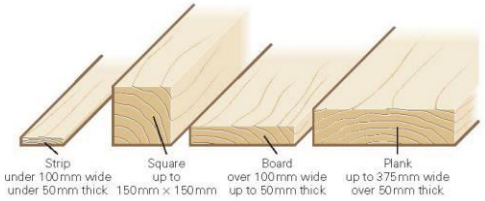
Examples of Softwoods

Redwood (Scots pine), western red, cedar and spruce are examples.

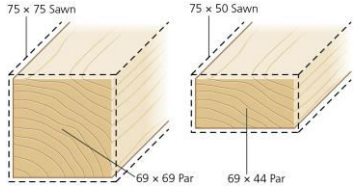
Examples of Hardwoods

Teak
Oak

Standard timber sections
Timber is usually sawn into standard shapes and sizes



Planed timber sizes
Rough sawn timber is also planed to give it a smooth surface.
Planed timber is more expensive than rough sawn timber, but has a smoother finish and more accurate size



Ceramics

Ceramics are typically an oxide, nitride or carbide of a metal.

Properties

- Hard
- Resistant to wear and scratches
- Resistant to corrosion
- Low tensile strength
- Low ductility
- Brittle
- Difficult to machine

Uses of ceramics

- Cups, plates, pots
- Building materials (concrete, bricks, plaster)
- Cutting and grinding tools (made from tungsten carbide)
- Insulation for furnaces (made from alumina and aluminosilicates)
- Lenses (made from silicates)

Further knowledge/ reading
https://www.sciencelearn.org.nz/resources/1769-what-are-ceramics
https://www.thomasnet.com/articles/other/what-is-timber/