NSW HSC

Engineering

Study Notes

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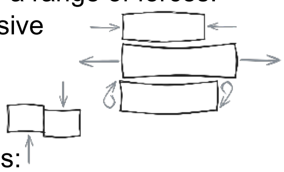
1. Civil Engineering

Bridge: span gaps with pathways.

Bridges are subject to a range of forces:

- Compressive
- Tensile
- Torsional
- Shear



Then a variety of loads:

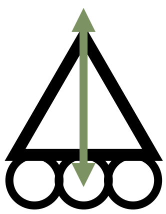
- Dead load: ever-present loads on the bridge (e.g., weight of the bridge)
- Live load: load that frequently changes (e.g., car traffic)
- Impact load: sudden application of a load (e.g., crash)
- Wind load: acts on all points on a face of a bridge.
- Frequency load: load is amplified due to aligning to its natural resonance.

5 types of bridges:

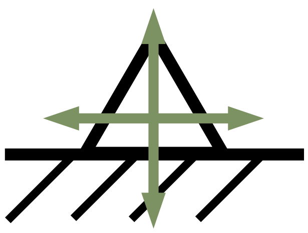
- Basic beam bridge: resting on supports.
- Cantilever bridge: anchored at one end (as the bridge is not supported at all points).
- Truss bridge:
- Arch bridge: using components always in compression which transfer forces into the foundation. Each to build without fasteners.
- Suspension bridge:

Pre-stressed concrete, pour concrete over tensioned iron rods and then release the tension creating a material that is strong in both tension and compression. This counteracts the bowing from weight.

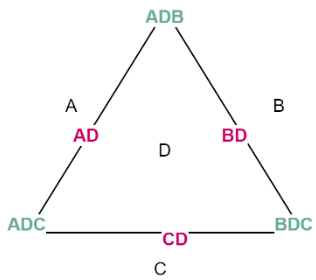
Roller support: moves to alleviate contraction and expansion in materials, it only experiences forces perpendicular to surface.



Roller



Fixed



Bow's notation labels all the spaces between a group of forces.
Joint notation labels all the joints.

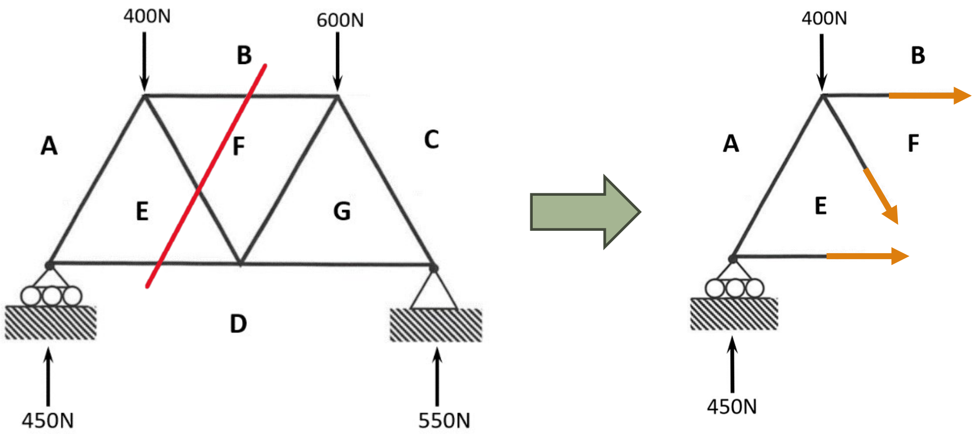
When working out internal truss forces,

- When a beam is in **compression** it seeks to push the external forces outwards.
- When a beam is in **tension** it seeks to pull the external forces inwards.

Assume the actions of the truss (e.g., compression or tension) and if the answer comes out as negative it has to be flipped.

Method of joints: assuming every joint is in equilibrium, then you just consider the members directly interacting with that joint and consequently forces.

Method of sections: cuts part of the truss to determine the forces in a given area. Only have to determine forces in beams which are cut.

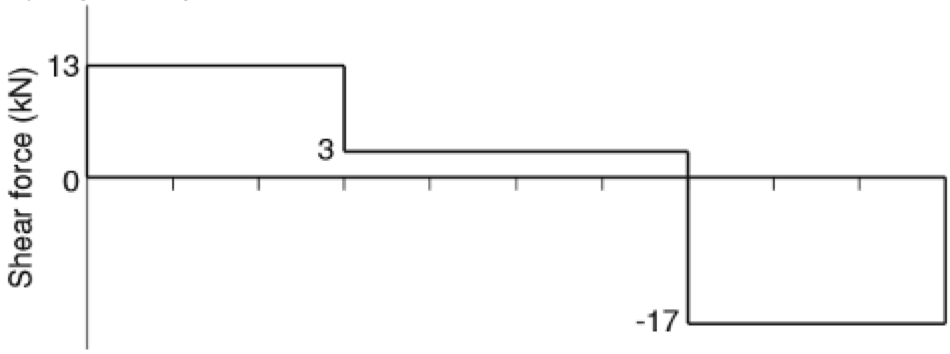


Shear force allows for us to know how a beam will be impact by point loads.

Given this beam,

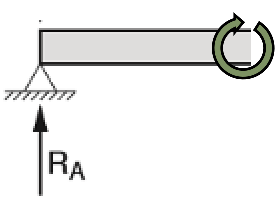
You can get the shear force at each interval (between two forces) by taking all forces to right of the cut and doing $0 = \sum F - \overbrace{\vec{F_S}}^{\text{shear force}}$

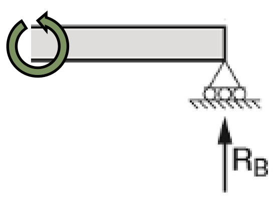
Then you get a diagram like this:

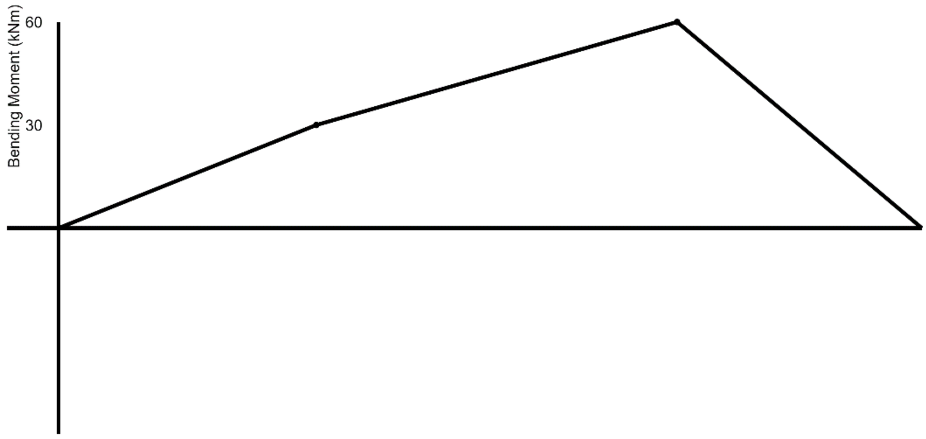


It should always return to 0 at then end.

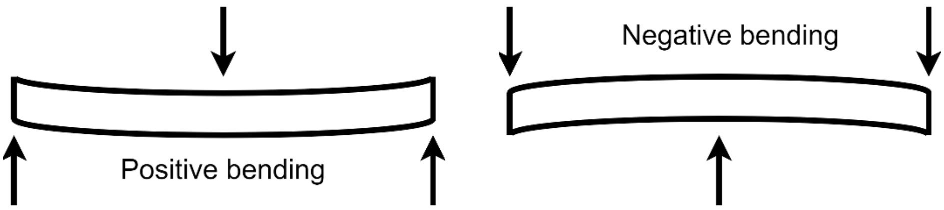
A bending moment diagram can then be made through looking at moments at sections of the beam.
 or *(always look at outwards forces, not inward)*



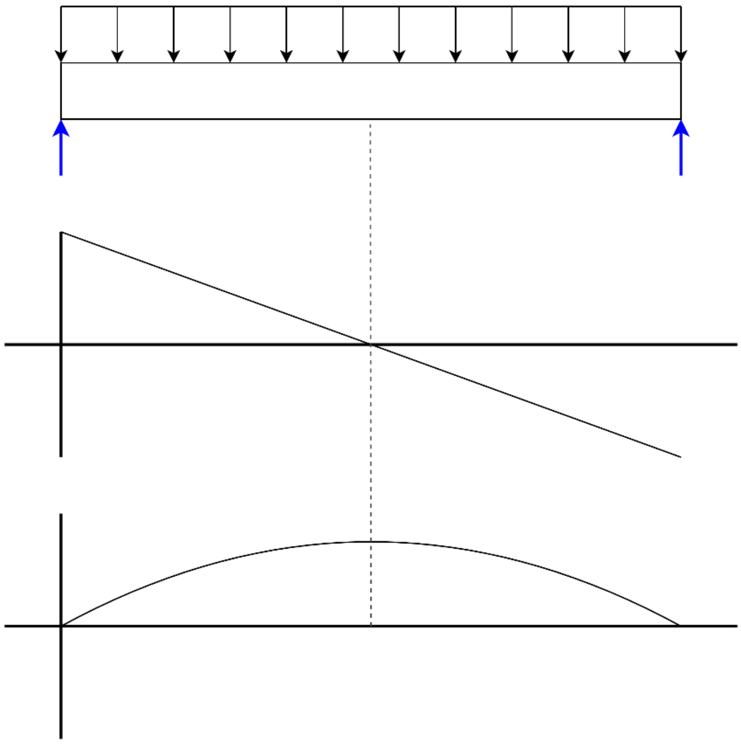


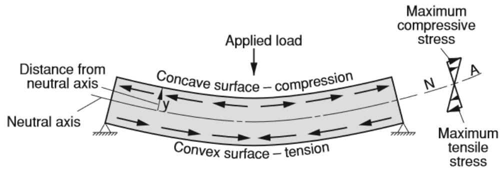


Bending moment diagram demonstrates the bending forces within a beam, and how they will affect the beam.



For uniformly distributed loads, the load is measured in N/m





$$\frac{\sigma}{y} = \frac{M}{I} = \frac{E}{r}$$

With:

σ = Stress (MPa)
y = Distance from neutral; axis (mm)
M = Bending moment (Nmm)
I = Second moment of area (mm^4) [rigidity]
E = Young's modulus (MPa)
r = Radius of curvature (mm)

$\sigma = \frac{L}{A}$, $\varepsilon = \frac{e}{l}$

Proportional limit stress is the stress at the end of elastic section of the stress-strain diagram.

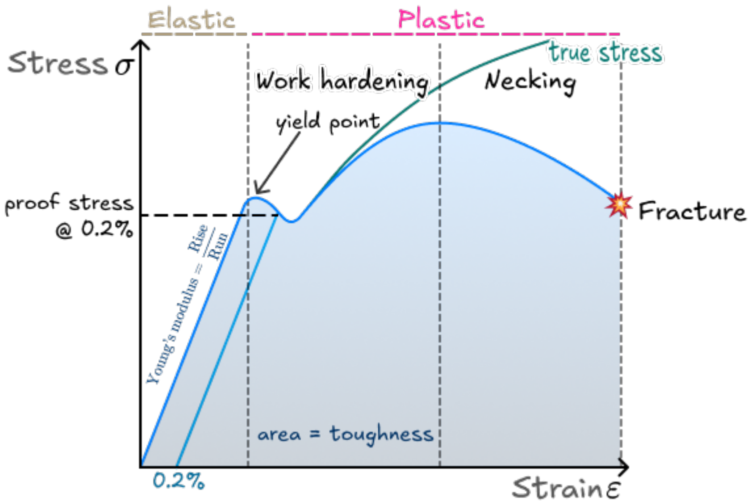
Maximum bending moment, determines the maximum bending stress in the beam:

$$\sigma = \frac{My}{I}$$

If **all** units are in mm the output is MPa, if **all** units are in m the output is Pa.

Yield stress (point) is where a marked increase in strain occurs without a remarkable increase in stress.

Proof stress is the stress necessary to produce a certain amount of strain, e.g., 0.1% proof stress leads to $0.001 \times$ original length.



Ultimate tensile stress is the maximum stress a material can withstand before it fails, top of the stress-strain curve.

Hooke's law is where the size of defamation is directly proportional to the deforming load (elastic region of graph).

Factor of Safety (FofS) allows for material to bend and flex by having a tolerance of safety. It measures the ratio of maximum safe stress to yield stress/UTS.

Ductile: $\text{FofS} = \frac{\text{Yield Stress}}{\text{Max Allowable Stress}}$

Brittle: $\text{FofS} = \frac{\text{UTS}}{\text{Max Allowable Stress}}$

Testing of materials for quality control:
Radiographic: uses high frequency waves to examine the internal detail of materials, looks for void and inconsistencies.
Ultrasonic: high frequency vibrations pass through the component, on finding a void they reflect early.
Tensile: stretching until failure.
Compression: pushing down on until failure.
Transverse: placing a beam into torsion (through 1 pair of forces opposed by a central force)

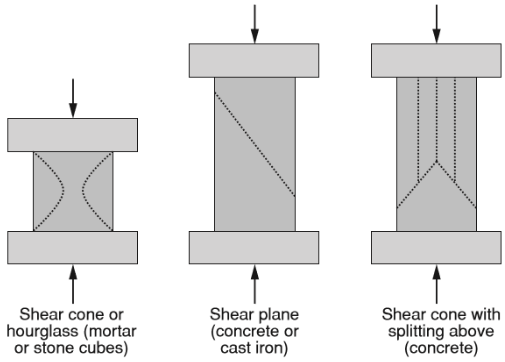


Figure 3.14 Compression failures of brittle materials

Composites can either be:
- Particulate composed of particles.
- Laminar composed of layers/sheets.
- Fibre composed of fibres.

Ceramics contain phases which are both metallic and non-metallic, have high hardness, brittleness, insulators and weather resistance.

Igneous rocks from volcanic materials forms basalt (used as a concrete aggregate or asphalt).
Granite is used for high-wearing surfaces and can be cut easily.
Sedimentary rocks are particles of weathered rock after been deposited in layers on lake beds and form under pressure, used as limestone for Portland cement or as sandstone.
Metamorphic rocks are sedimentary or igneous rocks subjected to extreme pressure and properties change.
Silicates such as asbestos, they are soft and easily split.

Cements are either hydraulic (set with water) or non-hydraulic (usually set with air), mixtures of materials of aggregates, sand particles and cement paste.
Additions to concrete allow us to modify the properties of concrete. Concrete can be made to lightweight by allowing it to aerate and bubbles to form in the matrix.

Steel rods can be placed in parts of concrete which are under high tension to provide reinforcement.
Concrete can either be made in-situ, where it is poured into the mould on site which is weather and labour dependent.
Otherwise, it can be made prefabricated which limits the size as it will have to be transported on to site.

When steel is cold worked it undergoes recovery, recrystallisation and grain growth.

Pre-tensioned concrete involves placing a steel beam already under tension then casting the concrete around it, after which the tension is released placing the concrete into compression increasing resistance towards load.
Post-tensioned concrete is where the steel is inserted into the concrete through pre worked tubes the tensioned, allowing for multiple slabs to be under compressive pressure.

Clays are a form of ceramics which come from broken down rocks, they are negative silicate structure with ions. Impurities in clay can increase desirable properties.

Plasticity: water is added to make it easier to form as it creates a film around the clay crystals.

Firing: a clay product is transformed into a rigid condition through drying, dehydration, oxidation and vitrification.

Bricks: are made from continual extrusion of clay, cutting then firing.

Glass: act as supercooled liquids, fusion of inorganic materials without crystallisation.
Is transparent, very brittle and low tensile strength.

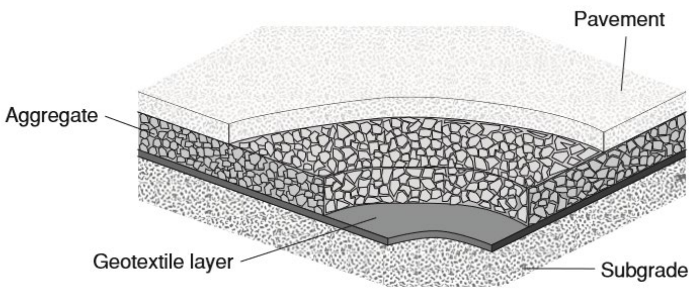
Glass fibre is 100 times as strong in tensile strength than compressive strength, due to a low surface area with no surface flaws.

Tempering/toughening: cooling the sides of molten glass with water to create a rigid skin in compression.
Safety glass: a sandwich of glass with a polymer in between which provides impact and cracking resistance.

Composites of timber:
Laminated beams: boards/planks of timber are strongly glued face-to-face, strong in one direction.
Plywood: thin slices of timber are layered at odd angles, allowing for strength in multiple directions.
Particle board: mass of woodchips is bound with resin into flat sheets.
Fibreboard: made from wood pulp pressed into sheets bound with resin, usually MDF.

Asphalt: is a waterproof, durable and spongy material. Formed from tar and aggregates.

Geotextiles: usually made from polymers to create tough, corrosion resistant materials.
Textiles which provide drainage, filtration, reinforcement and separation of soils in construction and civil applications.



Recycling can be used in a variety of materials: glass, bricks, timber and concrete. Usually from crushing and re-casting.

Corrosion is the deterioration of the material due to chemical interactions with environment:

- Chemical corrosion: from a dry environment, reacts with chemicals.
- Electrolytic corrosion: in a wet environment, from electric reactions.

Aluminium and stainless steel has a strong, oxidised layer which protects from corrosion.

Can protect from corrosion with ceramic coatings, impressed voltage (prevents electrons from being lost), metallic coatings: hot dipping, electroplating, cladding and sherardising (Zinc powder).

Water allows for a metal to exposed to oxygen and amplify corrosion.

2. Personal and Public Transport

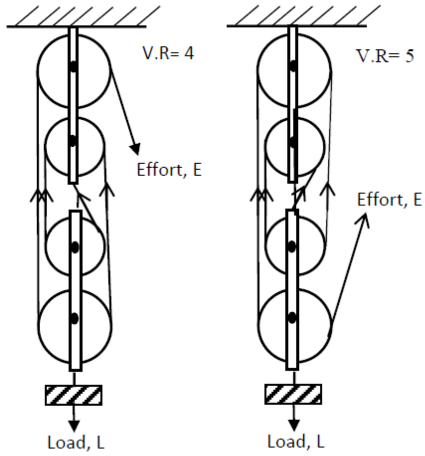
Personal transport is transport which individualised to few members.
Public transport is transport shared between many users, it is usually subsidised by the government, and they aren't likely to make a profit.

Bicycles is a form of human-powered personal transport, it evolved from simple two-wheeled contraptions to pedal powered bicycles.

Advantages:	Disadvantages:
- Low upkeep/cheap	- Discomfort
- Independence	- Lower safety
- Low environmental	- Cannot carry loads
- Flexible routes/better mobility	- Not fast/takes high effort

Personal transport is highly independent and allows for flexibility.
While public transport is more communal and is usually much more efficient than personal transport.

Can use moments to calculate the balance of levers, with *effort* being the force being put into a system and *load* being the work done because of the system.



Mechanical advantage: is the load out of a lever proportional to effort.
Mechanical advantage: $\mathrm{MA} = \frac{\text{load}}{\text{effort}} = \frac{L}{E}$,

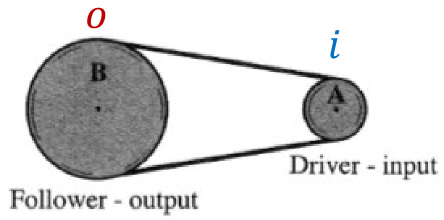
Velocity ratio: $VR = \frac{\text{velocity of effort}}{\text{velocity of load}} = \frac{\text{displacement of effort}}{\text{displacement of load}} = \frac{2\pi \times \overset{\text{effort arm}}{\widehat{r_E}}}{2\pi \times \overset{\text{load arm}}{\widehat{r_L}}}$

$\mathrm{VR} = \frac{d_E}{d_L}$

For 2nd order lever: $MA \,\&\, VR > 1$
For 3rd order lever: $MA \,\&\, VR < 1$

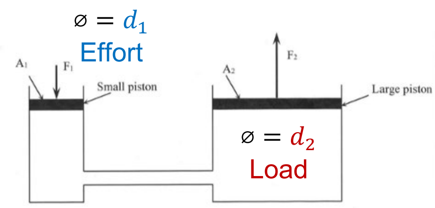
Efficiency (as a percentage): $\eta = \frac{MA}{VR} \times 100 = \frac{\text{output work}}{\text{input work}}$, a machine is almost never 100% efficient.
VR is ***never*** affected by efficiency.

Inclined plane: $VR = \frac{1}{\sin\theta}$
Block and tackle: $VR = \sum \text{ropes}_{\text{max}}$, determined by the number of ropes **supporting** the load.



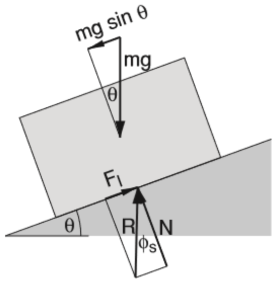
Belts and pulleys

Belts: $VR = \frac{v \text{ of input pulley}}{v \text{ of output pulley}} = \frac{r_o}{r_i} = \frac{d_o}{d_i} = \frac{c_o}{c_i}$
Revolutions: $1\,rev = \frac{\text{\# of my gear teeth}}{\text{\# of other gear teeth}}$
Gears: $VR = \frac{\text{\# of teeth of load}}{\text{\# of teeth of effort}} = \frac{\emptyset \text{ of driven gear}}{\emptyset \text{ of driving gear}} = \frac{\text{RPM of driving gear}}{\text{RPM of driven gear}}$



For an 100% efficient hydraulic system:
$MA = \frac{d_2^2}{d_1^2}$, $VR = \frac{d_2^2}{d_1^2}$, which d being diameter, d_2 is diameter of load piston.

Always work from effort to load for a compound lever.
Can multiply velocity ratios in a compound system.
Frictional force is a reaction force exerted between contacting surfaces. Limiting friction, impedes movement at low forces.



$$F_R = \mu mg\cos\theta$$

Angle of static friction (ϕ_S) is the angle between the normal forces and the total resistance vector, it is equal to the angle of inclination.
Angle of repose is angle of static friction upon which the object will start to slide.

Can utilise the three-force rule to calculate the forces upon an object.

Work is the change in energy and represented in Joules.

$$W = Fs = Fs\cos\phi$$

Can be the area under the force displacement graph.

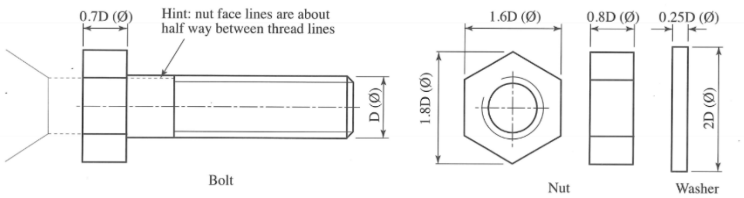
Energy is the capacity to do work, also represented in Joules.
Kinetic energy: $KE = \frac{1}{2}mv^2$, potential energy: $PE = mgh$, strain energy: $SE = \frac{1}{2}Fe$

Conservation of mechanical energy, when a body is in motion, the total energy is constant.

$$KE_1 + PE_1 = KE_2 + PE_2$$

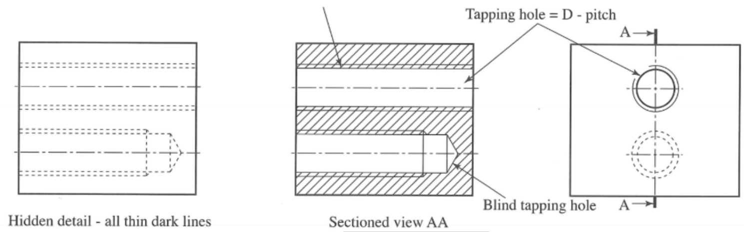
Power in a circuit is measured in watts (W): $P = \frac{W}{t} = \frac{Fs}{t} = Fv$

Drawing standards for bolts:



Don't section anything with a thread, webs and don't show hidden detail within a section.

Australian drawing standards:



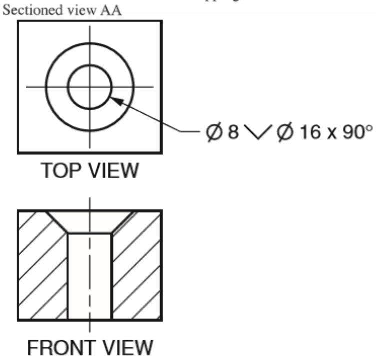
Holes:

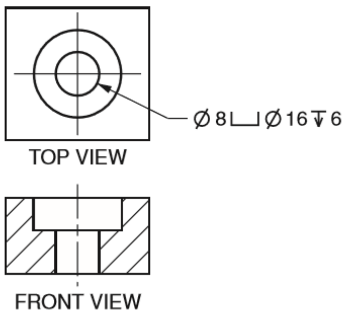
Square hole of side length h is represented by:
❑h

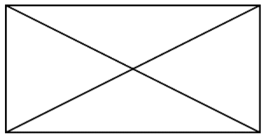
Round hole of diameter h is represented by:
$\varnothing h$

Depth of hole of depth w is represented by: ↧ w

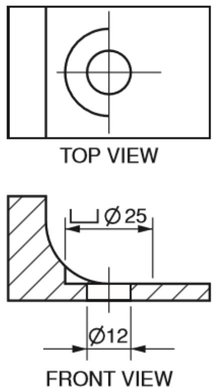
Counter sink is the process of drilling extra for a fastener to sit flat, a hole of diameter h and internal angle θ, is represented by $\vee \varnothing\, h \times \theta$





Counterboring creates an extra square hole for a component to sit  flush with the surface, a whole of diameter h and depth w is represented by ⌴ ⌀ h ↧ w

Spot face creates a flat surface on a rough or curved area to allow a component to sit flush with the surface, an area of diameter of h is represented by ⌴ ⌀ h

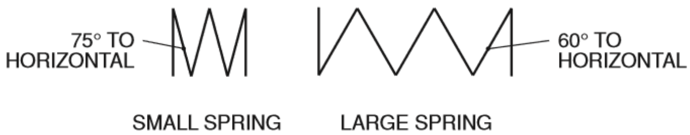


Spherical radius creates a part which is defined by a spherical shape, usually defines endcaps. Represented by spherical radius SR or spherical diameter S⌀

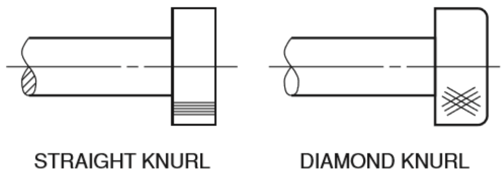
Chamfer allows for a corner to the flatten, a chamber of width h and angle of declination of θ is represented by $h \times \theta$

An acorn nut has a bulbous tip to create a safe end to the nut.

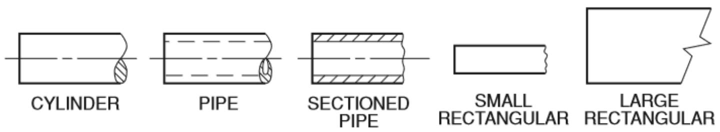
Compression spring is represented by a zigzag and the angle to the horizontal



Knurl allow a surface to be more grippy and less smooth, either straight knurl (represented by straight lines) or diamond knurl (represented by cross-hatched lines)
Flat surface on cylindrical component or a bearing is represented by when viewed side on.



Breaks are either shown by a figure eight pattern, a squiggly line or a z.



Hardness tests are non-destructive, meaning they can be used in industry to verify properties during the production process.

Brinell hardness test used a hardened steel or carbide ball where the diameter of the indentation is measured it is only used on soft materials such as cast iron or woods.
While the Vickers hardness test uses a pyramid shaped diamond where the surface area of the indentation is measured, any materials can be tested.

Rockwell either a cone or hardened ball is used, and the depth is measured after the minor indentation is set (~100kg), any material can be tested.

Impact tests measure the toughness of the bar, and a notch controls the fracture position. Izod test is like a cantilevered bar and the Charpy test uses three-point bending.

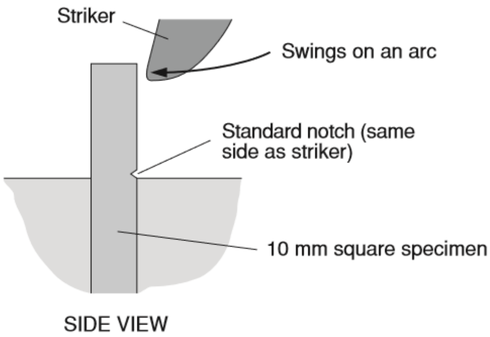


Figure 3.3 Izod notched-bar impact test

Casting allows for a material to be shaped through the molten material being formed into a solid shape.

Casting Method	Advantages	Disadvantages
Sand casting (sand mould)	Intricate shapes can be formed, simple equipment	New pattern required for every mould, labour intensive
Sheel casting (sand mould)	Metal patterns which allows for the mass manufacture of components	High initial cost of metal patterns
Die casting (steel mould)	Improved dimensional accuracy, excellent surface finish, high output rates	Confined mainly to zinc and aluminium alloys, costly to produce for large runs
Investment casting (plaster/sand mould)	Ability to accurately produce intricate shapes not possible with machining	Limited to small parts, labour intensive

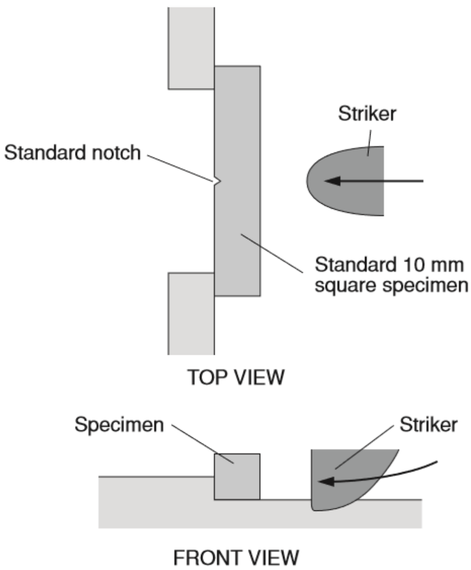
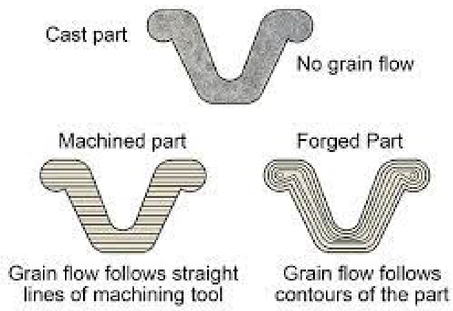


Figure 3.4 Charpy notched-bar impact test

Around the mould, hard and fine grains are created with a large amount of carbon called the *chill crystals*. While columnar grains form as the molten metal cools from the outside in. Then equiaxed grains form into the centre.
Cast irons are an iron alloy with large amounts of graphite (except for white cast iron).

Forging is where metal is plastically deformed into a new shaped through hammering or the like. It creates grain flow, as a new optimum grain structure is formed.



Hot forging allows for distorted grains to reform as equiaxed grains which removes internal stress. is easier to work when heated.

While cold forging is below recrystallisation temperature, so the grains maintain their shape and it creates some work hardening. Has higher surface finish and dimensional control.

Drawing is where a die is *drawn* over a bar shaping it into a wire.
Rolling is where rollers distort the shape through pressure. Cold rolling creates stronger products (body panels) while hot rolling creates more even grain structure.
Upsetting is a type of forging process using a die and force.
Extrusion is pressing metal through a die; it does lead to grain flow.

Sintering/powder metallurgy is where metal particles are pressed and heated together into a final object. Doesn't produce any grain structure so has inferior strength properties but higher dimensional accuracy.

Heat Treatment		
Heating above red hot		
Cooling in **water** – quenching	Cooling in **air** – normalising	Cooling in **oven** – annealing
← More brittle/hard, more malleable/durable →		

Cooling too rapidly can create martensite which is a brittle and hard material in a BCT (body centred tetrahedron) structure.

When it is above red hot/recrystallization temperature the material is just austenite (γ) and it cools into ferrite (α), cementite and pearlite.

Tempering is heating below red hot relive internal stresses.

Normalising creates a more homogeneous and equiaxed grain structure, it is stronger than annealing due to the finer grains. It also improves the machinability of component as they don't tear or split.

Hardening (aka quenching) leads to the formation of martensite (BCT), as the product cools too quickly for the carbon to reform. This leads to needle-like structures which have high hardness and brittleness.

Tempering is used on hardened steel to alleviate internal stress by heating below red hot and being cooled.

Surface hardening allows for a hard and wear resistant skin with a tough centre:
Carburising, the metal is soaked at red hot in a high carbon atmosphere, increase carbon content of skin (hardness)
Nitriding, high nitrogen atmosphere leading to martensite skin.
Selective hardening, heating and cooling so rapidly the core doesn't have time to change properties.

Copper has high conductivity, malleability and able to be cold worked.
Brass: copper-zinc, bronze: copper-tin

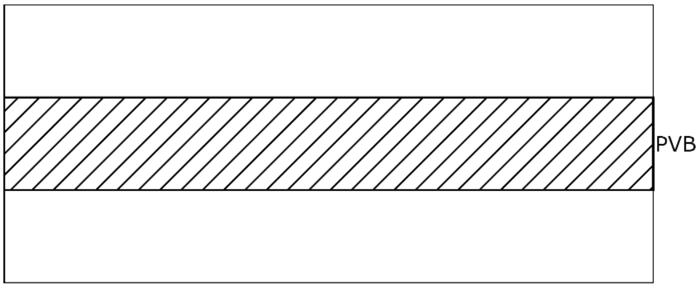
Aluminium alloys, alloying is used to increase tensile strength and machinability. Aluminium is very light and strong, corrosion resistant due to strong oxide coating. Alloys with copper, magnesium, silicon…

Titanium has a very high strength and great corrosion resistance.

Precipitation hardening: allowing for alien atoms to move in the structure increasing hardness and strength.

Laminated glass is two panes of glass glued to a polymer sheet, this makes absorb impact energy and minimises shattering.

Tempered/toughened glass is a pane of glass which has been heated and cooled rapidly, this creates a tough and hard skin which is under compression (as the soft core wants to cool as well). This means it has high compressive strength and can withstand higher bending loads. Though it shatters totally into pebbles.



Laminated glass


Tempered glass

To support glass in compression, arch or curved shapes can make us of this property.

Polymers consist of long repeating molecular chains.
Thermosoftening polymers reform under heat while thermosetting do not.

Thermosoftening polymers are long chains of molecules in an amorphous pattern.
They have a low softening temperature (~100°C).
The more amorphous (random) the structure of the polymer is, the less transparent (as crystalline polymers have much tighter structure – blocking light).

Some polymers have barbs with increase strength as they prevent sliding of the polymer chains.

Elastomers are thermosoftening polymers which have secondary bonds (cross-linking) which increases elasticity, a rubber like material.

Thermosoftening polymers:

Polymer:	**Properties**	**Applications:**
Polyethylene	Low melting temperature Tough Flexible	Brake cables
Polycarbonate	High impact strength Transparent	‘glass’, bike helmets
Polypropylene	Very tough Insulator Rigid	Seat belts, carpets, battery casings
PVC	Insulator Hard and rigid	Electrical wiring covers, handle grips
Polyamide	Weather resistance High strength Wear resistant	Gears, brushes
Acrylic	Transparent Weather resistance	Car weather shields, light lenses
ABS	Fatigue resistance Tough Hard Impact strength	Body trim

Elastomers:

Polymer:	**Properties**	**Applications:**
Vulcanised rubber	Low cost Flexible Tough	Car tyres, engine mounts

Neoprene	Heat resistance Tough	Radiator hoses, brake fluid lines
Butyl rubber	Good at holding fluids	Bicycle tyres, inner tubes

Thermosetting:

Polymer:	**Properties**	**Applications:**
Silicones	Inert Insulator	Insulators, seals
Polyurethane foam	Insulators Inert Trap air	Upholstery foam, noise insulators

Voltage is the difference in electrical potential energy, it drives a current to flow in a circuit.
Current is the flow of electrons through a conductor.
Conductors have free electrons, meaning electricity flows easily through it, e.g., silver, copper, gold, aluminium, iron.
Insulators have few free electrons, meaning it is tough to get an electrical flow, e.g., polymers, rubber, ceramics.

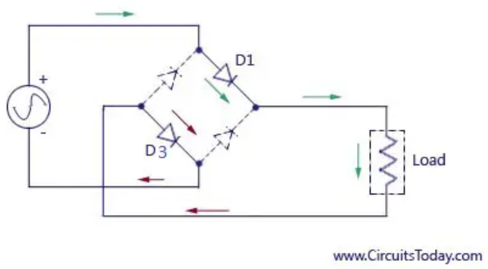
In a series circuit: $\sum R = R_1 + R_2 + \cdots$
In a parallel circuit: $\frac{1}{\sum R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

Power is usually generated from kinetic energy being converted into electricity through the rotation of a turbine, this is usually from steam.
Power can also be generated from photo-voltaic (solar) panels.

The higher the cross-sectional area of the conductor, the greater the resistance due to increased surface area. Meaning that high voltage transmission is usually multiple high voltage lines.

A fuse, ground wire and RCD (residual current device) all increase electrical safety by providing a safe path for current flow.

AC power can be converted into DC power using a rectifier.
Rectifiers use diodes (which only allow current flow in one direction).
They can also use capacitors to smooth out troughs in the waveform of the DC output.



Electrical power is now considered an essential resource as it powers heating, motors, lighting and radiation devices (microwaves and TVs).

Transformers use two copper coils connect through iron with flux linkage to *transform* one voltage into another. Can either act as a step-up transformer (increase voltage) or step-down transformer (decrease voltage).

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

Type of Motor	Stator current	Rotor current	Comments	Uses
DC motor	DC supply or permanent magnet	DC supplied	Can run at any speed (changed through voltage input) High starting torque	Trains Rolling mills
Brushless DC motor	DC supply	Induced	Decreased maintenance Higher power and torque	Computer peripherals Model vehicles
Universal motor	DC/AC supply	DC/AC supply	Can run at any speed (changed through voltage input) High starting torque	Sewing machines Drills
Induction motor	AC supply	Induced	Decreased maintenance Higher power and torque (3 phase)	Appliances Heavy machinery

Control system involves detecting and acting inputs to create a certain output.
PWM is a type of system to vary the amount of power outputted by a system by rapidly switching the output on and off.

- PWM is more efficient than a variable resistor as there is no energy lost as heat

Control system in cars:
ABS braking: the brakes are pulsed rapidly to allow for the car to maintain traction control and to increase efficiency of braking.
Regenerative braking: the motor are run backwards to create a current by converting the mechanical motion of the wheel to electric energy.
Airbags: the car senses a crash and deploys airbags to protect the occupant's head and neck.
Adaptive cruise control: senses the distance to the car in front and keeps a set distance reducing the likelihood of rear end collisions.

PWM is used in cars to drive fuel pump motors to regulate the speed.

3. Aeronautical Engineering

Aeronautical engineers usually arise from a university degree.
Morals to make safe devices.
Work in military or civil.

WH&S (work, health, and safety): dealing with hazards:

Most effective →	
	Eliminate the hazard
	Change equipment or materials
	Change work practise
	Use PPE

WH&S issues in aero:

- Fibrous dusts
- Noise

Engineers have to engage with community and effectively work with others to get the job done.

Aviation is heavily regulated to ensure safety, this means that engineers have to ensure compliance and make sure they are able to get an airworthiness certificate. Either from CASA (Civil Aviation Safety Authority – Australia) and ICAO.

Engineer work as managers and need good human relation skills, make sure quality management is upheld.

Engineers can work in a variety of roles within the aviation sector and have deal with a range of health and safety issues arising from their designs, as poor design can lead to aviation accidents.

Three main types of planes:

- Fixed wing: conventional planes
- Rotary wing: helicopters
- Ultra-light: certain gliders

Originally flight was achieved using airships and balloons made buoyant either by hydrogen or helium gas or hot air.

The Wright brother’s airplane was a biplane, biplanes increase lifting force (as there are two wings) and reduce bending moments due to the rigid structure.

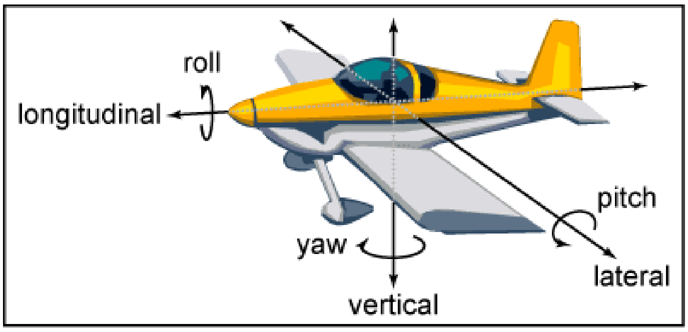
Then aluminium planes with rivetted skins were used to provide much lighter and more complex shapes for the planes.

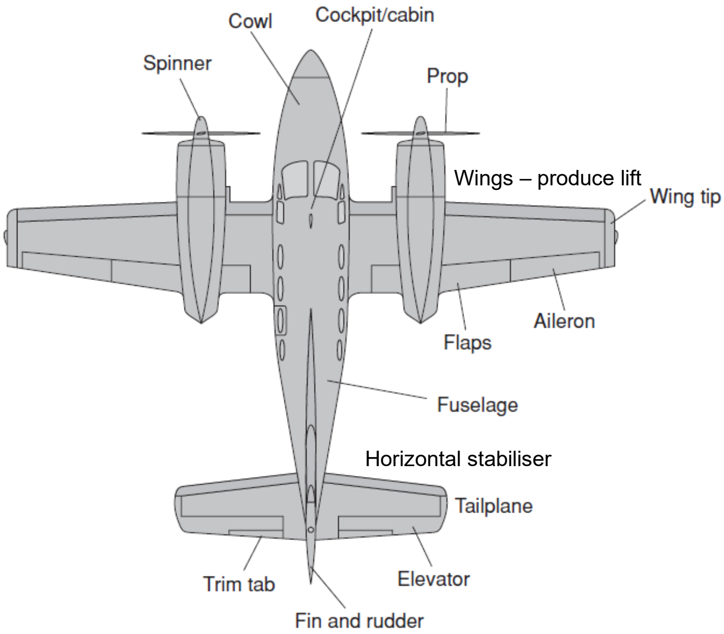
The Australian Lawerence Hargraves used box kites and achieved some aspects of flight which went on to directly influence the Wright Brothers flying endeavours. Aircraft have been key to Australia due to our vast landmass and long distances that need to be travelled to deliver people and supplies.

There are four forces acting on an aircraft:

- Lift: affected by air density, speed, shape of wing and angle of attack.
- Weight: force downwards by gravity (mg).
- Thrust: provides forward motion.
- Drag: resists motion in the direction of travel.

In stable and level flight: $T = D$ and $L = W$





Can change level of flight by angling up or down: pitch up increases lift and increases altitude while pitch down does the opposite.

A helicopter balances thrust and weight and angles its blades to change thrust characteristics to move the craft.

Flight control	Common location	Purpose
Ailerons	Wing	Controls roll
Elevators	Horizontal stabiliser	Controls pitch
Rudder	Fin/vertical stabiliser	Controls yaw
Flaps *(lift augmentation)*	Wing	Increases lift for slow speeds
Spoiler *(lift dumping)*	Wing	Decreases lift and increases drag

Wing chamber is the profile of the wing, through using an uneven profile. There is longer distance for the air to travel on top of the wing, decreasing the air pressure and increasing its speed which results in an upwards on the wing (lift).

Engines create thrust and increase speed, creating lift.

Propellers largely increase the velocity of the air passing through them while turbofans increase the mass of the air passing through them.
Rely on momentum to operate: $\Delta\text{momentum} = F \times \Delta t$

Drag is either:
- Parasitic: due to shape and ease of airflow.
- Lift induced drag.

Bernoulli found that total pressure in a fluid stayed constant.
$\text{total pressure} = \text{static pressure} + \text{dynamic pressure}$, with static being due to the weight of the fluid above and dynamic due to motion.

$$\begin{aligned} P_{total} &= P_{static} + P_{dynamic} \\ &= \rho g h + \frac{1}{2}\rho v^2 \end{aligned}$$

ρ, is density. h is height of air above.

This constancy of air pressure creates the suction effect of the air above the wing, as the P_{static} decreases with increasing $P_{dynamic}$.
As momentum is conserved, as A decreases, v must increase.

Venturi effect is where a reduction in fluid pressure as the fluid speeds up. It decreases pressure when higher velocity as $\frac{1}{2}\rho v^2$ increases.

Wheel brakes within an aircraft is a series of disc brakes all connected to the main axle, as a plane needs more braking pressure.

(Hydro)static pressure is the pressure exerted on a point due to the weight of all the particles above that point pressing down. Air pressure is a type of static pressure, calculated with:

$$P = P_0 + \rho g h$$

Hydrostatic pressure is not affected by the area or shape of an object as it acts equally at a certain altitude (given by $\rho g h$).

Dynamic pressure is the pressure from a moving fluid,
$P_d = \frac{1}{2}\rho v^2$, with ρ being density and v being velocity.

Aeroplane instruments fall into three categories:

- **Pressure** instruments, use variations in atmospheric pressure.
    - Altimeter, *height*
    - Vertical speed indicator
    - Air speed indicator
- **Gyroscopic** indicator, use properties of gyroscopes.
    - Angle to a reference plane:
        - Attitude, *pitch*
        - Artificial horizon, *roll*
- **Compass** systems, use earth's magnetic field.

Altimeter measures the height of the aircraft above a pre-selected surface level.

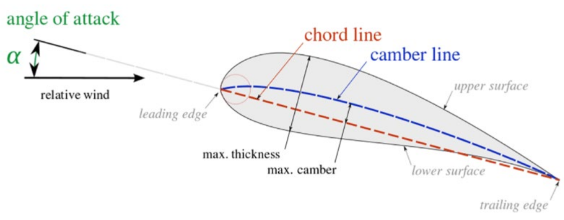
Pitot tube measures static pressure and total pressure, by measuring the air around the airframe and the airflow into the airframe. Dynamic pressure (and speed) can be determined with $P_d = P_t - P_s$

Static port measures the static pressures around the airframe, which determines altitude.

Lift to drag ratio measures the efficiency of the wing is aerodynamically.

Lift-induced drag is due to the perpendicular nature of lift (to the cord line) as some lift is evident as drag.

Higher camber increases lift, as the pressure difference between the top and bottom surface is increased. But it also increases frontal area, which rises drag.



A stall is due to a separation of the air on the upper surface which measures that weight is greater than lift.

Vortices are due to high pressure from the lower wing trying to get above the wing, which increases drag as it disrupts laminar flow.

Parasitic flow, is constant and is directly proportional to speed as it is only determinate on the area of the airframe.
Air becomes turbulent as it passes over an object and unsticks from the surface, leading to a large loss in lift and increase in drag.

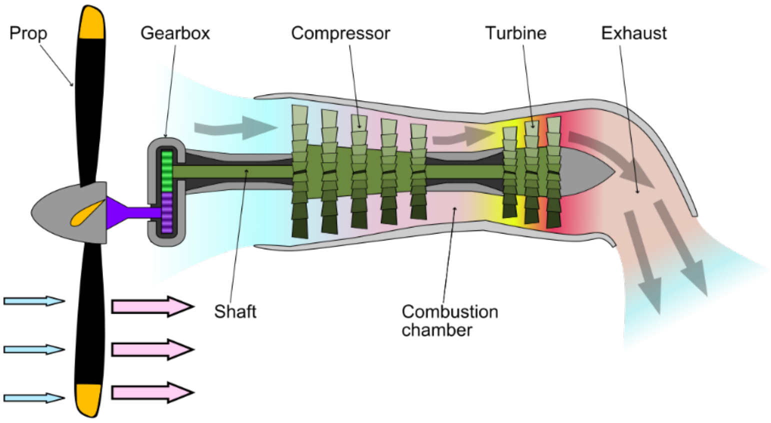
A wing experiences a range of bending stresses throughout flight, the fuselage usually experiences negative bending. While the wings experiences negative bending when on the ground and positive bending when in flight.

Propulsion systems in aircraft create a high-pressure area behind the engine and a low pressure area before the engines, this moves the engines go forwards. It generates this pressure differential through thrust, which is from fan pushing air backwards and adding momentum in exhaust gases.

Types of aircraft engines:

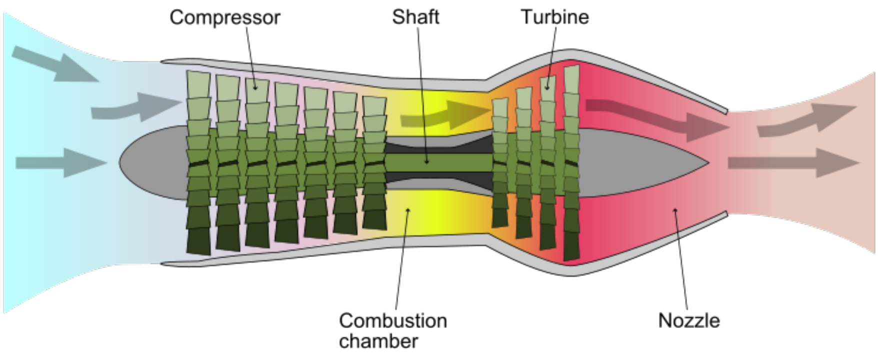
Turboprop: jet engine drives a propeller.

Can get greater power than a piston engine. Good fuel efficiency.	A propeller needs that slower air speed than a turbojet or a turbofan.



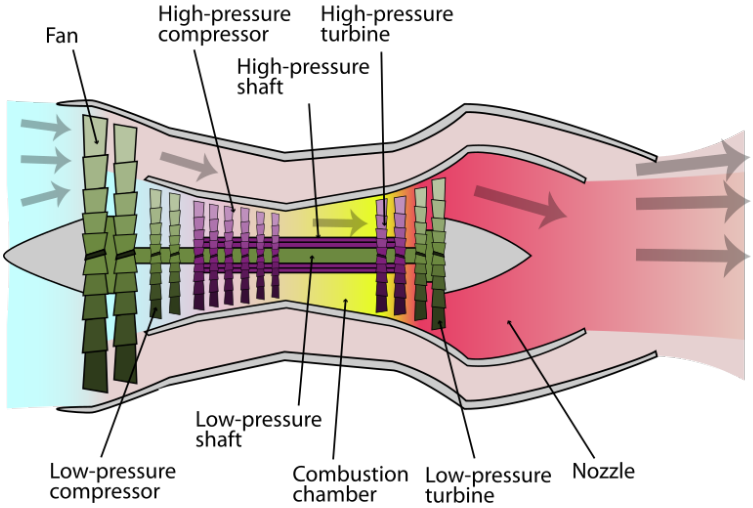
Turbojet: all air enters the engine through the core.

High power to weight ratio. Suitable for high speed and manoeuvrability aircraft.	High noise. Poor fuel efficiency.



Turbofan: large portion of air going through the engine bypasses the core .

Good fuel efficiency. High subsonic speeds. Lower noise compared to turbojet.	Large diameter intake. Fan blades subjected to high loads throughout rotation.



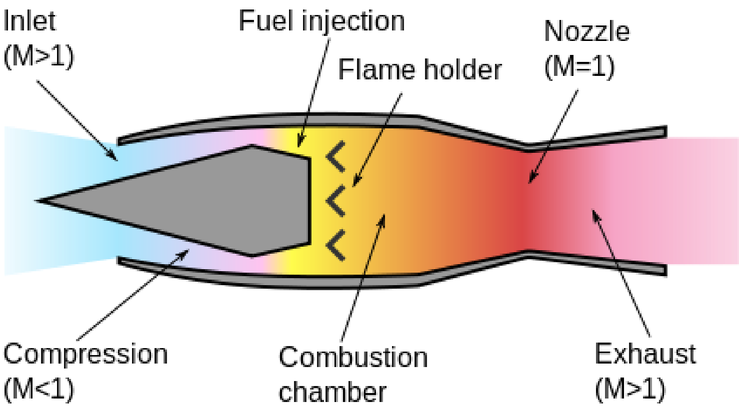
A helicopter uses a rotor (rotating wing) to generate lift and thrust, this wing can be pivoted with a swash plate to pitch, yaw and roll the aircraft. This changes the angle of attack of the blades when they are leading and when they are lagging.

Rockets create enough thrust to propel their craft against gravity and above escape velocity.

Aircraft have had large benefits across Australia as they have allowed far-flung places to be connected and helped the transport of goods and people.

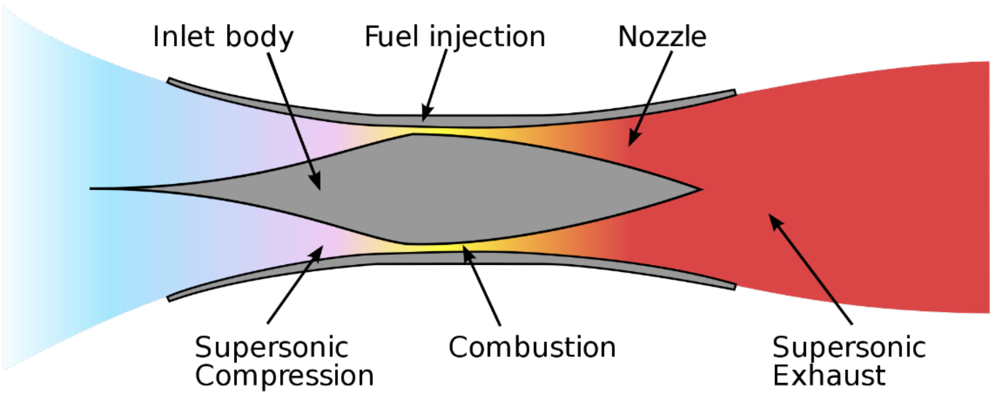
Ramjet: designed for high Mach number operation, doesn't need a compression stage, as the air is already heated enough due to high speed.

Works at high speeds ($3 < m < 6$) Small footprint.	High noise. Poor fuel efficiency.



Scramjet: designed for high Mach number operation.

Works at high speeds ($6 < m < 12$) No moving parts.	High noise. Poor fuel efficiency.



In an aircraft, a fly by wire systems operates by sending the flight control inputs as electrical signals to the flight controls which are actuated by hydraulics.

Advantages:	Disadvantages:
- Reduces weight. - Increases flight safety: inhibits pilot's risky manoeuvres.	- Pilot must understand the automation. - System complexity to construct. - More expensive.

Cables: use mechanical linkages between the flight controls and the flight surfaces. Cheaper and has force feedback compared to fly-by-wire but requires large amount of maintenance and heavier.

Autopilot: uses autopilot thrust control system and flight directors to manoeuvre aircraft based on large amount of data.

Advantages:	Disadvantages:
- Reduces flight workload. - Increases safety and efficiency. - Accurate flight routing.	- Pilot must understand how the autopilot operates: limitations and strengths. - System complexity to construct. - More expensive.

Black boxes were an Australian invention to record flight data and the audio in the cockpit to be saved for investigations into incidents and accidents. Is a bright orange box designed to survive large shocks and water.

Aircraft were originally largely constructed from aluminium and steel (1960s), but now they are being made largely of composites with titanium and aluminium (due to better strength characteristics, a lower weight).

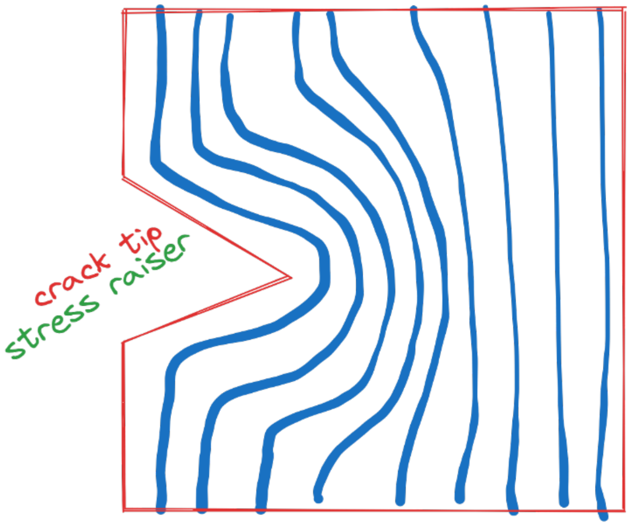
Testing to identify material properties of:

- Tensile
- Compressive
- Shear
- Environmental (corrosion)
- Toughness (notch test)
- Burn test
- Fatigue
- Hardness

Testing of components to test design (full-scale or partial-scale):

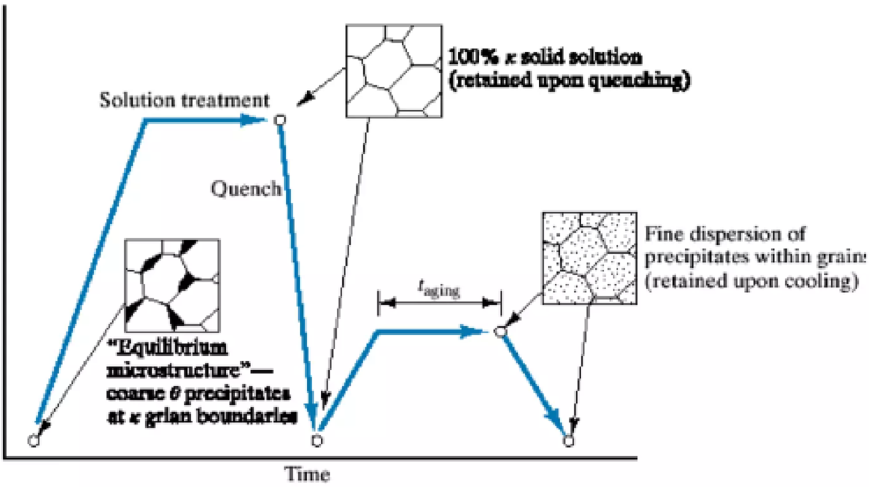
- Aerodynamic performance
- Ultimate load testing
- Fatigue testing

Cracks are due to a material that is prone to cracks, undergoing permanent defamation due to cyclical tensile stresses.



Non-destructive tests:

Name	**Description**	**Use**
Visual inspection	Magnifying glass used to identify flaws.	General surface defects.
Magnetic particle inspection.	Used on ferritic materials to show cracks, as particles collect.	Subsurface defects in complex magnetic shapes.
X-ray	Used to image internal deformities.	Subsurface cracks or voids in any material. Not used for forgings.
Dye penetration	Dye is spread over a surface, allowed to go into cracks and scrapped off.	Small surface defects in a material.
Ultrasonic flaw detection	Sends sounds waves, which reflect differently off voids and flaws, only needs one side.	Us sul



Aluminium is used in many aircraft due to its lightweight and good strength properties; however pure aluminium (1000 series aluminium) is extremely ductile and malleable.

Through the solution heat treatment process and participation hardening, the alloys of aluminium are dispersed throughout the grain structure which increases strength due to the inclusions reducing dislocations, yet it also makes it softer.

Common alloying elements with aluminium include:

Name	Benefits
Copper (2000 series alloy)	Maintains ductility and malleability, increases shock resistance – prevents fatigue cracks, and increases hardness.
Manganese	Increases wear and corrosion resistance and increases strength.
Silicon, non-metal	Harder but not brittle, makes the alloy easier to cast.
Magnesium	Lighter, increases tensile strength and corrosion resistance, hardness and weldability.
Zinc (7000 series alloy)	Stiffer and more brittle, but with heat treatment it drastically increases strength.

Zinc-aluminium alloys are used on the upper surface on the wing, as they are under compressive stress (and only tensile strength leads to fatigue).

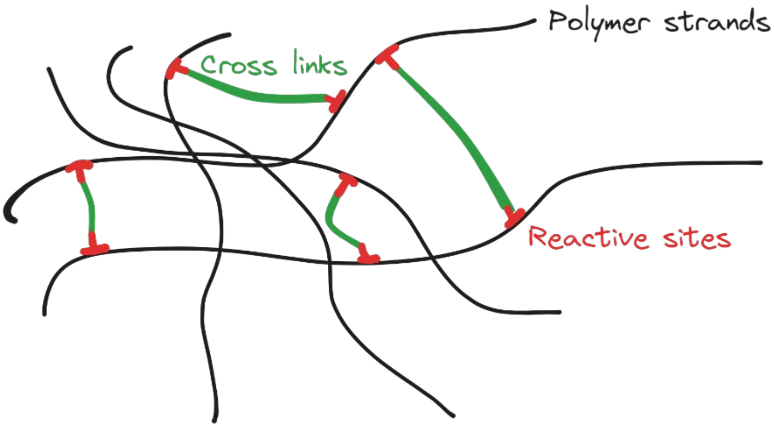
Precipitation hardening increases hardness and ductility within aluminium, can happen artificially through the precipitation hardening process or naturally occur in room temperature environments.

Metal	**Benefits**	**Uses**
Titanium	High tensile strength and less dese than steel.	Hot air exhaust.
Stainless steel	High strength, corrosion resistance	Structural ribs, skins and fasteners
Chrome-plated steel	Highly resistant to shock and corrosion	Engine mounts and shock struts
Magnesium	Castable, high temperature resistance	Landing wheels, turbine intakes and frames

Thermosetting polymers have a high amount of cross-linking meaning once they are set (and undergone their chemical reaction) they stay in their formation permanently.

These polymers are typically: stiff, strong and stable at even high temperatures.

Examples include:
- Epoxy resins (e.g., carbon fibre and Kevlar)
- Polyester resins
- Phenolics (Bakelite)
- Vulcanised rubber
- Urea formaldehyde (e.g., glue)



Composites are materials are high strength fibres suspended in a continuous material called a matrix.

Common organic fibres used within aircraft composites:

Glass is low cost, light weight, and high strength: used mostly in interiors and trailing edges.
Kevlar high toughness, tensile strength, and stiffness with low density, has poor compressive strength so not really used in commercial aircraft. Used in military aircraft as armour plating.
Carbon/Graphite high strength and stiffness, good fatigue strength, used in ribs and skins due to high strength. It doesn't corrode but is hard to repair and inspect.

Corrosion most affects anodic materials (magnesium/Alclad), it involves the material forms an oxide compound which has lower mechanical properties.

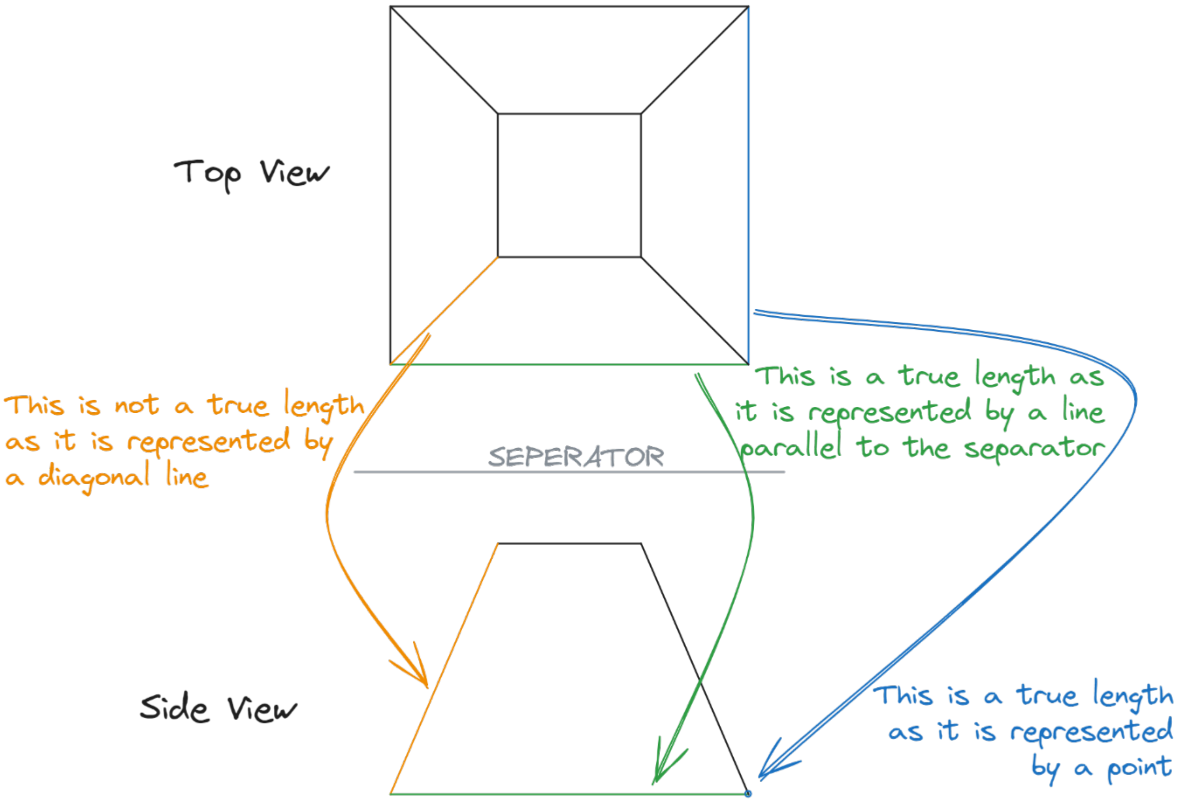
Types of corrosion:
- Pitting corrosion: where unprotected surfaces chemically interact with the environment which causes small pits/holes to form in the material decreasing ductility and strength.
- Uniform etch: general corrosion across the surface of the material.
- Fretting corrosion: due to vibration acting on the joining of two materials, causing rapid corrosion.
- Intergranular corrosion: acts at grain boundaries and causes internal cracks.

- Crevice corrosion: acts at gaps between two materials if poorly sealed, as capillary action traps water in the gap.
- Stress corrosion: experiencing stresses can cause some metals to develop internal corrosion.
- Exfoliation: intergranular corrosion which causes the material to flake off due to material swelling.
- Galvanic corrosion: dissimilar materials in contact with one another, lead to the exchange of electrons.

Corrosion occurs when the material is susceptible to corrosion, environment is hostile, and electrolytes are present (moisture/ions).

Types of protection from corrosion:
- Chemical conversion for magnesium
- Cadmium or chromium for steels
- Adonisation and primer for aluminium
- To prevent galvanic corrosion, stop dissimilar from contacting one another and use sacrificial coatings.

Developments are drawings where you create a net from a 3D object.
- Every line must be true length
- To identify if something is true length, it must be represented as a parallel line to the separating lines to the drawings or a point in the other view.



CAD allows for:
- Communication: quick distribution
- Storage: easily stored, copied and backed up
- Analysis of forces: integration stress and fluid analysis
- Accuracy: to scale and adjustable, iterate on design
- Speed: easy to make changes and correct errors

The purpose of an engineering report is to:
- Outline a particular area

- Analyse data
- Draw conclusions
- Acknowledge history

Structure of a report:

- Title
- Abstract: brief summary
- Introduction: purpose and subject
- Profession: ideas of scope and training needed for these sorts of roles
- Project/innovation
- Issues (health, societal and safety)
- Conclusion
- Bibliography
- Appendices: equations, drawings, diagrams or photos.

4. Telecommunications

Telecommunication engineers are responsible for managing and designing digital communication networks.

Telecommunications service a basic human need for communication to share knowledge and experience. Electricity has particularly enhanced this endeavour, as you can modulate the current sent.

Early on, fires or semaphores were used to transmit the signals. Then electromagnets were used to modulate an electrical signal to send codes down wires. Later the telephone was developed which could transmit voice, then radio was developed and TV. Now computer networks using fibre optics or radio signals transmit data.

Processes involved:

1. Encoding of data
2. Transmission of data
3. Medium for data
4. Decoders for data
5. Display for data

Types of displays, which display information to a user:

CRT	LCD	LED	OLED
Use analogue signals to display an image. Utilise a cathode ray to excite a screen.	Utilise a CCFL light to act as backlight where light is passed through a colour filter.	LED backlight more efficient than CCFL, digital signal which allows for more resolution.	Organic LED, individual diodes emit the light and has good viewing angles.
They are bulky, fragile and have low resolution.	White backlight leads to greyish blacks, use a higher amount of energy.	Poor image if viewed from angle.	Higher costs due to technological complexity.

Voltage has to be tested in parallel and current in series.

A cathode ray oscilloscope (CRO) uses the bending of cathode rays with the interaction of voltage to determine frequency and amplitude of voltage.

Megger testing involves measures the amount of moisture, current leakage and faults in an insulator. Resistance testing is achieved through running a small voltage through a material and measuring the current (and therefore the resistance). Usually, can be done with a multimeter.

Materials used in telecommunications:
Pure copper:
Usually electrolytic tough pitch (ETP) copper, 99.90% copper due to excellent electrical and thermal conductivity.
While oxygen free high conductivity copper (OFHC) can also be used, with a 99.99% copper content.

Copper Beryllium Alloy: Beryllium is added to increase the strength to weight ratio of the copper and stiffness of the material, which significantly increases the strength of the copper and can be hardened through the participation process.

Copper Cadmium Alloy: this increases wear resistance, strength especially used for overhead wires. It also has an equiaxed grain structure.

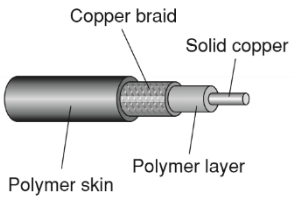
Copper zinc (brasses) alloys: used in weapon casings or marine propellers.

Copper-tin (bronzes) alloys: used for sheets, rods, wires or marine castings.

These alloys reduce the conductivity of the copper while increasing mechanical properties.

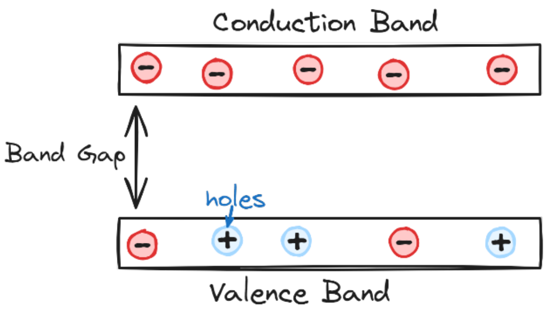
Copper-tin-phosphorus alloys (phosphor bronzes) they improve tensile strength, corrosion resistance and reduce coefficient of friction.

Copper-aluminium alloys (aluminium bronzes): high strength and good resistance to corrosion.



Coaxial cable:
The polymer layers provide electrical insulation and rigidity.
The copper braid shields the wire from EM interference.
The copper wire allows for the transmission of low voltage signals.

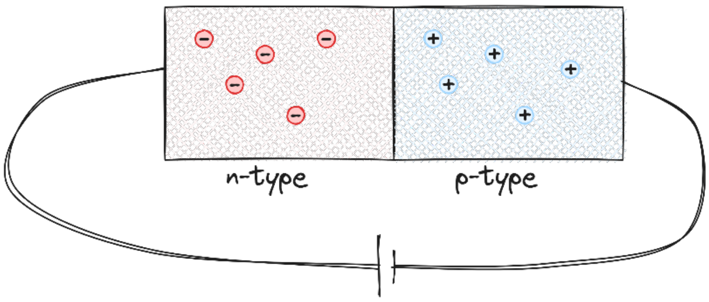
Aluminium is used for overhead wires as it is inexpensive and lighter.
Gold is very expensive but has good wear resistance and conductivity.



Semiconductors are materials that exhibit both conductor and insulator-like properties.

The band gap in a semiconductor allows for these properties, when (electrical/thermal) energy is provided, the electrons are able to jump the gap.

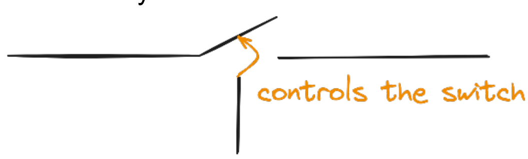
To improve electrical conductivity, alien atoms can be added into the structure called *doping*.



Donor materials are added (to increase the number of electrons), usually elements with 5 valence electrons, i.e., potassium.

Acceptor materials are also added (to increase the number of 'holes' – the places the electrons can flow into), usually elements with 3 valence electrons i.e., boron.

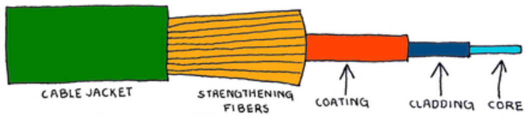
Thermistors: change conductivity rates with temperature.
Pressure transducers: an input (e.g., strain, force) leads to different conductivity.
Rectifiers: used to convert AC to DC.
Transistors: used for **amplification** and **switching**.



Diodes: allow electric flow in one direction only, used for AC→DC rectification.
Zener diodes: act as a diode to a certain voltage, beyond this voltage current can flow both directions used for voltage regulation.

Light Emitting Diode (LED): emits light when current is passed through it.
Integrated circuits (ICs): contain numerous electric components to perform an operation.

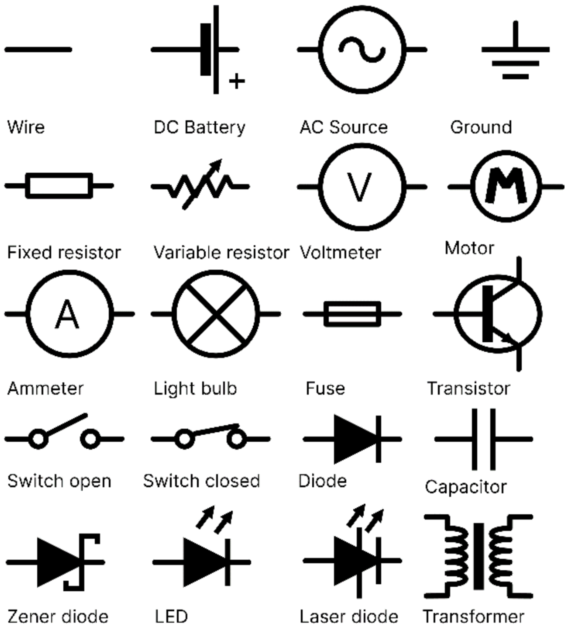
Lasers: release a single wavelength of light when current passes through.



All of these microcomponents are made of semiconductors and use their p- and n-type properties to construct useful properties.

A transistors uses a PNP or a NPN configuation to create a functioning transistor.
While a diode uses a forward biased semiconductor to force current to flow in one direction.

Polymers are materials that have tightly bound electrons meaning that they insulate from electrical currents from passing through them.



Type:	Usage:	Example:
Polyethylene	High insulation Good stiffness Weather resistant Expensive Softens easily	Inner cable sheathing
Polyvinyl chloride (PVC)	High temperature resistance Tougher Less insulative	Electrical boxes
Polypropylene	Tougher High softening temperature Great insulator Not flexible Expensive	Heavy-duty cabling
Nylon	Hard and smooth surface	Insect proof coatings

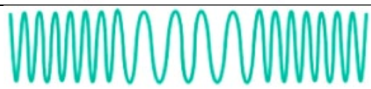
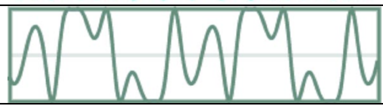
Ceramics are used as insulative materials (even with metal atoms inside them, as they increase strength) due to low number of free electrons.
Fibre optic signal uses photons (light) to transmit messages and needs the glass as the medium.

Component	Material	Function
Core	Glass	Medium for signal transmission
Cladding	Polymer	Insulators, protects form interference for the light signals.
Buffer coating	Polymer	Protects the fibre system from external wear and tear.
Strengthening member	Kevlar or Fibreglass or metal	Provides rigidity for the fibre optic bundle.
Armour	Steel	Covering to protect against cable damage while buried.

Jacket	Polymer	Outer coating which protects fibre bundle.

EM Signal comprises:
- Carrier wave: the frequency of the wave designated for carrying the signal
- Message: the desired information to be transmitted
- Modulating: the method for encoding the information into the signal

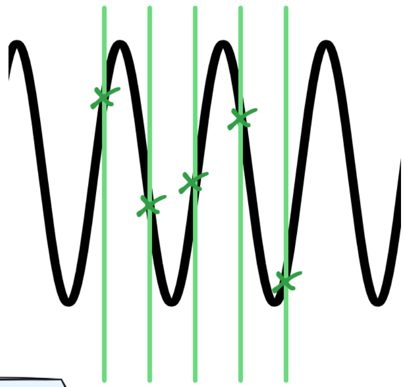
Methods of modulation:

Amplitude: changing the amplitude to the relative message, susceptible to noise, easy equipment.	
Frequency: slightly adjusting the frequency of the signal, requires more complex equipment, quality of signal is high.	
Pitch: changing the pitch/angle of the wave to encode the message.	

Digital signals are used now days as they can represent more complex information and can interface with different systems.

Unguided media is communication links which are not physically connected i.e., ‘wireless’.

Converting from AC to DC:
1. Sampling, at a distinct interval a discrete value is taken from the symbol.
2. Quantising, take the values from the samples.
3. Digitising, decode the value into a digital signal.



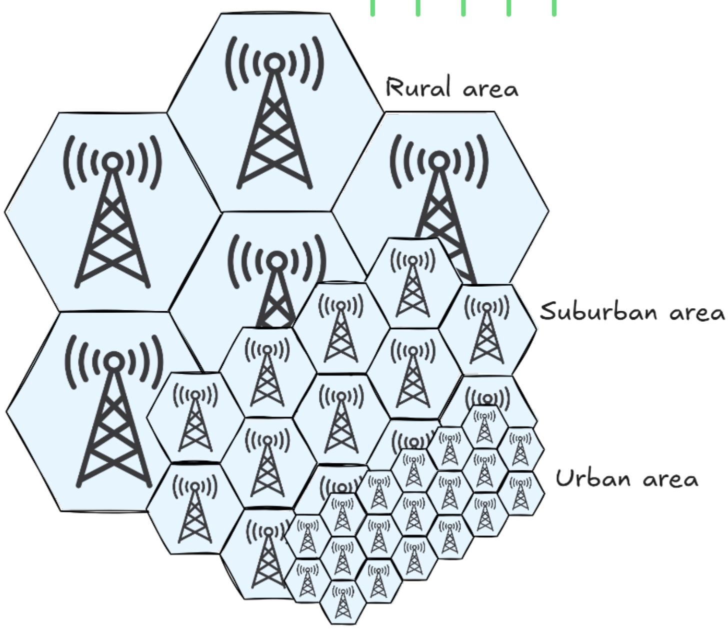
Mobile phones use unguided media and a cellular network to connect to an antenna in their local vicinity.

These antennas then connect to one another to get the signal to the tower nearest the recipient.

These towers operate over digital signals, and their coverage usually overlap allowing for ‘hand-off’ points where the connect is seamlessly changed from one tower to another.

Due to the towers short range, multiple towers are all able to use the same frequency bands.

Satellite signals are another form of unguided media.



They use the high-frequency microwave band, but not too high frequency as it may be susceptible to interference – especially from the atmosphere.

GPS systems use accurate timings from multiple satellites to triangulate a user's position on Earth.

Types of orbits:
LEO, low-earth orbit: (500-2000km), used for telecommunications, low latency and cheapness.

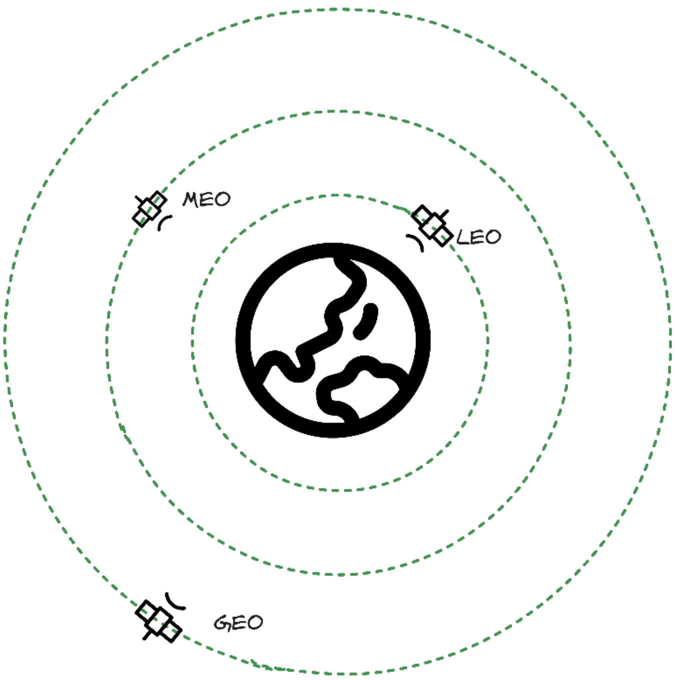
MEO, medium-earth orbit (2000-36 000km) used for GPS or space science, fewer satellites need to cover an area.

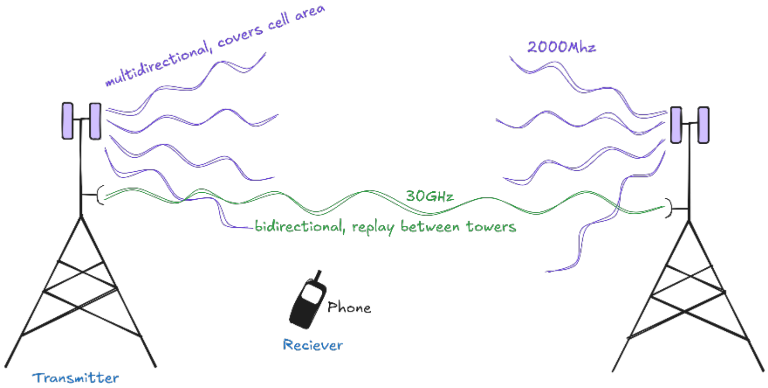
GEO, geostationary/geosynchronous orbit: (39 786km) allows for data collect and transfer at a fixed point and constant observation. Only 3 satellites required to cover the entire Earth.

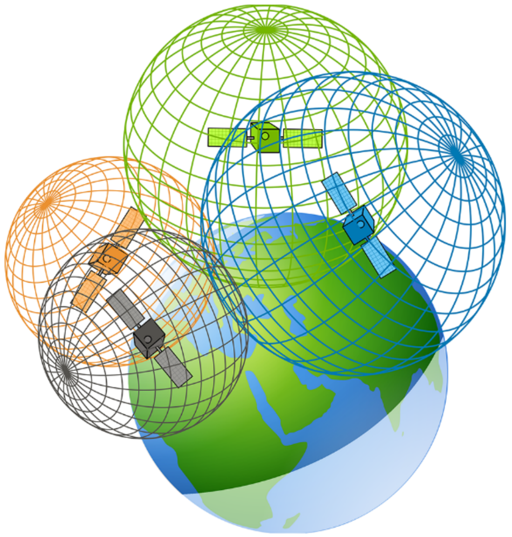
Infrared are used for short-range transmission, especially for remotes and the like in properties.

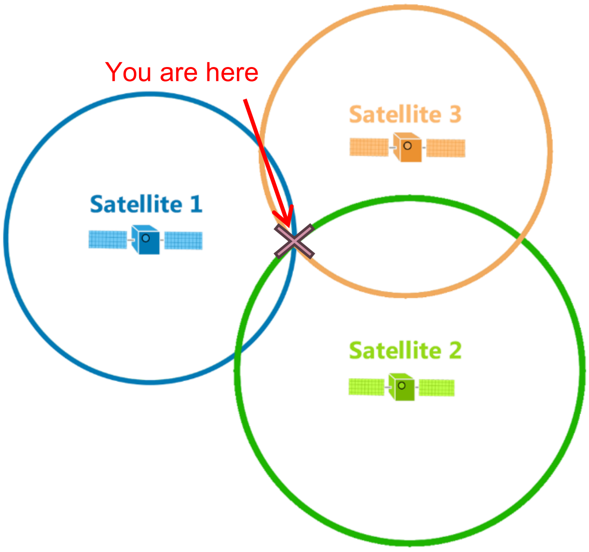
Typically, a transmitting antenna has to $\lambda, \frac{\lambda}{2}, \frac{\lambda}{4}$ tall to be able to transmit the appropriate signal correctly.
AM radio can diffract around large obstacles, giving it a long range.

GPS satellites use triangulation: basically using the distance from three or more satellites to determine exact location on Earth.



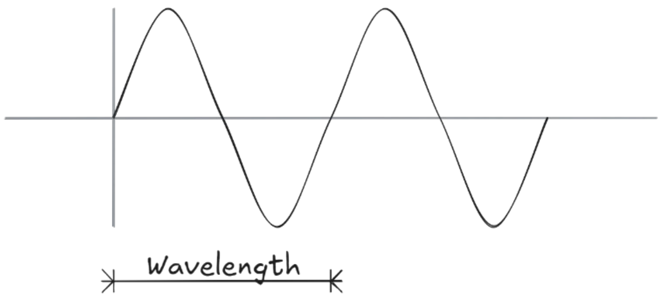




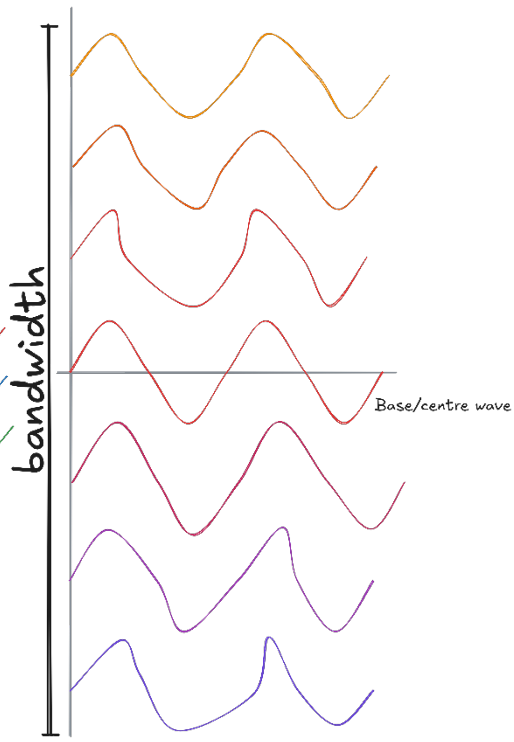


Properties of unguided media:

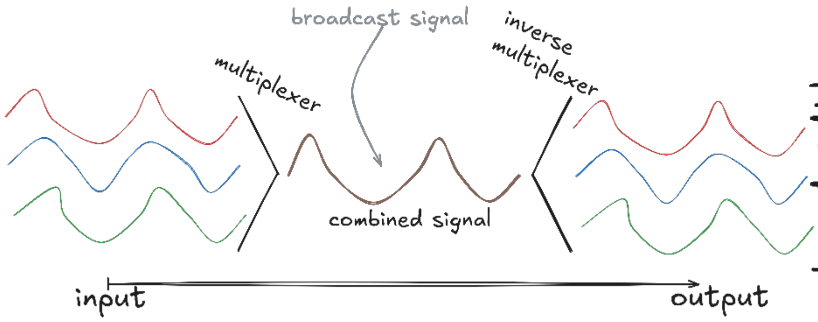
- Frequency: the effective information capacity (shorter wavelengths are better)
- Range: the ability to diffract around obstacles and maintain power (longer wavelengths are better)
- Directionality: either point-to-point or broadcast
- Half- or full-duplex: one-way or two-way connections respectively



To broadcast the full range of information, connections have a bandwidth which is a range of signals on which they broadcast leading to higher fidelity.



Modulation allows for signals to be layered on to one another and allows for parallel signalling.

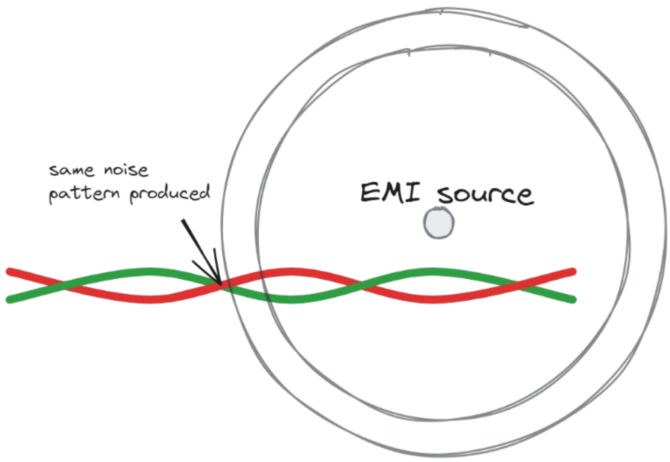


Telecommunications cables allow for the transmission of data or information.

Twisted pair cables

This is two metal (usually copper) wires twisted together, covered with a polymer shield and the potential difference between the wires is the signal.

These cables are not subject to EMI (electro-magnetic interference) as they have differential signals, and they are crossed so they experience the same EMI.

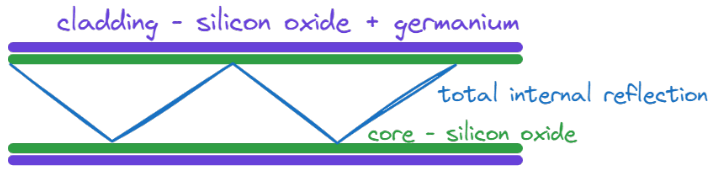


Usage: ethernet, telephone lines

Advantages:
- Cheap
- Easy to manufacture
- Eliminates noise and interference due to EMI
- Minimise signals leaking from adjacent wires

Disadvantages:
- Low range
- Low throughout and bandwidth

Coaxial cable:
Single wire which can only carry signal one direct, very chunky cable.



Usage: modulate signals – TV

Advantages:
- Higher range
- Higher frequencies (GHz)
- Very easy to manufacture
- Metal shielding eliminates noise
- Can go longer

Disadvantages:
- One copper wire, lower throughput
- Expensive due to material

Fibre optic cable:
A glass fibre which reflects a laser signal.

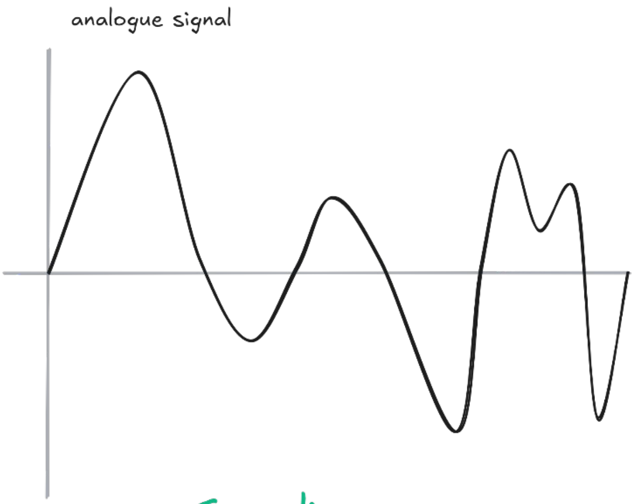
Usage: broadband (NBN), extremely high-speed digital connections

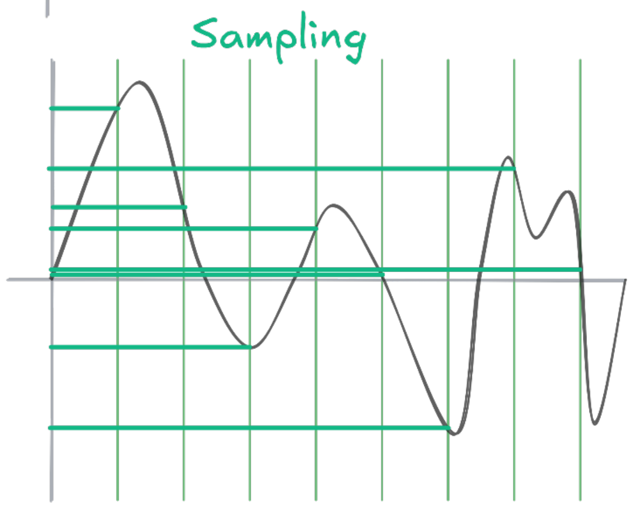
Advantages:
- Can travel very long distances without needing repeaters
- Incredibly high frequencies (THz), very fast transmission of data
- Not susceptible to EMI
- Lighter and thinner

Disadvantages:
- Expensive
- Can do sharp turns in wire
- Complex to manufacture
- Tricky to terminate

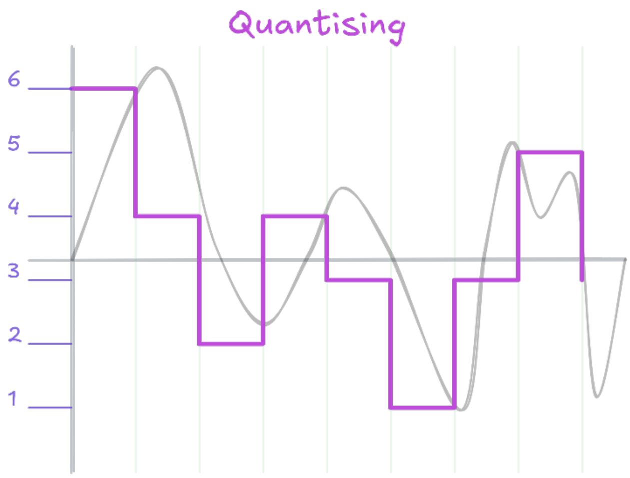
Fibre optics are made using modified vapour deposition, where extremely high heats are used to make extremely thin fibres.

Analogue to Digital conversion:
Takes an analogue signal and transmits across a digital medium, allowing for better clarity, more information to be transmitted and multiplexing.





Sampling involves taking a discrete value from the analogue waveform at set intervals.



Quantising results in an ‘approximation’ or rounding of the discrete value to allow for this data to be easily transmitted.

The sampling and quantising if done too coarsely can lead to data loss as some of the waveform is ‘skipped’.

Digitising involves converting these discrete values into binary. i.e., $6 \implies \texttt{110}$

This allows for the proper transmission of a range of information, including images, videos or audio along with accompanying information.

Binary is the representation of information in a computer, and it is either 1 or 0, this was chosen as the one and zero state are far away from one another and would diminish the effects of electrical noise and interference on the signal.

Compression reduces the file sizes for certain types of files, reducing bandwidth costs and increasing speeds across the internet.

Compression is either:

- Lossless: the compression process when undone results in the exact same file.
    - Run-length encoding, compresses repeating sequences with length markers.
    - Substitution, process substitutes common byte sequence for smaller representations.
- Lossy: the compression process results in some information being lost along the way, usually file format loses information which is less key to human perception.

Logic gates allow for a predictable judgement to be made on a series of logical inputs.

Gate	Symbol	Description
NOT		This gate flips the input signal.
AND		This gate is true only when both inputs are true.
NAND		Opposite of the AND gate.
OR		This gate is true when at least one of the inputs are true.
NOR		Opposite of the OR gate.
XOR		This gate is true only when one of the two inputs is true.
NXOR		Opposite of the XOR gate.

A capacitor stores current through two plates to hold a charge, allowing for charge to be stored and voltage to be smoothed.

A ground connection allows for the dissipation of current.

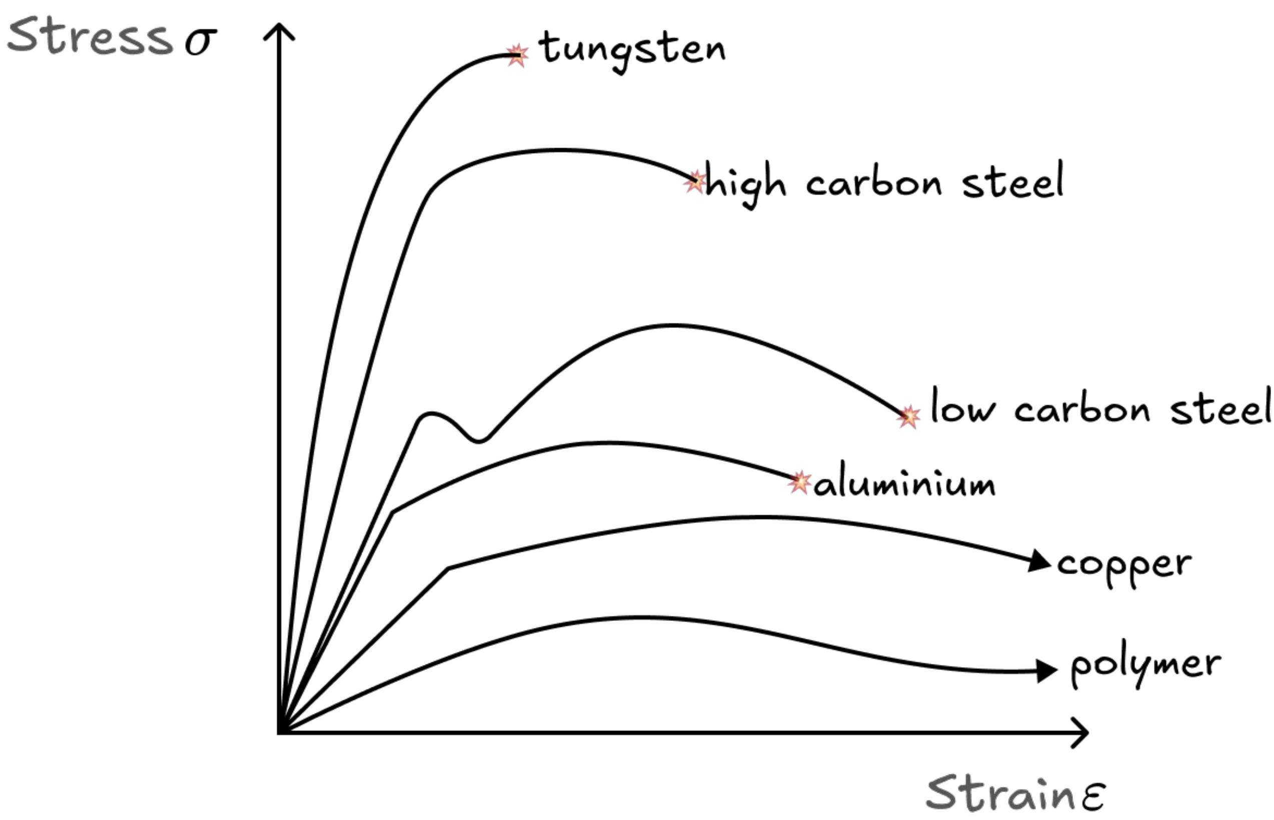
Materials Summary

Main types of materials:

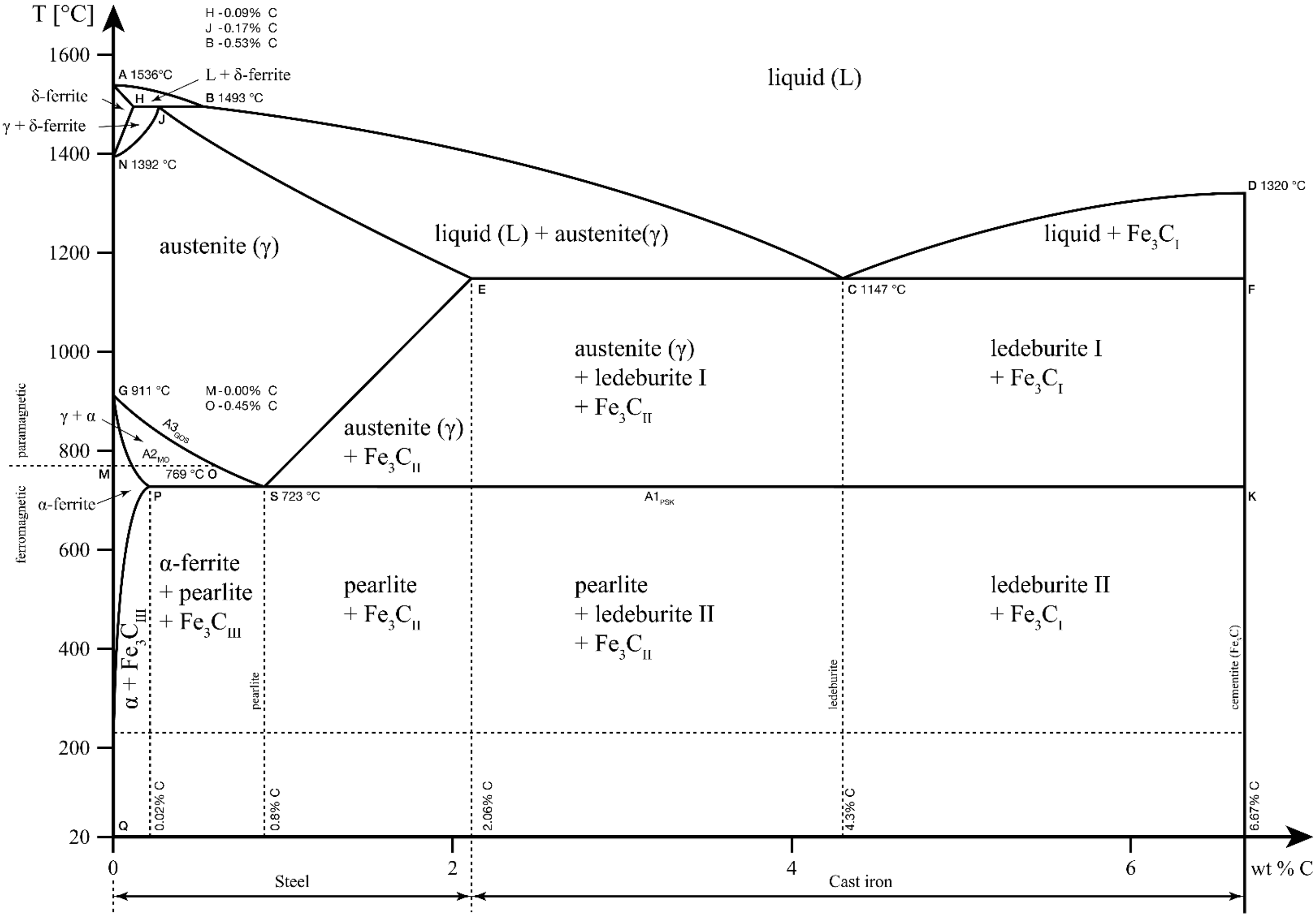
- Metals
- Ceramics
- Polymers
- Composites

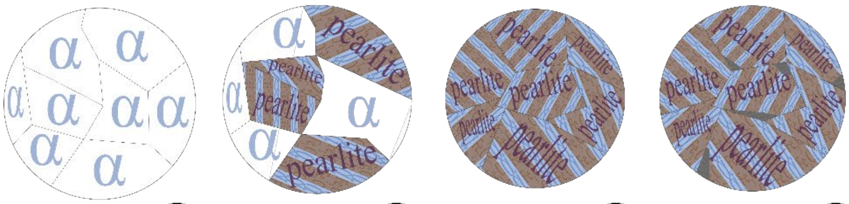
Mechanical properties:

Brittleness	Lack of plastic deformation, will fracture when affected by a load.
Ductility	A material's ability to be plastically deformed by elongation (tensile load).
Hardness	A material's ability to resist changes to shape from external loads.
Malleability	The ease at which a material is deformed under compression load.
Stiffness	The resistance to deformation by an external force.
Strength	The ability to oppose deformation from external loads.
Toughness	The ability to absorb external stresses and plastically deform instead of fracturing.



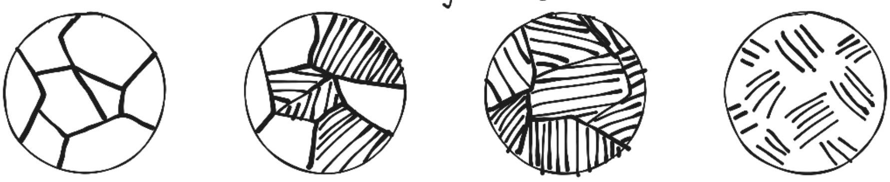
Ferrous Metals:





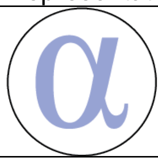
0.0% C 0.4% C 0.8% C 1.4% C

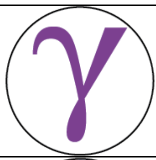
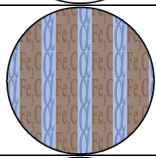
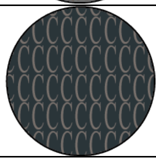
Drawing Grains



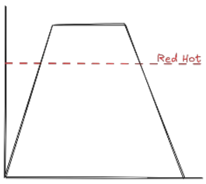
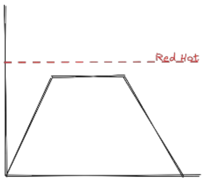
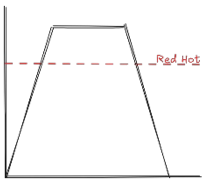
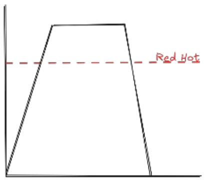
0.0%C 0.4%C 0.8%C 1.4%C

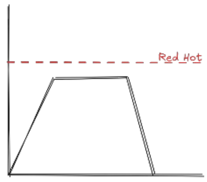
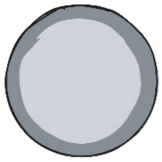
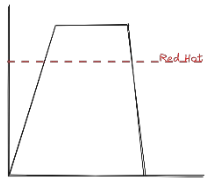
The carbon within iron exists in multiple states:

Name	Symbol	Produced	Representation	Properties
Ferrite	α	Low carbon content iron		Soft, ductile, tough

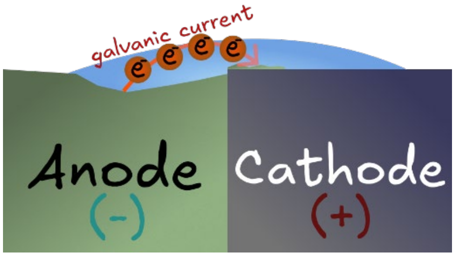
Austenite	γ	In iron over ~700°C		Very soft, ductile (FCC) → denser, more slip planes
Pearlite	*pearlite*	When iron has to much carbon, so it forms a lamellar structure.		Intermediate properties
Cementite	Fe_3C	Very high carbon content iron.		Hard, brittle
Graphite	C	Where the carbon itself forms a new grain structure.		Very brittle, hard

Heat treatment:

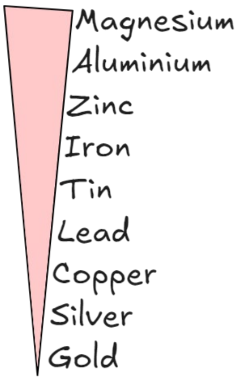
Name	Process	Effect on 0.4%C steel	Chart	Effects
Full annealing	Heated to red heat Cooled slowly in oven *Can lead to *oversoaking*, where grains are too large.	 Large, equiaxed grains		Increased malleability and ductility
Summary annealing	Heated to below red hot Cooled slowly in oven	 Same initial structure, reduced internal stresses		Increased ductility
Normalising	Heated to red heat Cooled in air	 Fine grain structure		Increases hardness and increases strength
Quenching	Heated to red heat Cooled in water	 Leads to the formation of *martensite*, as the material is given sufficient time to phase change. Acicular (needle-like)		Very hard and brittle

Tempering	Heated below red heat Cooled in water	 Draw as all grey, as changes are subatomic		
Surface hardening	Heated to red heat Surface is cooled very rapidly	 Marsenite shell *Normalised* core		Case: hard, wear resistant Core: soft, ductile

Corrosion:



Galvanic corrosion:

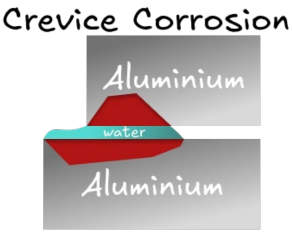


This is where the joining of two dissimilar metals, creates a galvanic cell due to an aqueous environment.

The more corrosive element, (determined by the chart left), becomes an anode and begins to lose electrons to the cathode by creating a current which enabled by the electrolyte (water).

The rivet corrodes easier than the plates due to the larger exposed surface area.

Pitting/crevice corrosion:



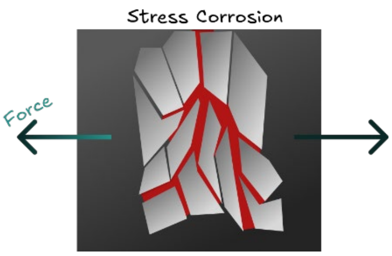
Corrosion due to water getting stuck within a crevice and crack, leading to rapid galvanic corrosion.

Major reason for aircraft skin failure, due to expansion and contraction of the skin combined with condensation.

Uniform/bulk corrosion:

The entire surface of the material is subject to an even corrosive attack.

Intergranular/stress corrosion:



A component is subjected to high tensile stress, in the right environment and material begins to corrode at the grain boundaries.

Fretting corrosion:

When a component is subject to high vibrational forces, meaning that surfaces rub against each other leading to wears and crevice/pitting corrosion.

Exfoliation:

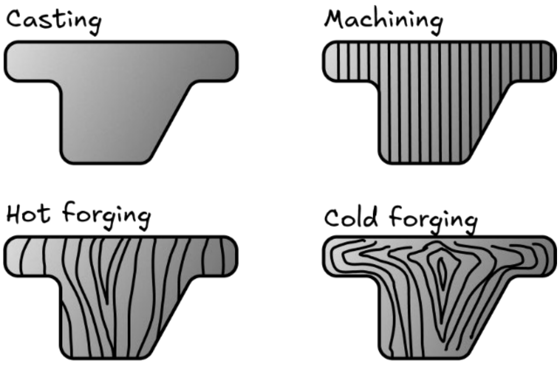
Form of intergranular corrosion, where the grains corrode just below the surface due to very thin materials.

Forming methods:

Forging – leads to <u>grainflow</u>

Hot forging allows for the grains to reform – meaning it is more malleable.

Cold forging leads to substantive grain flow – meaning that it is more fatigue resistant.



Forging

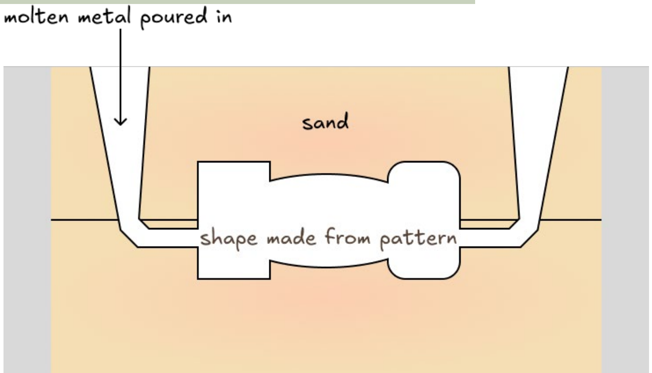
A metal is plastically deformed through hammers.

Rolling

The metal is passed through a series of rollers.

Casting

Casting allows for intricate shapes to be constructed, especially for rapid, consistent manufacture.

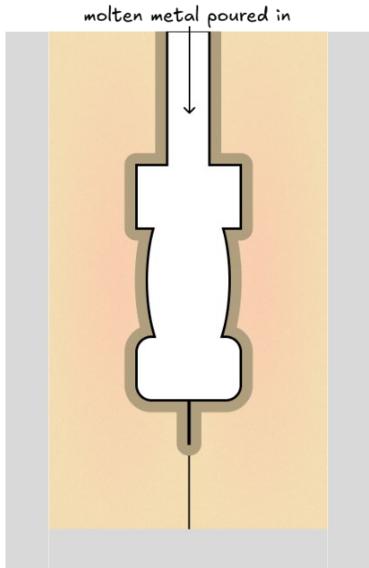


Sand casting

Firstly, a sand mould is prepared from a pattern (usually made of wood), this sand is then cured, and molten metal is poured into it. A new mould is required for every manufacture.

Leads to an ok surface finish but it is very simple and cost effective.

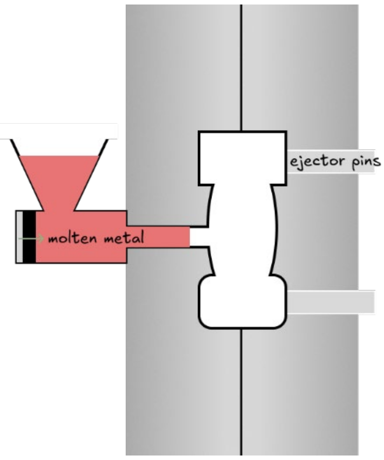
Examples: engine blocks, train bogies.



Shell casting

A pattern is again prepared, yet this time the pattern is used make a thin shell in which the molten metal is poured in.

This improves the surface finish and reduces the chance of defects, though it is more complex.



Examples: crankshafts

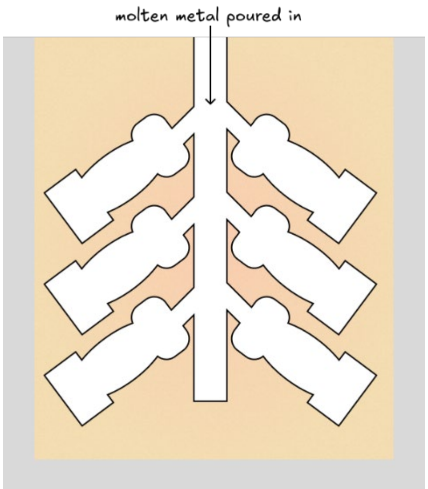
Die casting

A metal mould is prepared to which the metal is rammed and cast into.

This allows for a much more accurate piece with more dimensional accuracy. However, is very expensive and needs special metals to make sure they don't melt.

Examples: cams, levers

Investment casting



Patterns made of wax are attached to a central shaft and placed into a slurry, while the wax is melted out. When the molten metal is poured in, and the piece can be broken off.

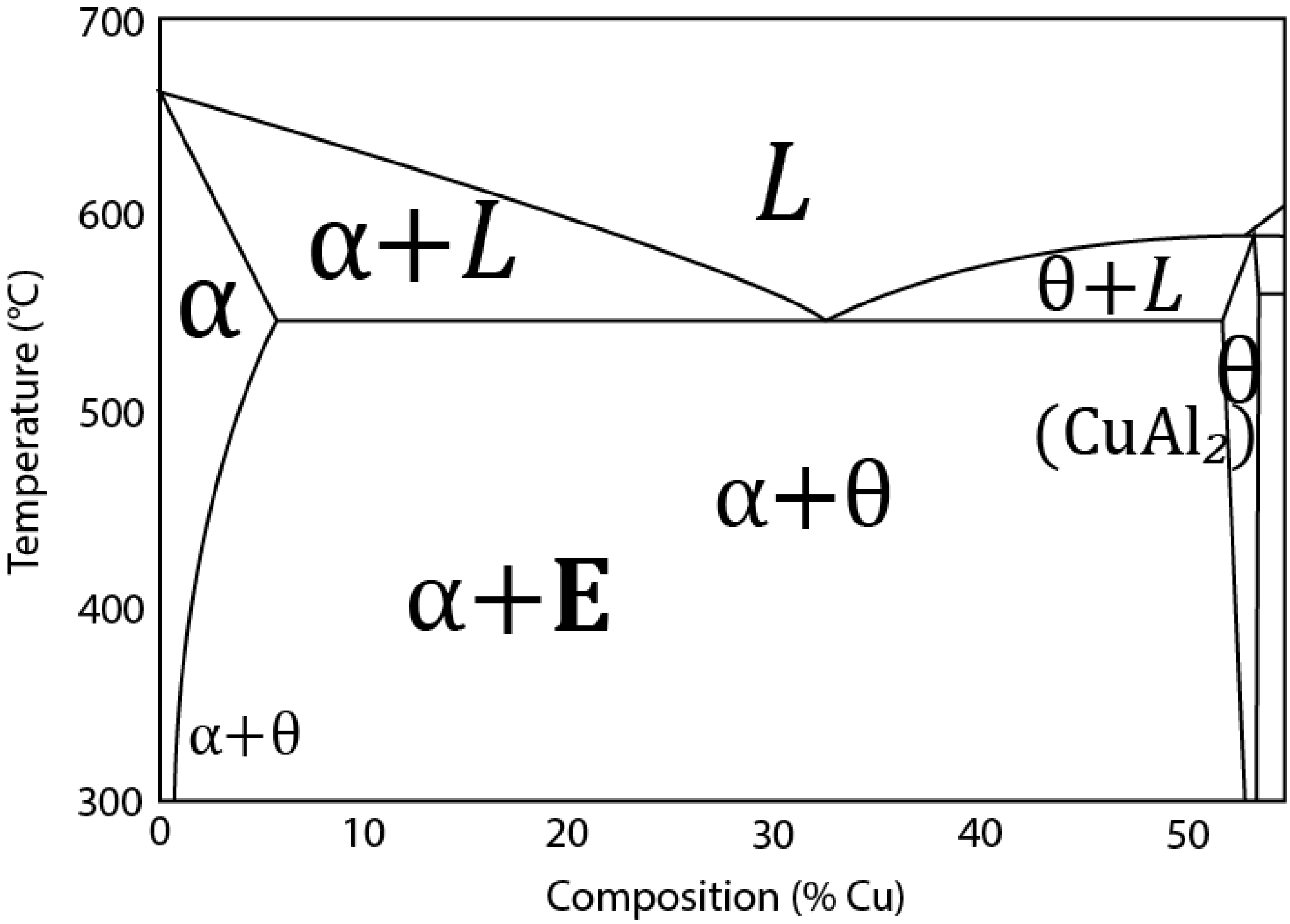
Allows for intricate piece, with more complex shapes, but it can only be used for small parts.

Powder metallurgy/sintering

Metal powder is rammed and heated into a certain shape, this allows for high dimensional accuracy and high production rates – but doesn't lead to grainflow (like casting) and has impeded strength (due to internal inconsistencies).

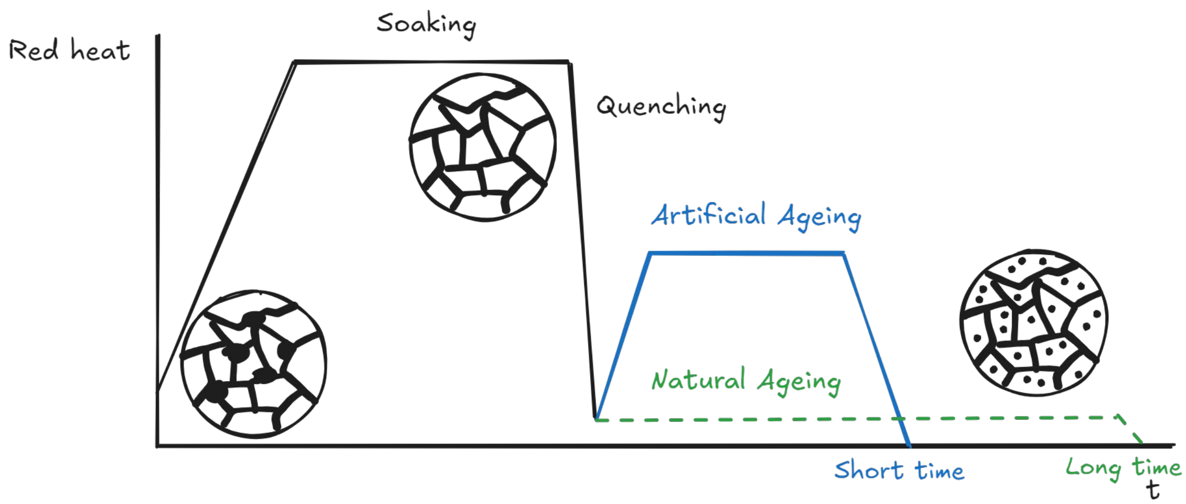
Non-ferrous Metals:

Copper-Aluminium Phase Diagram (Duralumin)



For non-ferrous metals:

- They take a few days to full age harden – this is due to the perception of the material and leads to a more complete grain structure which is more malleable
- Can be artificially age hardening, through precipitation hardening which can allow for this process to be sped up and allow for more malleable materials



Common Aluminium Alloys

- Magnesium: increases electrical conductivity and corrosion resistance
- Copper: increases qualities from precipitation hardening

Common Copper Alloys

- Electrolytic tough pitch copper: used largely for high electrical conductivity
- Copper beryllium alloy: increases the strength of the copper, while maintaining high electrical conductivity
- Copper cadmium alloy: high wear resistance, fair strength and low resistance.

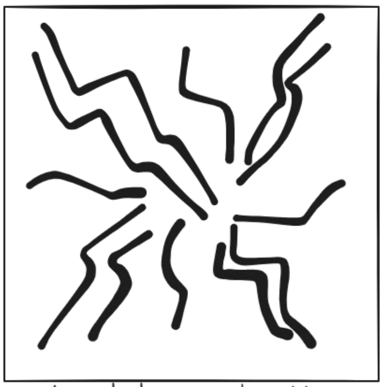
Bronze: mainly copper and tin alloys, used for high toughness and shock resistance.

Brass: copper and zinc alloy, corrosion resistant, high strength and wear resistant.

Ceramics & Glasses:

Ceramics are materials that are non-organic, non-metallic materials which are fired at high temperatures.

Glass is formed from a cullet (which is often both broken and recycled glass) combined with sand and soda ash forming molten glass.



Normal glass crack pattern

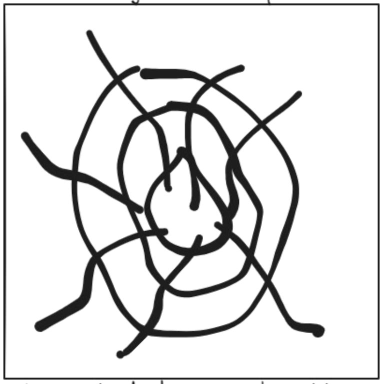
Types of Glass Treatment:

Normal Glass

Glass when subjected to a load or thermal changes, it tends to shatter as it a very brittle materials and it has no slip planes to relieve stress. This exacerbates stress raisers.

Laminated Glass

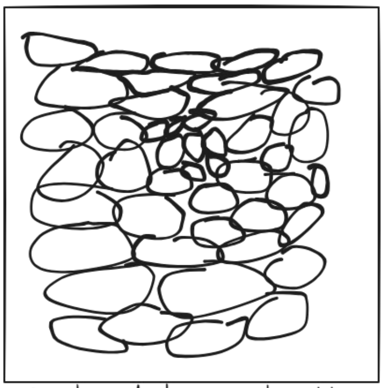
This glass is formed by placing a polymer layer in between the glass layers, allowing the glass to stay together when cracked.



Laminated glass crack pattern

Toughened Glass

The glass is heated, then cooled rapidly leading a taught outer skin, increasing hardness and reduces the chance that the glass cracks into a sharp pattern.

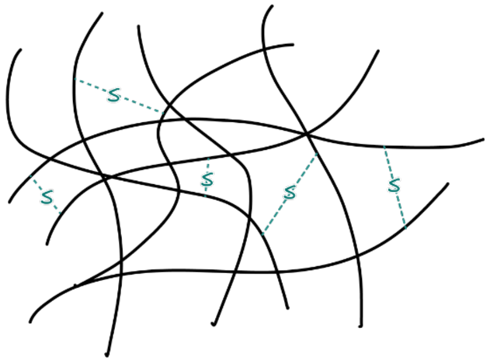


Toughened glass crack pattern

Polymers:

Molecular chains, defined by their repeating patterns.

Types of Polymers:

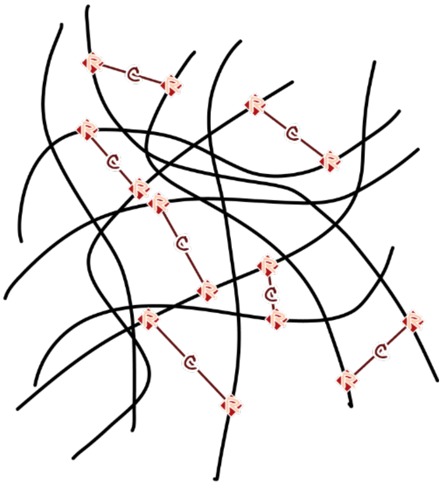


Thermosoftening

These polymers are held together by weak secondary links and are easily able to be broken into new chains or structures especially under heat.

Examples:

- Polyethylene
- Polycarbonate (impact resistant, weather resistant)
- Polypropylene
- PVC (insulator, softer)
- Nylon
- Acrylic
- ABS (especially hard, rigid)



Thermosetting

These polymers consist of a large number of cross-links, which was they especially rigid. Once, they are heated, the structure is set, and it cannot be reformed again under heat.

Vulcanisation:

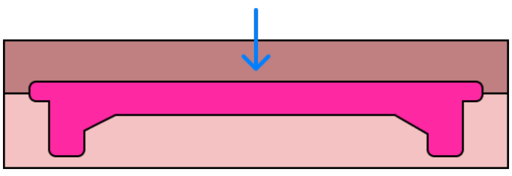
This is the process of adding sulphur to the polymer meaning that there are increased number of cross-links increasing tensile strength.

Polymer Additives:

i. Stabilisers: minimises damage from UV radiation to polymers.
ii. Plasticisers: work to lubricate the polymers making them more malleable and flexible.
iii. Pigments: colours the polymer.

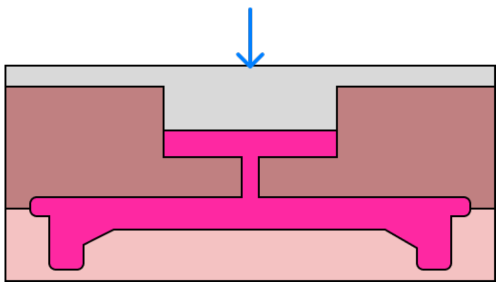
Forming methods:

Compression moulding



Used for ‘flat’ shapes, especially for thermosetting polymers and involve forcing the polymer into a shape under heat.

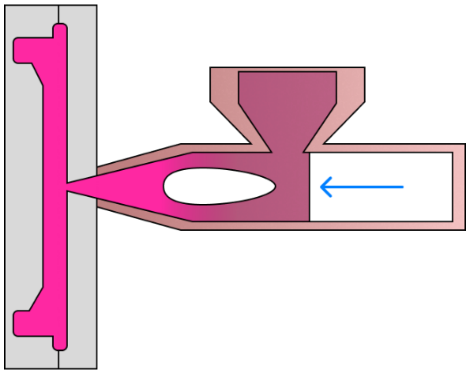
Transfer moulding

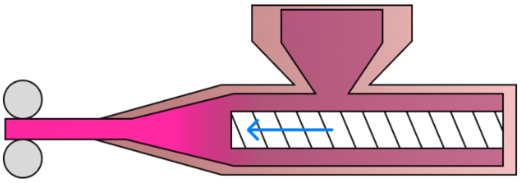


A faster process then compression moulding and allows for more complex shapes. Again, used for thermosetting polymers.

Injection Moulding

Used for thermosoftening polymers, ‘raw’ polymers grains are fed into the hopper and cast into shape.



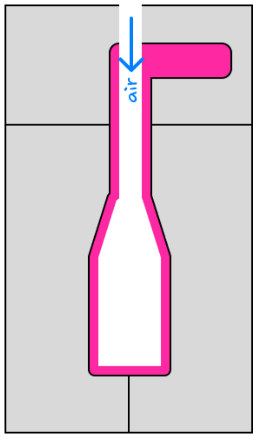


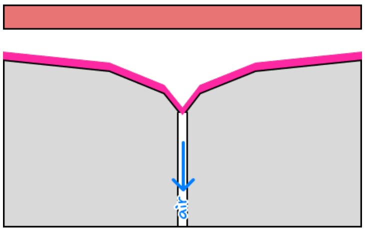
Extrusion

Used for thermosoftening polymers, the polymer is melted as extrude into a circular shape.

Extrusion Blow Moulding

Through using high pressure air, a hollow polymer creation is formed. It is then cooled in the mould, to allow the shape to set.



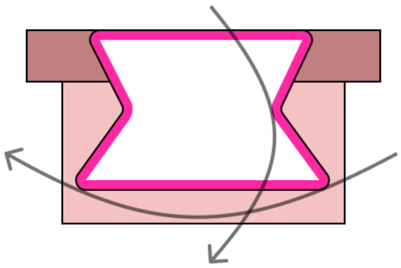


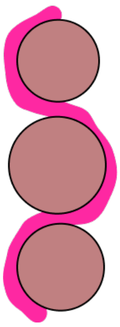
Thermoforming

A suction force is created to create complex ‘2d’ formations.

Rotational Moulding

Especially used for large cylindrical structures (i.e., water tanks), this works to create a large hollow polymer vessel.





Calendaring

Used for thermosoftening polymers, a thin film is able to be created.

Geotextiles:

Materials which are woven together made of synthetic or natural polymers which are especially used to support road base or soil formation.