Level 1/2 Engineering

Knowledge Organisers

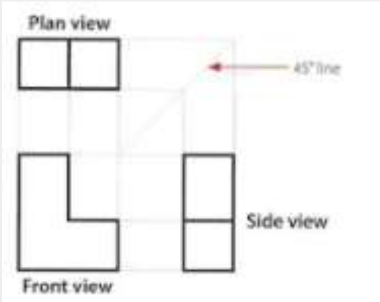
wjec
cbac

Drawings and calculations

Orthographic drawings: standard drawing conventions

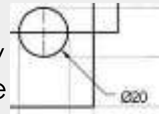
Construction lines:

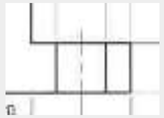
- These are used to **help you** accurately draw all views
- Construction lines are drawn very **lightly** and not rubbed out afterwards
- Construction lines are drawn vertically and horizontally from the front view
- A 45° line is drawn from the front view



Circles

- The dimensions are shown with an arrow pointing to the edge of the circle in R or ⌀
- Circular holes are shown with hidden lines at the edges and centre line through the centre

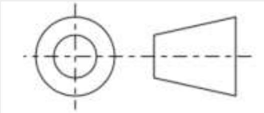




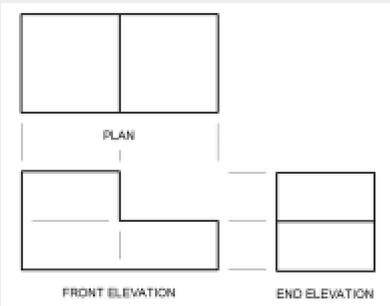
Section drawings show the **internal details** of a drawing if it was **cut in half**. **Hatched lines** at 45° are used to show parts that would have been cut. A slice line is drawn on the orthographic drawing and labelled A:A

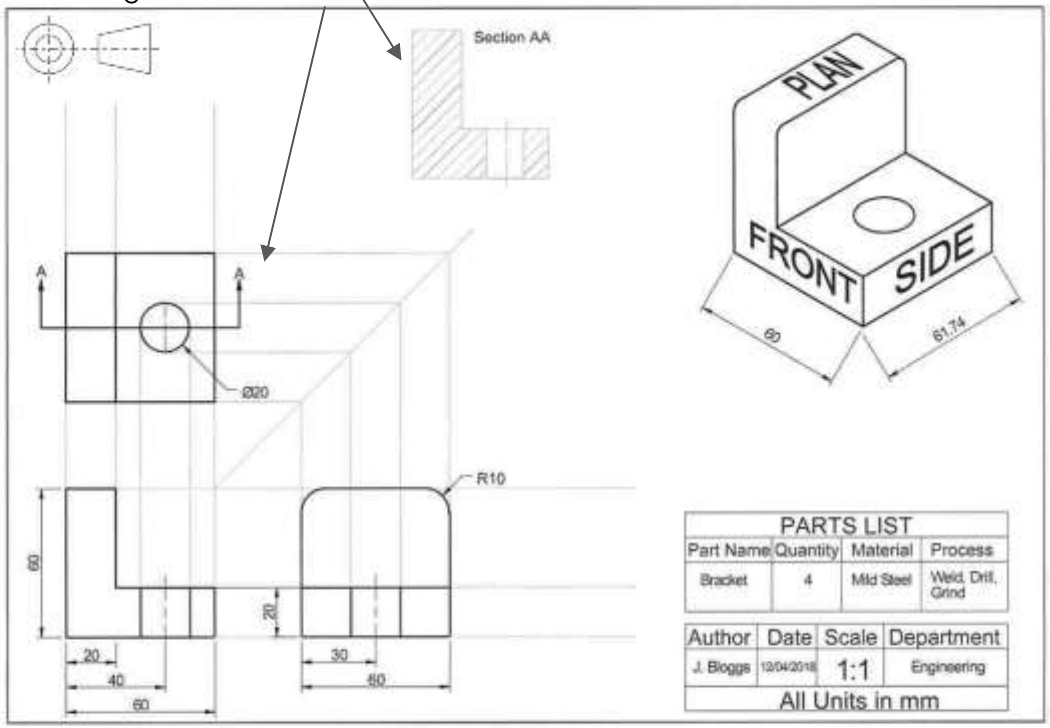
Layout:

3rd angle orthographic:



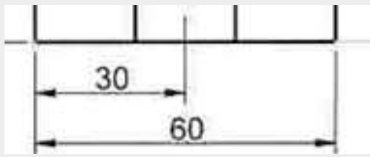
- Front elevation is in the bottom left corner of the page
- Plan(top)elevation is directly above the front elevation
- End (side) elevation is directly to the right of the front





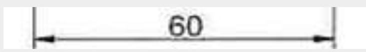
Dimensions:

- Extension lines lead from the corners being measured. The do not touch the drawing.
- Straight, double ended arrows with solid heads are drawn with the dimension **above the line** in millimeters.



Line types:

- **Hidden line**
- **Centre line**
- **Construction line**
- **Weighted line**
- **Dimension and extension lines**



Key word	Definition
BSI 8888:2017	The name of the list of standard conventions
Elevation	View
Scale	The size of a drawing in proportion to the real object. e.g. 1:1 = full sized 1:2 = half sized 2:1 = double size
Weighted line	Thicker lines used to define the object you are drawing
Constructi on line	A light line used to construct the shapes you are drawing. They help you to line up views.
Dimension s	Measurements of a drawing
Diameter ⌀	(shown with ⌀) the distance across the centre
Radius R10	(shown with R) the distance of half the diameter of a circle. Often used to measure curves

Parts list

- Part name
- Quantity
- Material
- (Process)

Title block

- Author
- Date
- Scale
- Title of drawing

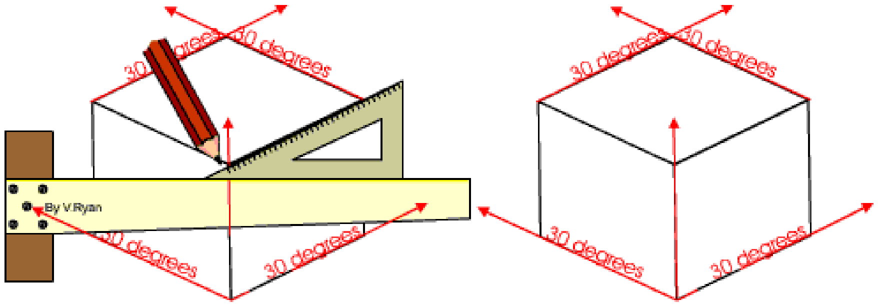
Isometric drawings:

What are isometric drawings?

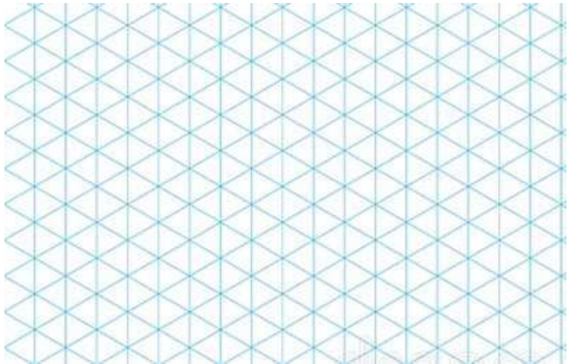
They are 3D drawing technical drawings.
There are no horizontal lines, instead they are drawn at 30° from horizontal.

How do I draw in Isometric?

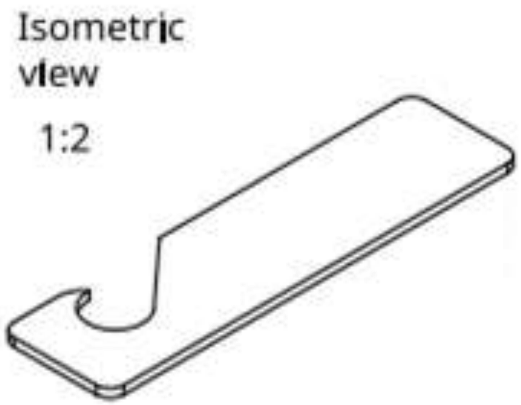
Either by using isometric grid paper, or using plain paper with a ruler and 30° set square.



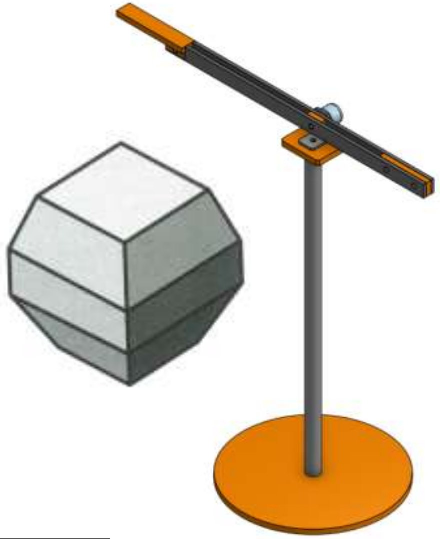
Isometric grid paper (vertical lines not included)



Isometric grid paper (vertical lines included)

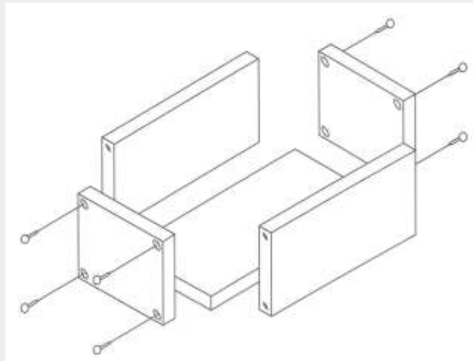


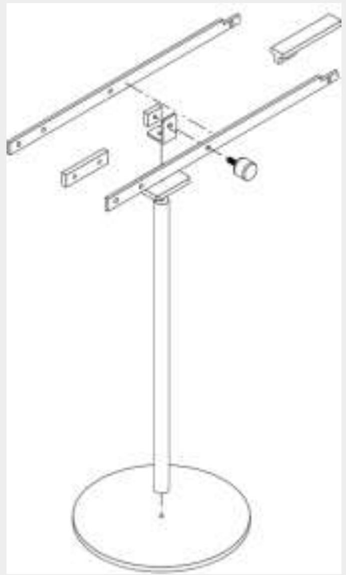
Isometric drawings may be done by hand or using CAD. They may be left plain, or rendered to look like the final materials.



Exploded Isometric drawings.

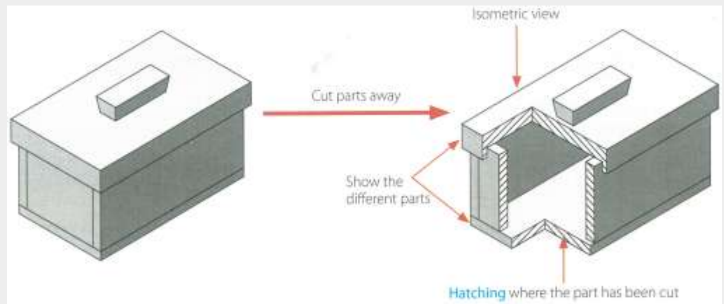
This is a drawing style used to show how parts fit together.
Parts are 'exploded' in isometric, so that they in line with their original position.





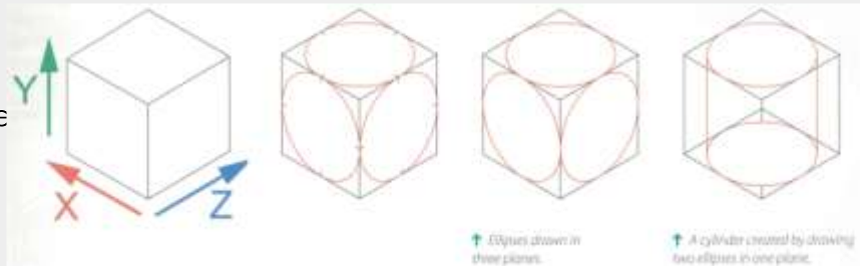
Cutaway drawings.

This is a drawing style used to show the inside of a solid object, where part of the drawing has been 'cut away'. The lines that have been 'cut' are filled with hatched lines.



Drawing circles and curves in isometric

In isometric, circles actually appear as ellipses.
Circles can constructed by drawing an isometric square and drawing the circle within.
Often, ellipse templates are used for drawing.

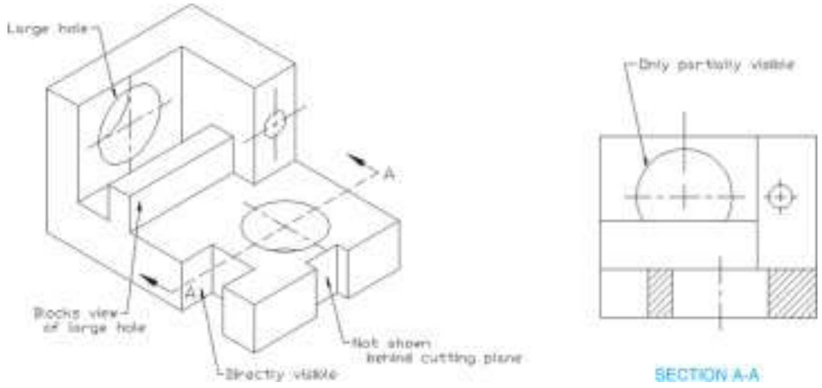


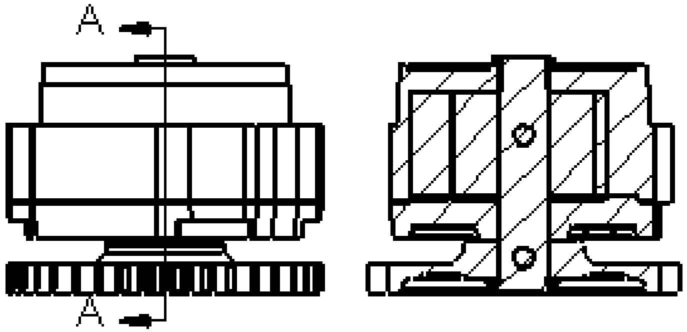
Section drawings:

What are Section drawings?

These are 2D drawings which show the inside of a product.
They are labelled with an arrow and two letter, which then match the section drawing: as shown below A:A

The arrow shows the **cutting plane** section to be shown in the section view. Cutting plane lines may also be shown on a **isometric drawing.**



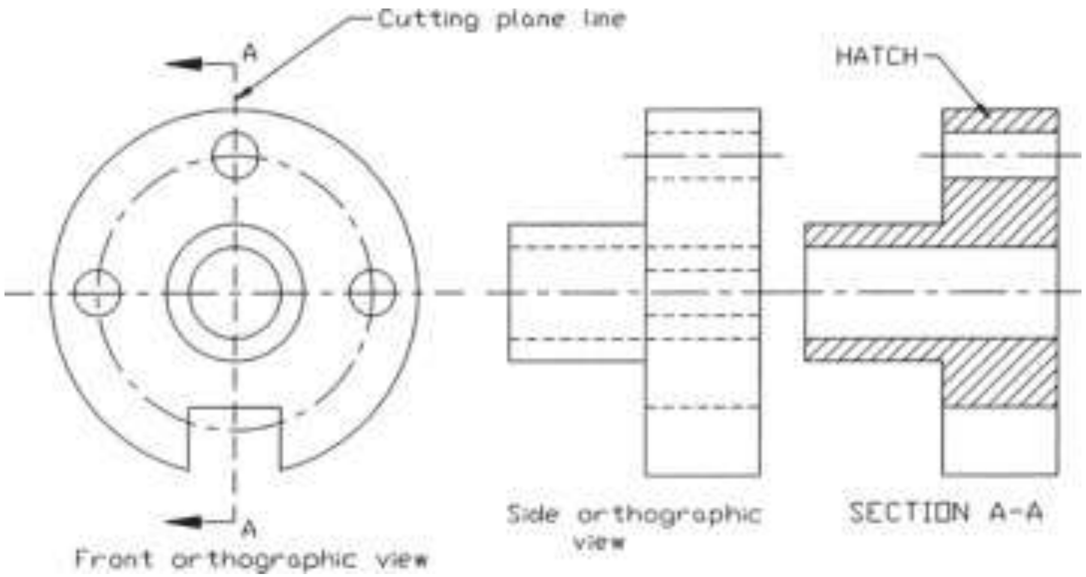


SECTION A-A

How to draw a section drawing?

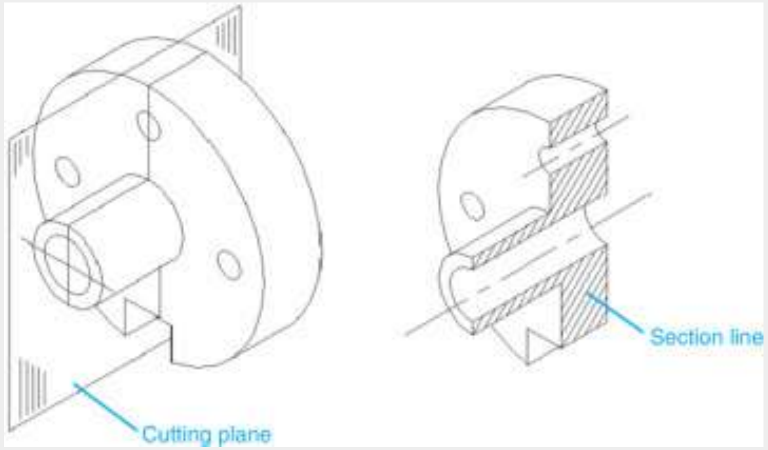
Section drawings are the same scale as the orthographic drawing that they accompany (unless otherwise stated)

Hatched lines are drawn on a section drawing to show solid parts that have been cut through. Different parts touching will have opposite direction hatched lines.

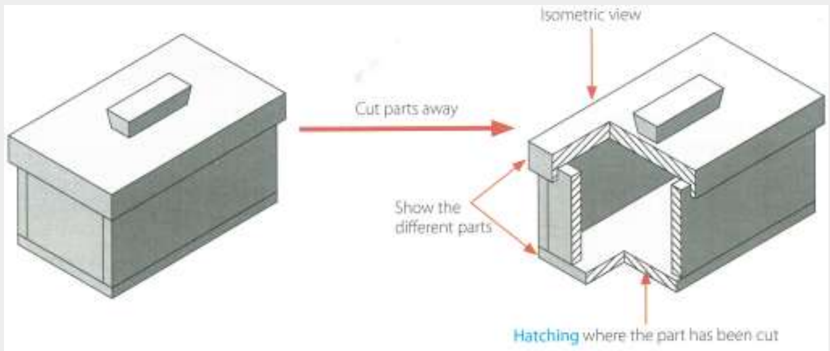


Cutaway drawings.

This is the same principle as section drawings, but it in **isometric.**



The lines that have been 'cut' are filled with hatched lines.



Engineering calculations Knowledge organiser

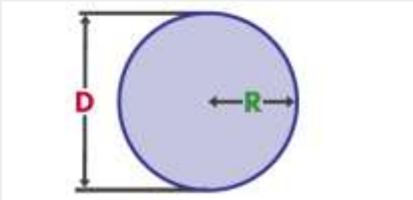
Calculating areas

Area of rectangles

A = Area
L = Length
W = Width
A = L x W

Area of a circle

A = π x r²



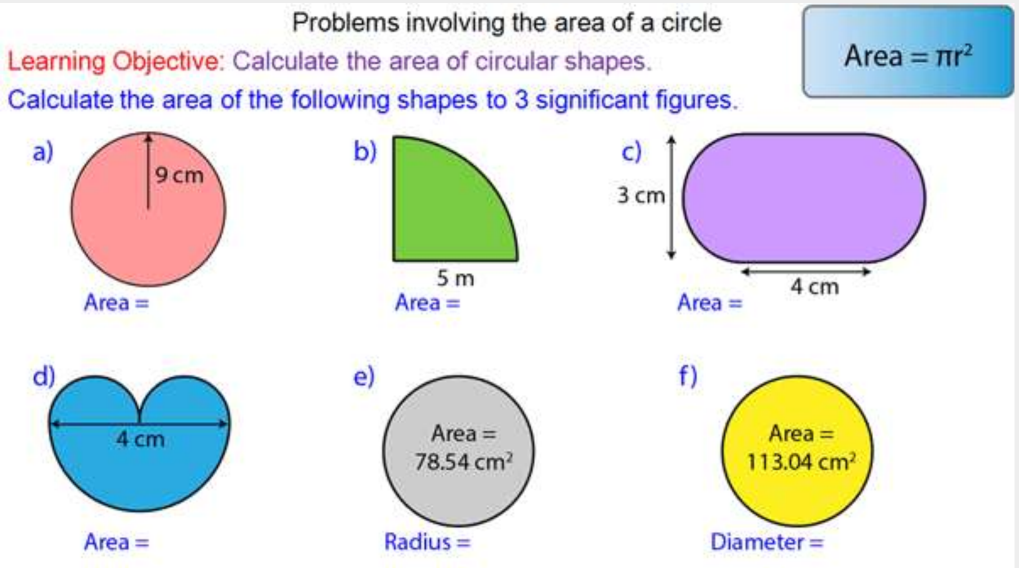
Area of a triangle

A = ½ b x h

Diameter Ø is twice the Radius

Calculating the area of compound shapes

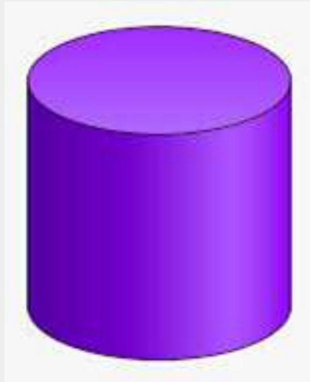
To calculate the area of a compound shape, start with the formulas your know, then add or divide them to make the shape you need, *e.g. for q.b below, you would calculate the area of a whole circle then divide by 4.*

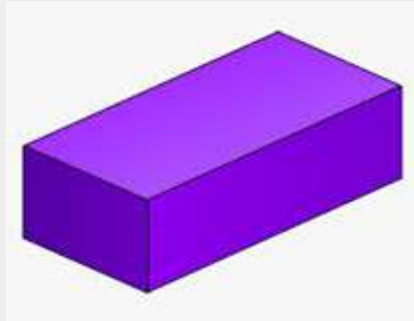


Calculating volumes

Volume of prisms

For the volume of prisms, you calculate the cross sectional area, then multiply by the height.





Cylinder

V = (π x r²) x h

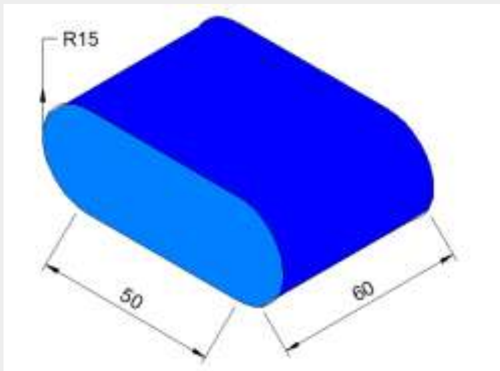
Cuboid

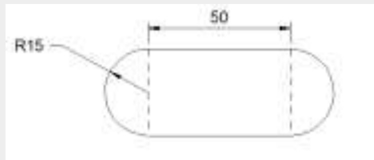
V = (l x w) x h

Calculating the volume of compound shapes

To calculate the volume of a compound shape, calculate the area by adding/ subtracting the simple areas, then multiply by the height, e.g:

For this pill shaped cuboid, we would first calculate the cross-sectional area

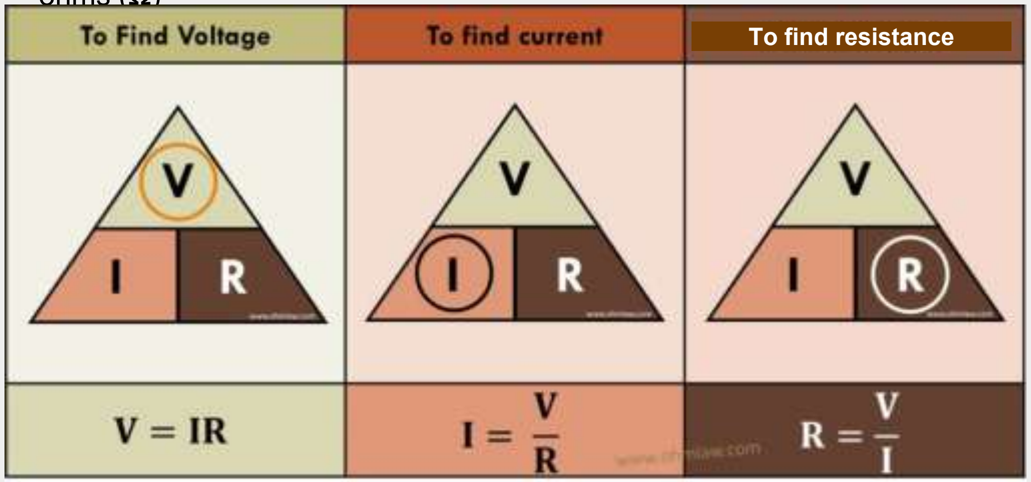




Semi circles = (π x r²) / 2
Rectangle = 50 x (R15 x2)
= 50 x 30
Area = 706+706+1500 = 2912mm²
Volume = 2912 x 60 = 174720mm³

Electronic calculations

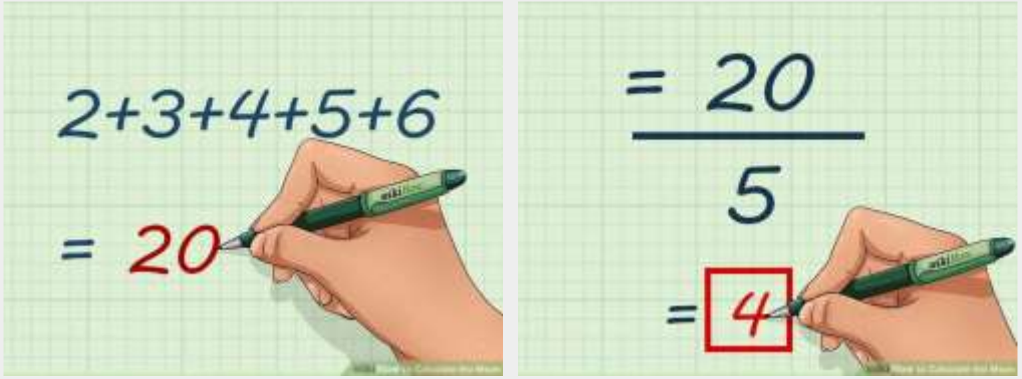
You may be asked to calculate voltage **(V)**, current **(I)** or resistance **(R)**
Units:
Voltage= volts (**V**)   Current = amps (**A**)   resistance = ohms (**Ω**)



Calculating mean

To calculate the mean, add up all the values and divide by the number of values

e.g.



Calculating costs

You may be asked to calculate the cost of materials etc.

For this, remember that £1 = 100 pence

Example question:
Table A lists the cost per litre of paints. Calculate how many 5L cans of green paint you can buy for £50. Give your answer to the nearest whole can of paint.

£50 x 100 = 5000p [convert pounds to pence]
5000/5.80 = 862.068 [how many litres for cost]
862.068 / 5 = 172.41 [divide into 5 litre cans]
Nearest whole number = ***172 cans***

Colour	Price per litre
Green	5.80
Red	2.32
Blue	1.29

Table A

Calculating percentages:

To calculate the percentage of something you divide it by the total
E.g. *You have 500mm of steel, you have cut off 3 lengths of 150mm. What percentage of the material has been waster?*
150 +150+150= 450mm   500mm - 450mm = 50mm
50/500 = 0.1
0.1 x 100 = 10%

Calculating ratios:

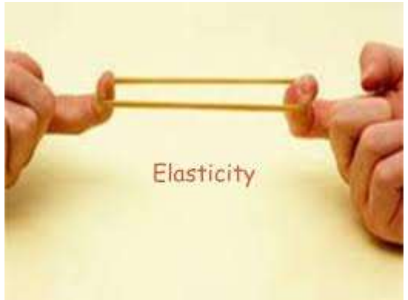
A ratio is a mathematical term used to describe how much of one thing there is in comparison to another thing.
Example:
In a bag of 20 sweets, there are 8 blue sweets and 12 pink sweets. What is the ratio of blue to pink sweets?
8 blue : 12 pink = 8:12   common factor of both is 4
8/4 = 2   12/4 = 3
Ratio is **2:3**

Materials

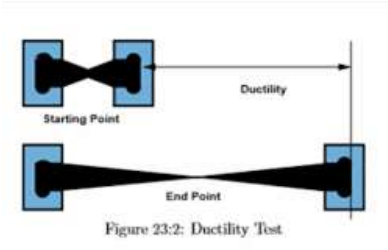
Material properties Knowledge organiser

Material properties are broken down into two main categories:

- **Physical properties** (the properties before it is used, appearance, conductivity etc)
- **Working properties** (how the material behaves)



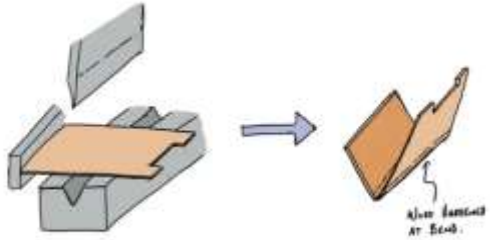
Elasticity
The ability to regain its original shape *(e.g. rubber)*



Ductility
The ability to be stretched without breaking *(e.g copper stretches in wire)*

Malleability
The ability to be pressed, spread out or hammered *(e.g. lead can be easily shaped as it is malleable)*

Hardness
The ability to resist scratching, cutting or wear and tear *(e.g. high carbon steel drill bits don't get worn down by drilling into other materials.*

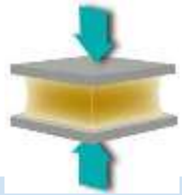


Work hardening
When the properties of a material change due to working *(e,g bending a sheet will make it stronger at the joint)*

Brittleness
Will snap easily and not bend *(e.g. glass)*

Toughness
Is resistant to breaking and bending *(e.g. cast iron)*

Tensile strength
Retains strength when stretched.



Compressive strength
Retains strength when under pressure, *e.g. concrete.*

Corrosion resistant
It will not corrode in its environment (e.g. doesn't rust)

Non-toxic
Is not harmful to humans (e.g. *non-toxic paint is used on baby toys)*

Shiny/ High lustre
When a material is very shiny and reflects light well. e.g. gold or brass when polished.

Matt finish
When a material does not reflect much light and appears dull

Density
How solid a material is. *(A denser material will weigh more than a another material of the same size)*

Conductivity
How well a material conducts heat (thermal conductivity) or electricity (electrical conductivity)

Metals Knowledge organiser

Types of metal

Metals generally fit into 2 categories:

- **Ferrous metals**
  These **contain iron**. This means that they are **magnetic** and will **rust** (unless they have corrosive resistant properties e.g. stainless steel)
- **Non-ferrous metals** do not contain iron

And the subcategory:

- **Alloys** (these are made up of ferrous and non-ferrous metals)

Ferrous metals

Ferrous metals are never 100% iron as iron is too soft to use on its own, so other elements are mixed with it.
You can easily identify a ferrous metal as iron **corrodes** (rusts), so anything with rust on the surface (**oxidation**) must contain iron. Also, iron has **magnetic** properties.

	Material	Properties	Common uses	Made up from
	**Mild steel**	• Good tensile strength • Good toughness • Corrodes easily	Used for many products such as: • PC carcasses (body frames) • Xboxes, etc • Fences • Signs • Structures e.g. bridge	• Iron • 0.1-0.3% carbon
	**High-carbon steel** *(or tool steel)*	• Tough • Hard • Can be brittle	Tools such as: • Saw blades • Drill bits • Tap and die	• Iron • 0.5-1.5% carbon
	**Stainless steel**	• Corrosive resistant (doesn't rust) • Tough	• Medical instruments • Cutlery	• Iron • Nickel • Chromium
	**Cast iron**	• Good compressive strength	• Drain and manhole covers • Engine blocks	• Iron • 2-6% carbon

For material property key words, see your **material properties** knowledge organiser.

Key word	Definition
Oxidisation	When a metal **containing iron** reacts with **oxygen** in the air. **Rust** on the surface of a metal is evidence of this. *(When rust is present on the surface, oxidisation has occurred)*
Fabricate	To shape and join materials to make a product *(Mild steel is easy to fabricate using many different methods such as welding)*
Extract	To remove from something else. Metals are extracted from the earth by digging them up.
Refine	Metals are refined by separating them from others into a **pure metal.**
Corrosion	The breaking down of a metal due to chemical reactions e.g. rust. This causes its physical appearance to change. *(To corrode/is corrosive/ corrosion is visible by the evidence of rust)*
Tarnish	When a surface loses its colour/brightness/shine *(e.g. silver tarnishes easily so needs polishing)*
Galvanise	The process of coating a ferrous metal with zinc to protect it against corrosion

Non-ferrous metals

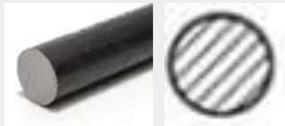
Non-ferrous metals do not contain iron. They have different properties and many different uses. Non-ferrous metals mostly have a much greater **resistance to corrosion** than ferrous metals and are **not magnetic**. However, as they are not as common as iron (except aluminium), non-ferrous metals tend to be a lot **more expensive to** refine from their ore. They are also more **expensive to** fabricate compared to iron.

	Material	Properties	Common uses	Made up from
	**Aluminium**	• Light • Soft • Malleable • Corrosion resistant • Non-toxic • Polishes well	• Good for alloys • Products used outside • Aircrafts • Ladders	• Aluminum
	**Lead**	• Ductile • Malleable • Heavy	• Roofing • Batteries	• Lead
	**Copper**	• Good electrical and heat conductor • Ductile	• Piping • Electrical wiring	• Copper
	**Gold**	• Soft • Malleable • Tarnish/corrosion resistant • Good conductor of electricity	• Jewellry • High-end stereo connections • Circuit boards contact points	• Gold
	**Brass**	• Hard • Corrosion resistant	• Musical instruments • Ornamental products	• Copper • Zinc
	**Titanium**	• High strength • High corrosion resistant • Low density • Ductile • High shine (lustre)	• Aircrafts • Spacecrafts • Missiles • Prosthetic limbs	• Titanium • Often alloyed with other metals
	**Zinc**	• High corrosion resistance • Good conductor • Very weak • Poor strength to weight ratio • Low melting point	• Used to galvanise other metals (such as iron) • Batteries	• Zinc

Standard forms

Metals are ordered in the shape required for manufacturing.

The most common metal forms ordered are **extrusions.** These are a fixed sectional shape that is continued for a long as desired:

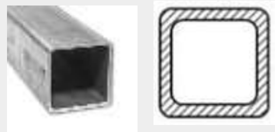


Round section/ bar

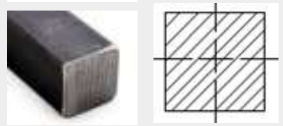
Round tube section

L channel/ angle section

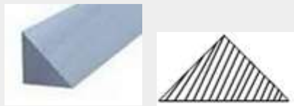
U channel section



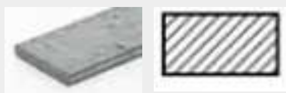
Square tube/ box section



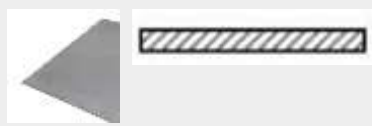
Square section



Chamfered section



Flat bar



Sheet

Alloys

An alloy is a **mixture** of elements that usually have a metal as the main part (**parent metal)**. Alloys were developed to create different properties than those available in pure metals. By heating up and mixing different metals you can create new metals with different properties.

	Material	Properties	Common uses	Made up from
	**Brass**	• Hard • Corrosion resistant	• Musical instruments • Ornamental products	• Copper (parent) • Zinc
	**Bronze**	• Harder • More corrosion resistant • Easier to melt and cast	• Axe heads • Statues Bronze age: 2500-800 BC	• Copper (parent) • Tin)
	**Stainless Steel**	• Corrosive resistant (doesn't rust) • Tough	• Medical instruments • Cutlery	• Iron (parent) • Nickel • Chromium
	**Duralumin**	• Lightweight • Strong • Extremely corrosion resistant	• Car parts • Air craft parts	• Aluminium (parent) • Copper • Magnesium • Magnese

Alloying agents

Modern Engineers use different alloys to change the properties of materials.
These are commonly used alloying elements in modern-day practice and what properties they can add to an alloy:

Nickel:
Increases strength,hardness and resistance to corrosion

Chromium:
Increases hardness, toughness and resistance to corrosion.

Vanadium:
Increases toughness of steel and wear resistance

Origin

Metals come from **ores** which are naturally occurring rocks that contain metals.
Iron ore is used to make iron and steel.
This material source is **non-renewable**, meaning that once it has been mined it can not be replenished and will eventually run out.

Some metals are more difficult to **extract** from the earth and other metals they are mixed with. This can make them much more expensive to **extract** and **refine**.

Finishes

Finishes are applied to surfaces to **protect** them and/or improve the **aesthetics** (e.g. colour, shine etc). Sometimes they are used to add **texture** (e.g. for grip)

Plastic dip coating

Used mainly on **steel.** Metal is heated and dipped into plastic powder. Good for anti corrosion and a range of colours for aesthetics.

Anodising

Aluminium is placed in an acid bath and an Electric current is passed through and coloured dye added.

Painting

Creates a barrier for corrosion resistance. Is prepared first with a **primer**. Needs regular maintenance

Blueing

Steel is heated then dipped in oil. This creates a anti-corrosion layer which is usually blue/black in colour

Powder coating

Similar to dip coating but the powder is sprayed on. This is used more in industry and mainly for white goods e.g. washing machines.

Galvanising

A **ferrous metal** is coated in a thin layer of zinc to protect it from corrosion. Use on street lights and fences. Has a durable and speckled finish.

Enamelling

High temperatures are used to melt glass onto a metallic surface for corrosion resistance and aesthetic appeal. Used for the tin mug and jewellery.

Plastics Knowledge organiser

Types of plastic

Plastics generally fit into two main categories:

- **Thermoforming** plastics (or thermoplastics)can be re-shared when re-heated and are therefore re-mouldable. They are therefore also recyclable. There are no links between polymer chains in a thermoplastic.

- **Thermosetting** plastics are joined across polymer chains, which gives them a strong bond between the monomers. Thermosetting plastics cannot be re-heated and re-moulded like thermoplastics.

Thermoplastics (p49-51)

Picture of use	Material	Properties	Common uses
	**Acrylic**	• Hard-wearing • Brittle • Shiny • Range of colours	• Signs • Glass substitute phone covers • Baths
	**HIgh Impact Polystyrene (HIPS)**	• Tough • Rigid • Cheap • Range of colours	• Toys • Cutlery dividers • Draw organisers
	**PVC**	• Hard-wearing • Cheap • Matt or shiny	• Doors and windows • Waste pipe • Electric tape • Plumbing fittings • Medical industry
	**Nylon**	• Low friction	• Door runners • Gears • washers
	**ABS**	• Rigid • Abrasion resistant • Impact resistant	• Power tool casings • Crates • Lego

For material property key words, see your **material properties** knowledge organiser.

Key word	Definition
Crude oil	Crude oil is a finite resource that is found in the Earth's crust
Monomer	Single plastic molecules
Polymer	A chain of plastic molecules. The word ‘polymer’ often used instead of ‘plastic’
Polymerisation	The industrial process used to create plastics from naphtha
PVC	Polyvinyl chloride
uPVC	Unplasticised polyvinyl chloride. A hard form of PVC

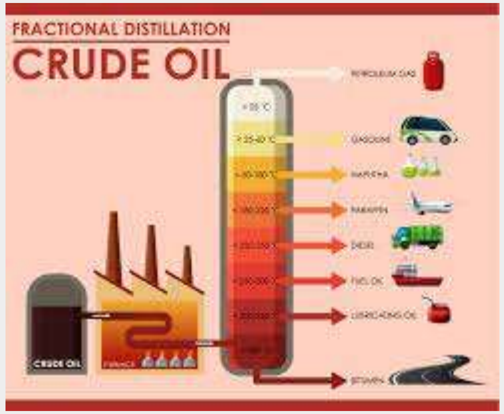
Thermosetting plastics

Picture of use	Material	Properties	Common uses
	**Epoxy resin**	• Rigid • Durable • Heat resistant	• Laminating • Skateboards • Printed circuit boards
	**Urea formaldehyde**	• Smooth finish • Range of colours • Heat resistant	• Electrical switches • Plug sockets • Door handles
	**Melamine formaldehyde**	• Hard • Brittle	• Picnic wear • Laminates for kitchen worktops

Origin (p48-49)

[explanation of where plastics come from]

Chemicals derived from crude oil are used to make plastics. Crude oil is extracted from the field and transported to a refinery, where it goes through the refinement process called **fractional distillation**.The refining process produces a variety of chemicals, one of which is naphtha. The polymerisation process is then used to further process naphtha to manufacture plastics.



Finishes (p58)

Finishes are applied to surfaces to **protect** them and/or improve the **aesthetics** (e.g. colour, shine etc). Sometimes they are used to add **texture** (e.g. for grip)

Self finishing

When a material does not have to go through another process to finish it

Glossy, smooth finish

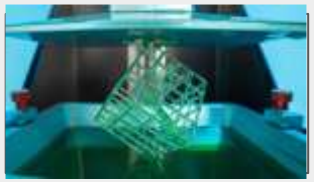
Mould with a smooth surface on interior

Rough, textured finish

Mould with textured surface on interior

After cutting or sawing

This process would leave a rough edge with plastic burrs and may need smoothing down.



After 3D printing

Made from plastic wire that leaves ridges around the product.

Composites Knowledge organiser

A Composite is when **different materials are joined together** to make a **new material**

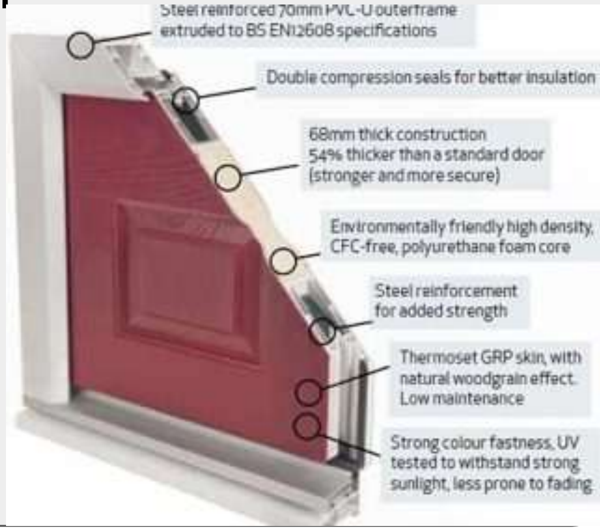
Composites are made to gain and **combine the properties** of different materials that have been added together, e.g. to make a stronger, more lightweight material.

Note: an alloy is not a composite material as this creates a chemical change.

Keywords:
Composite: when different materials are joined together to make a new material with enhanced properties

Composite front door

These doors have a polyurethane core with steel reinforcements, sandwiched between two outer layers of GRP *(see below)*



Man-made / manufactured boards

Plywood, MDF and chipboard are made by combining wood sheets/chips/ dust with resin.
These manufactured boards can be made much larger than natural timber boards and have a greater resistance to warping, twisting, splitting etc ans they do not follow the natural wood grain.

Products made manufactured boards: cheap furniture, laminated kitchen worktops, underflooring, etc.

GRP

GRP is Glass Reinforced Plastic. This is where fibreglass is layered up with resin into moulds and creates a hard material when cured. As the fibreglass is flexible like fabric, it can be layered up into moulds with complex shapes

Properties: High corrosion resistance, high tensile strength (more than steel), lightweight, non-conductive and chemical resistant.

Products made from GRP include: boats, storage tanks, PPE

Carbon Fibre

Carbon fibre is similar to GRP, as a textile-like fibre sheet which is layered up with epoxy resin to create a complex shape when cured.

Carbon fibre is known for its black, woven, shiny appearance.

Properties: lightweight, tough, high tensile strength to weight ratio, expensive,

Products made from Carbon Fibre include: race cars, automotive and space applications, sport equipment, expensive bike frames

A **Smart material** is a material that changes it properties in response to an external stimuli (e.g. heat, light, sound or electrical current)

Keywords:

Thermo: From the Greek word for **heat**

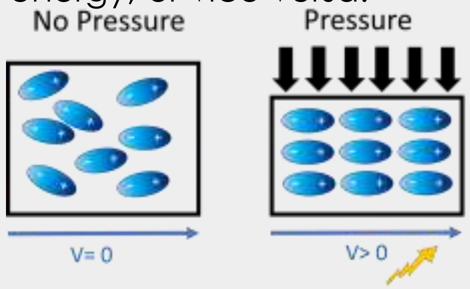
Hydro: From the Greek word for **water**

Photo: From the Greek word for **light**

Chromo: From the Greek word for **colour**

Piezoelectric

Piezoelectricity is the process of using crystals to convert mechanical energy into electrical energy, or vice versa.



Products: microphones, lighters

Thermochromic pigment

These pigments are added to materials to make them change **colour** when **heat** is applied, and **change back** when cool

Products: thermometers, heat warnings e.g. baby spoons

Hydrochromic pigment

These pigments are added to materials to make them change **colour** when **liquid** is applied, and change back when **dry**

Products: Colour changing car paint. Moisture detectors

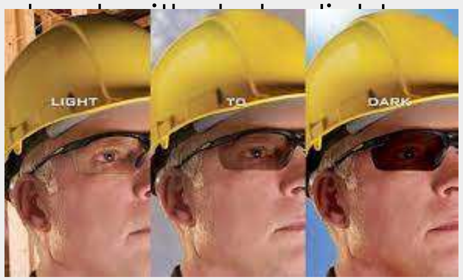
D3O

This material has high impact absorption and is used for impact protection.

Products: Protective sportswear e.g. shin pads

Photochromic pigment

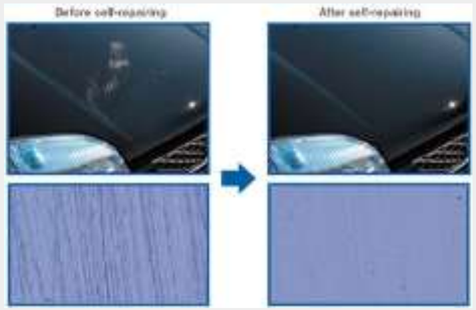
These pigments are added to materials to make them change dark when bright light is present, and change



Products: welding goggles, sunscreens

Self-healing materials *(e.g. self healing paint)*

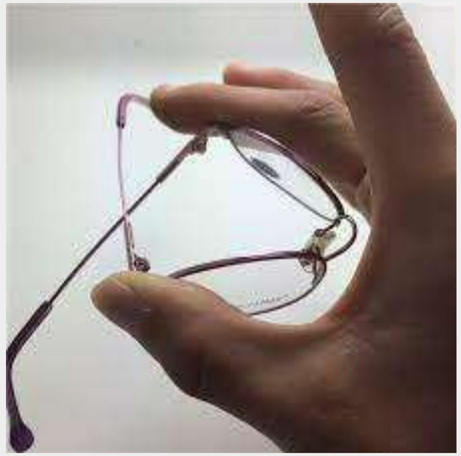
These are materials that can heal themselves without human influence.



Products: Kawasaki motorcycle paint

Shape memory alloys

These move in response to an external stimuli, e.g. they can be bent out of shape then return to original shape when heat/ electricity is applied



Products: Glasses frames, dental braces, windows that close in the heat,

Electronic components Knowledge organiser

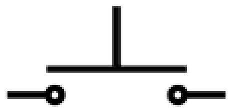
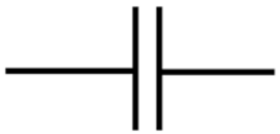
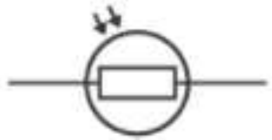
WJEC Engineering textbook p162-163

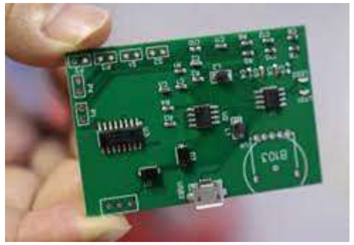
There are many electronic components that make up circuits.
These are **some** of the components that you may be tested on in your Engineering exam.

When designing and drawing circuits, circuit symbols are used to identify the components.

Useful websites:
Technology student

BBC bitesize

Component photo	**Component name**	**Purpose in a circuit**	Circuit symbol
	Resistor	To limit the current and to control the flow of current to other components	
	Push switch	To turn a circuit on and off	
	Capacitor	It stores and releases electricity in a circuit.	
	Light dependent resistor (LDR)	The resistance of a LDR depends on light intensity.	
	Lamp	An electrical current heats the filament in a bulb so that it gives out light.	
	Light Emitting Diode (LED)	Produces light when electricity passes through it (in one direction only)	
	Integrated circuit (IC)	performs high-level tasks such as amplification, signal processing, or calculations	



Components are often attached to a **Printed Circuit Board (PCB)** which is made from Epoxy resin, a thermosetting polymer which is a good electrical insulator.

Key words:
Voltage: the power supply of the circuit, the push (e.g 9 volt battery)
Current: The amount of electricity flowing around the circuit
Resistance: How the current is slowed down by econdountering things in the way e.g, wires and components.

Calculations: OHM's law

Voltage (V)= current x resistance

Current (I) = $\frac{\text{voltage}}{\text{resistance}}$

Resistance (R) = $\frac{\text{voltage}}{\text{Current}}$

Units of measurement:
Voltage = volts (V)
Current = amps (A)
Resistance =ohms (Ω)

Testing materials

Materials are tested so that their properties can be identified and the correct material is chosen for a use.

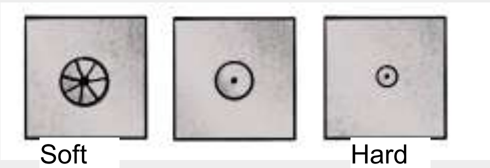
Other links:
https://technologystudent.com/joints/matsind1.html

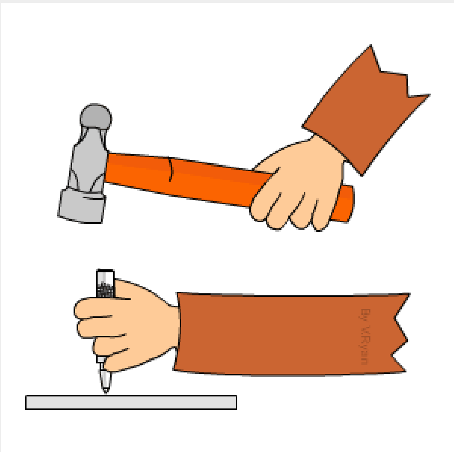
Hardness test

Hardness is the ability to withstand scratching, wear and indentation

Workshop test:

- Using a centre punch to 'indent' the surface of a material, is a basic test. Different materials require a different amount of force to form an indent.
- **Result:** The harder the material is,the smaller the indentation will be



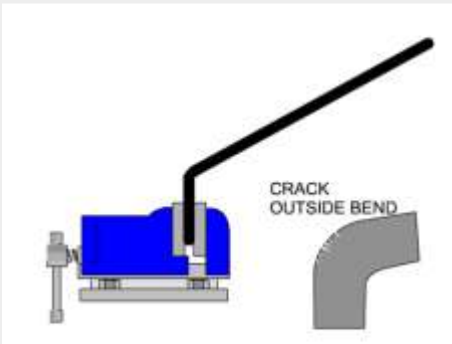


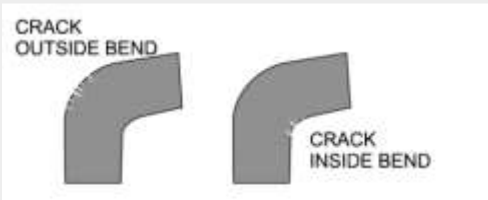
Ductility and Malleability test

Ductility is the ability of a material to change shape (deform) usually by stretching along its length

Workshop test:

- A piece of tube is placed over a piece of material and used as a lever. The material is folded to 90 degrees.
- **Result:** Cracks / damage on the **outside** of the bend represents a **lack of ductilit**y. Cracks / damage on the **inside** of the bend represents a **lack of malleability**.



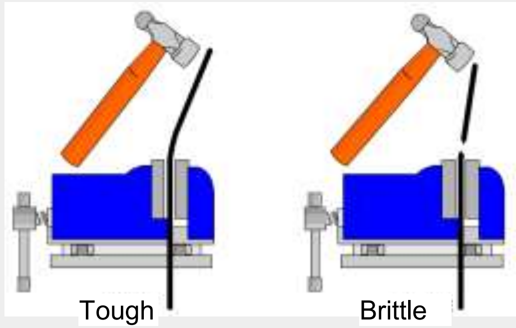


Toughness test

Toughness is the ability of a material to absorb sudden shock without breaking or shattering.

Workshop test:

- hit a sample of material with a hammer, whilst it is secured in an engineers vice.
- **Result:** If it survives the blow, without bending too far, it can be said to be tough. If it shatters, it can be said to be brittle.



Conductivity test

Conductivity is the ability of a material to conduct electricity or heat

Workshop test (heat conductivity):

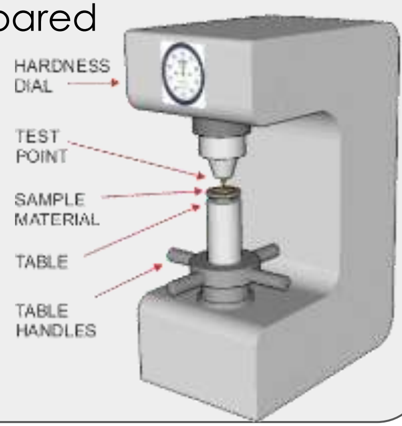
- Put a bunsen burner at one end of the material and a thermometer at the other. Time how long it takes to get to a chosen temperature.
- **Result:** The quicker it takes, the better that material is at conducting heat

Testing in industry

Industry testing is very similar, but highly accurate machines are used to apply pressure and given numerical results that can be compared

For example, in this industrial hardness test:

- A sample test material is clamped on the table. The table is moved upwards until it comes in contact with the 'test point'. The dial is set to '0'.
- The pressure in increased and the diameter of the indent made is measured. This gives a measure of the samples 'hardness'.



Processes, tools and equipment

Processes vocabulary Knowledge organiser

***Process**: A series of steps within an activity which are followed to achieve an end goal*

Preparation

Marking out: using tools (e.g. engineer's blue, scriber, steel rule)to mark out a material from a plan

Scribing: The process of using a **scriber** to mark a line onto a workpiece/material

Annealing: heating a metal to change its physical properties which makes it more ductile and easier to work with.

Manufacturing processes (making activities)

Wasting: Processes which **remove** material

Turning: Using a **centre lathe** to reduce the diameter of a part

Milling: using a **vertical milling machine** to cut or shape metal using a rotating tool

Drilling: using a drill bit (on a pillar drill or centre lathe)to remove a circular hole

Filing: removing edges of a material using a **file**

Cutting: removing part of a material by cutting with a tool e.g. hacksaw, junior hacksaw, tin snips, etc.

Kurling: Adding a textured finish to a cylindrical part using a **knurling tool** on a **centre lathe** to provide grip to a part.

Tapering: Reducing the diameter of a part down towards a point.

Quenching: rapidly cooling a metal to change its molecular structure and make it harder

Finishing: *The process of removing swarf, scratches and imperfections from a product after manufacturing.*

Polishing: Applying **polish** to make the material **shiny**

Sanding: Removing rough or scratched surfaces using sandpaper (wood) or wet and dry paper (metals and plastics)

Painting: applying a paint to a material, which can be water or oil based

Galvanising: Dipping **steel** into molten **zinc** to protect it from rusting

Anodising: Dipping **aluminium** into an acid bath with an electric current flowing through. This is used to add a protective and coloured layer.

Bluing: Dipping steel into hot oil to protect it from corrosion, scratching and reduce glare.

Fabricating: Processes which **join** materials

Soldering: Either the joining of electronic components to a PCB (printed circuit board), or the joining of metals by melting a low temperature metal (solder) to create the joint.

Welding: joining metals together using a welding machine which is electrically powered (spot welding/ arc welding/MIG welding/ TIG welding)

Brazing: Joining steel to itself or other metals using a melted lower temperature metal e.g. brass

Joining: joining two materials together using fixings, e.g. nuts and bolts, rivets, etc.

Marking out tools Knowledge organiser

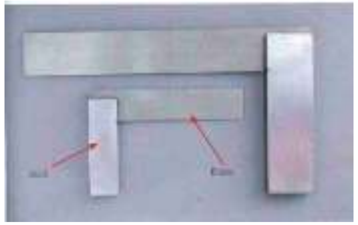
Key words: **Scribing** = to mark out

Engineer's blue

A **liquid** that can be painted onto a surface of metal that you can **scribe through** to create a thin line

Engineer's (tri) square

A tool for **scribing 90° lines** on a section of material. The stock is placed on the side of the material and the blade rests on top**.**



Centre punch

For marking out the **centre of a hole** to make it ready for drilling. This stops the drill bit from skating around the surface and accidentally drilling in the wrong place. They are used with a **hammer**.

Steel Scriber

These come in different shapes but are used to **mark out** metal for machining/ cutting/ drilling etc. The end is made from high carbon steel

Steel rule

Uses for **measuring** out on flat surfaces. It in has increments of 1 mm.

Dividers

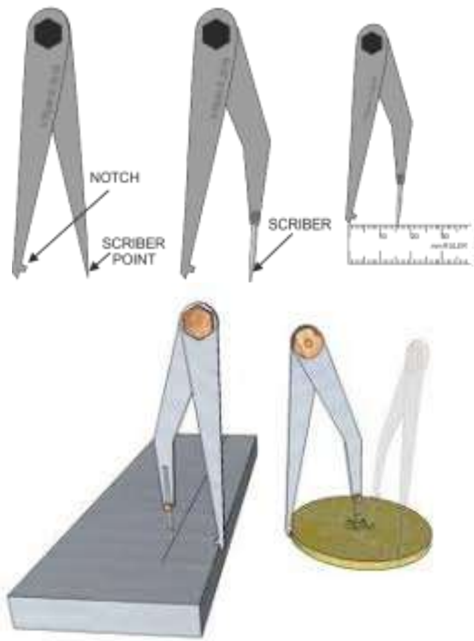
These work very similarly to compasses but instead of a pencil at one end, there is a scriber at both ends. This enables you to scribe **circles** onto metal. You must use a **centre punch** first to help the dividers stay in place at your centre of rotation.

Marking Gauge

Used for marking a line **parallel** to the edge of the surface.

Odd leg Calipers / Jenny Calipers

Used for marking a line **parallel** to the edge of the surface or circle

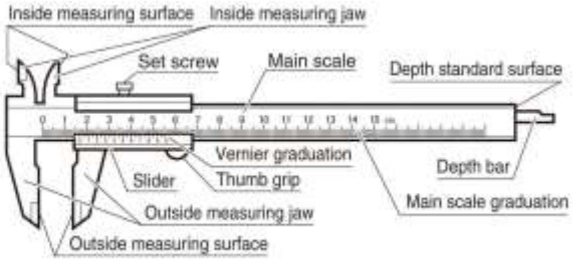


Measuring tools Knowledge organiser

All measuring tools are available in metric (mm) and imperial (inches) but in the UK for Engineering we use metric

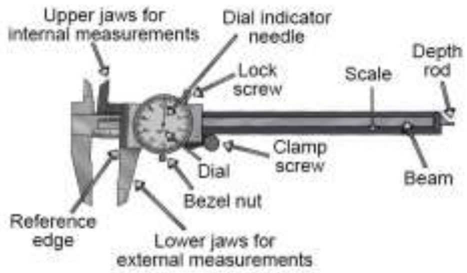
Vernier Callipers

These are used for measuring **outer diameters** or **thickness** of objects. The depth bar can also be used to measure the **depth of holes.** *Can also be digital*



Dial Callipers

Works the same as a vernier calliper but shows additional readings on a dial for each **0.2mm** increment.



External callipers

is used to measure the **external diameter** of an object, or to measure the thickness of an object

Internal callipers

Used for measuring **internal diameters.** These look like dividers but have curved bottoms

Multimeter

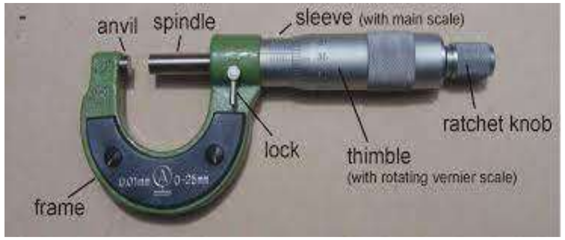
A multimeter is a measuring instrument that can measure multiple **electrical** properties. A typical multimeter can measure voltage, resistance, and current

Steel rule

Used for **measuring** out on flat surfaces. It in has increments of 1 mm or 0.5mm.

Micrometer

Is mainly used to measure external diameters and material thickness. They can measure up to a **hundredth of a millimeter**



Tape measure

Uses for measuring flat surfaces in **metres**

Calculating tolerance
25mm +/- 0.5

This means that the 25mm measurement is allowed to be 0.5mm larger and smaller.

25mm + 0.5mm = 25.5mm
25mm- 0.5mm = 24.5mm

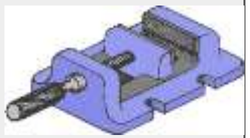
Key words:
metric = measurements in millimeters or metres
Tolerance = how much larger or smaller a part is allowed to be
M8 = Metric 8mm. This type of measurements is used for standard sizing, e.g drill bit sizes
M8x0.5 = This is used to show the measurement of a thread: 8mm diameter and 0.5mm thread pitch

Hand tools Knowledge organiser

Work holding

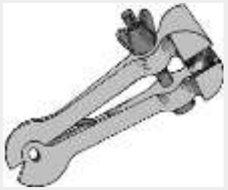
Flat vice / machine vice

Screwed to the pillar drill bed and used to hold work whilst drilling on a pillar drill



Hand vice

useful when working on a drilling machine, or working with small parts that need to be clamped together.

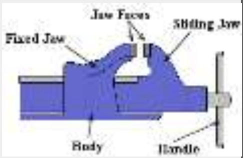


Soft jaws

Slotted onto a engineers vice and used to pretect soft metals from imprints from the vice jaws.

Engineer's vice

Attached to a work bench and used to hold work in place



G-Clamp

Used for general clamping in the workshop. Can achieve high pressure levels

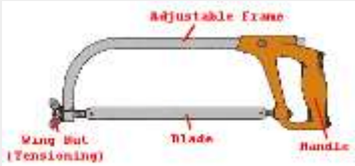
Quick release G clamp

Used for the same purpose as a G-clamp, but has buttons to allow it to quickly open and close

Cutting tools

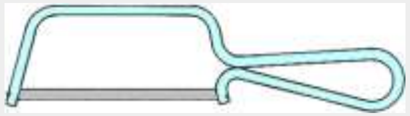
Hacksaw

The Hacksaw is used for cutting materials, and for cutting away waste parts of the work. Most Hacksaws are made from **Low Tungsten Stee**l or **Carbon Steel**, however the more expensive blades are made from **High Speed Steel.** The tension on the blade is formed by the frame.



Junior Hacksaw

The Junior Hacksaw is used with a shorter blade on smaller or thinner pieces of material.



Tap and die

These are used for cutting threads into materials to use with bolts and machine screws. Taps and used with a tap wrench to add a thread to a pre-drilled hole and dies with die holders are used to add a thread to the exterior of a cylinder/rod

Tap wrench

Die wrench/holder

Shears

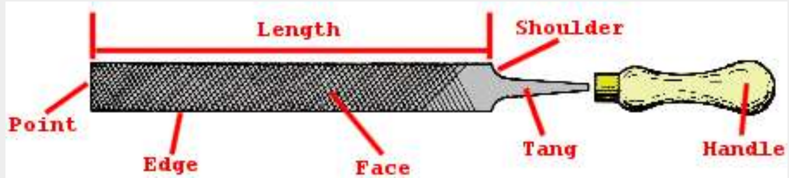
Tin snips

Shaped like scissors, tin snips are used for cutting through thin sheets of metal.

Shaping tools

File

Files are used to square ends, file rounded corners, remove burrs from metal, straighten uneven edges, file holes and slots, smooth rough edges, etc. There are different shaped files: Flat file / round file / square file / etc



Wet and dry paper

This is available in different grades, rough to smooth and is used to sand metal and plastic.

This will remove scratches and bring it to a high shine.

Metal Shears

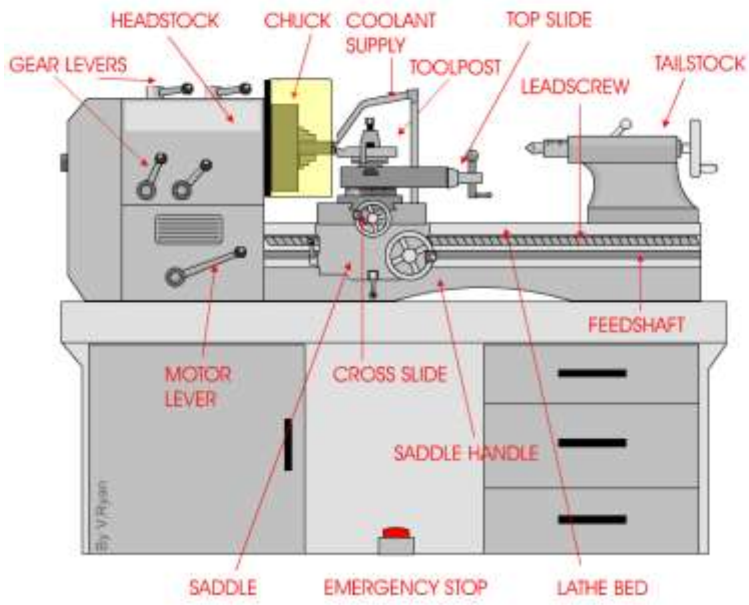
Shears work by holding the metal in place and applying a downwards force with a blade. This is used to cut large sheets of thin metal.

There are different types available for different sized materials and uses

Centre lathe Knowledge organiser

What is a centre lathe used for?

A centre lathe is used to manufacture mainly cylindrical products/ objects. Lathe can be operated both manually (in the workshop) or using CNC in industry.



Fitting tools

The workpiece (material) on a lathe is held in place using a chuck. This uses 3 or 4 jaws to **self-centre** the workpiece as they come together.

A **chuck key** is used to tighten the jaws of the chuck.

Spring loaded chuck key

This has a spring so that it cannot be left in the chuck and cause injury to the user.

4-jaw centre lathe chuck

Useful websites:

[Technology student: centre lathe]

[BBC bitesize]

[DT online: centre lathe]

Safety precautions

- A **risk assessment** must be completed before using this machine.
- Safety goggles and apron must be worn.
- Long hair must be tied back
- Limited persons around the machine e.g. user plus instructor only.
- Workpiece must be securely closed in the chuck.
- Machine guard must be set to the correct position.
- Tools must be sharpened and set up correctly.
- Correct machine speed must be selected.

Common phrases:

Turning:

Reducing the diameter of a cylindrical object.

Facing off:

Ensuring that the **end** of a cylindrical object is flat (perpendicular to its sides)

Parting off:

Cutting the workpiece to a specific length with a specific cutting tool (parting tool)

Taper turning:

Creating a **taper** down the length of the workpiece*(think cone-shaped)*

Knurling:

Creating a **textured surface** on your workpiece

Grooving/ face grooving:

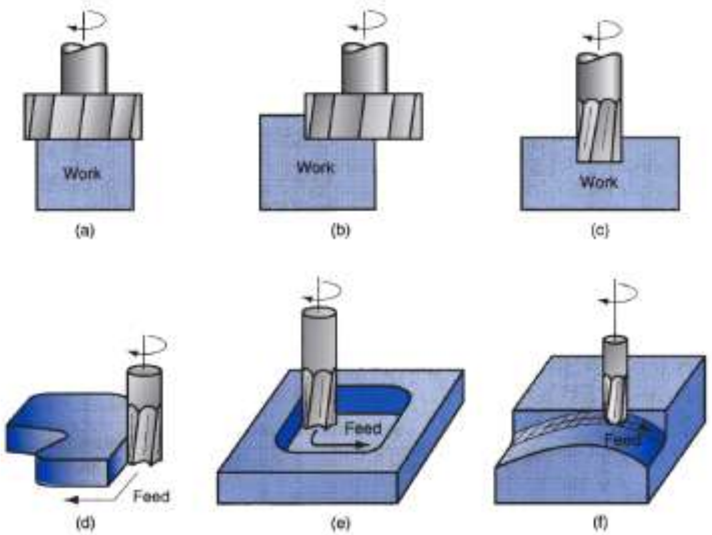
Creating a **groove** on the **external diameter** or **face**

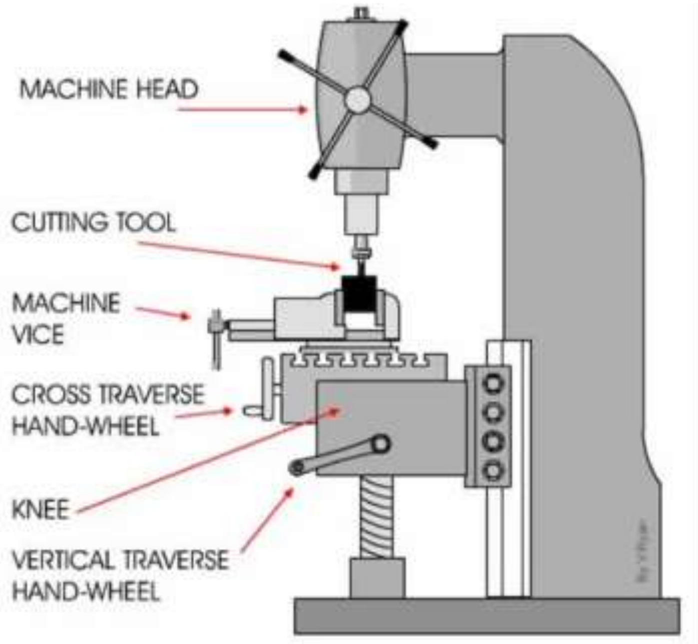
Boring:

Enlarging an existing hole in a workpiece using cutting tools or a 'boring bar'

Vertical milling machine Knowledge organiser

What is a vertical milling machine used for?
This machine uses a rotating cutting tool to produce machined surfaces by progressively removing material from a work piece.
The machine vice is controlled using handles to allow it to accurately move along 3 axis.
More advance machine can be partly or fully automated.



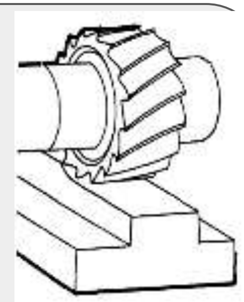


Different sizes and shapes cutting tools are used to remove material as needed. By controlling the X,Y & Z axis, the machine can be used to accurately cut out areas such as slots.

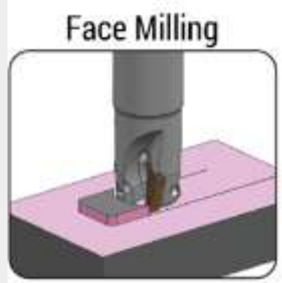
Safety precautions
- A **risk assessment** must be completed before using this machine.
- Safety goggles and apron must be worn.
- Long hair must be tied back
- Limited persons around the machine e.g. user plus instructor only.
- Workpiece must be securely closed in the chuck.
- Machine guard must be set to the correct position.
- Tools must be sharpened and set up correctly.
- Correct machine speed must be selected.

Useful websites:
Technology student: vertical miller
BBC bitesize
DT online: vertical milling machine

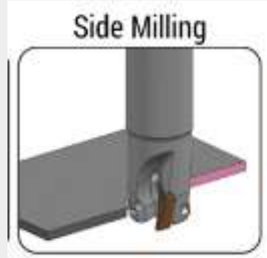
Common operations:



- **Plain milling/ surface milling:**
(this the the most common operation) this is performed to the flat, horizontal surface, parallel to the cutter.



- **Face milling**
Removing material from the top face of the workpiece



- **Side milling**
Removing material from the side of the workpiece

- **Shoulder milling**
Removing material from the side of a workpiece

- **Boring/ hole expansion drilling**
Enlarging an existing drilled hole

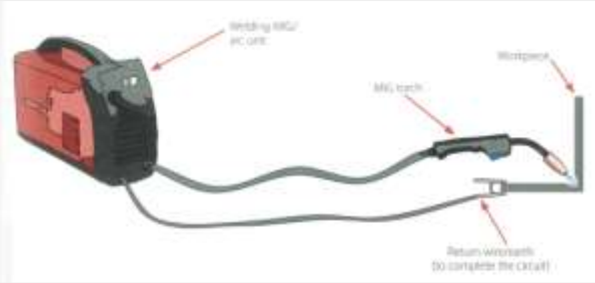
- **Tapping**
adding a screw thread to a pre-drilled hole

Metal Joining processes (permanent) Knowledge organiser

WJEC Engineering

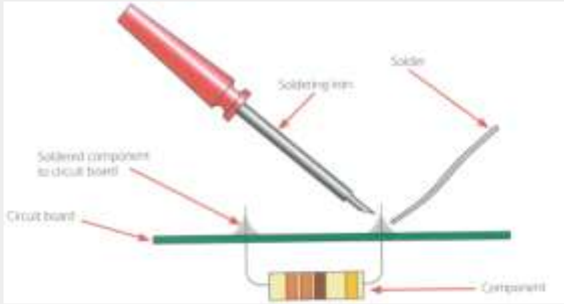
MIG Welding

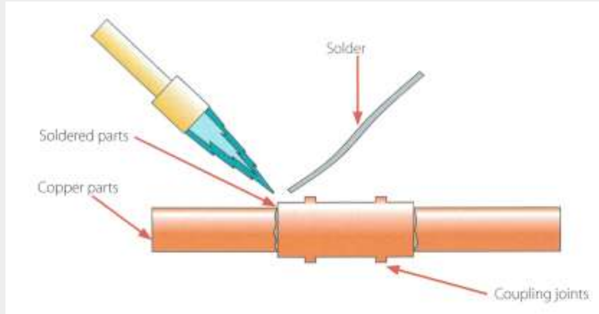
Metal Inert Gas welding for joining smaller, thinner pieces of steel.



Soldering

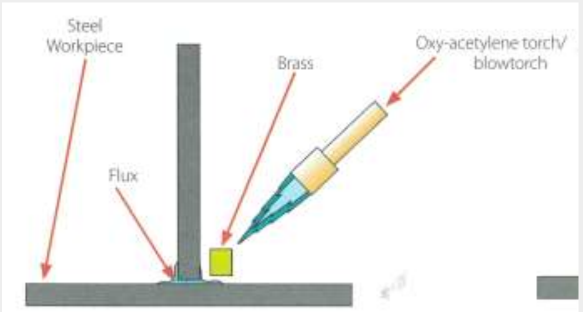
Uses a tin alloy to solder wither electronic components to a PCB *(printed circuit board)* or soldering copper pipe together





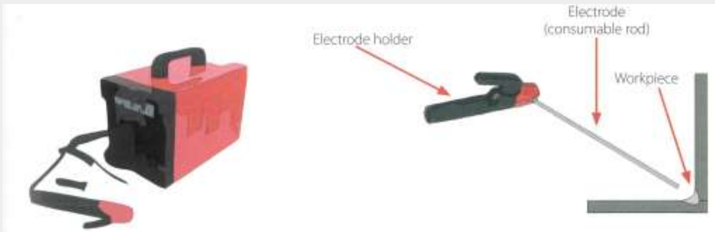
Brazing

Joining steel to steel or other metals. Uses a brass filler metal called a **brazing rod**



Arc Welding

Used to join steel in medium to large projects, with thicker material. The consumable electrode is pushed against the joint and creates a current to join the metals.



Key words:

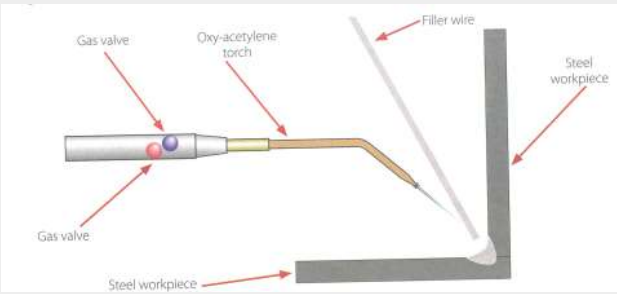
Capillary action= Where solder flows into gaps when heated

Filler metal: the metal used to fill the joint between two materials, e.g. solder

Flux= Applied to a joint prior to welding or soldering. It chemically cleans the joint as it melts and helps the filler material to flow into the joint.

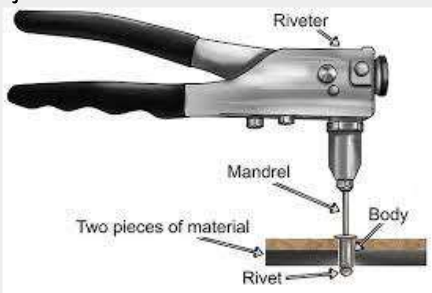
Oxy-Acetylene Welding

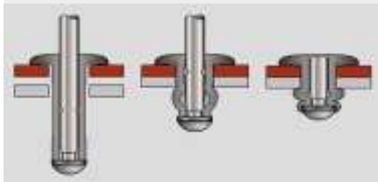
A high temperature welding process used to join steel by melting the two pieces together and pushing in a filler wire to the joint.



Pop riveting

Thinner metals can be joined using this process where a rivet is pushed through a hole in both materials then squeezed to expand and hold the joint





Metal Joining processes (temporary) Knowledge organiser

WJEC Engineering

Nuts, bolts and screws

The sizes for these are **metric** e.g. M8 which means 8mm

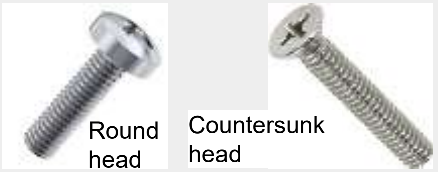
Machine screws are used in pre-threaded metal holes and have a flat bottom, unlike wood screws.

Bolts are used on drilled holes. They pass all the way through and are secured with nuts. **Hex bolts** are the most common

Washers are used to distributor the load/ pressure applied on a material from a nut and bolt.

Nuts are used to secure a bolt or machine screw in place. Nylon lock nuts have piece of nylon in to prevent them from vibrating loose

TYPES OF SCREWS



TYPES OF BOLTS

TYPES OF WASHERS

Split washers are designed to stop nuts from vibrating loose

TYPES OF NUTS

Temporary vs permanent joining methods

Temporary joints:

- ☑ Can be **dismantled** without breaking the assembled parts.
- ☑ Is useful when frequent **assembly** and **disassembly** is required.
- ☑ Often easier and more cost-effective to carry out **inspection**, **maintenance** and **repair** as parts can be disassembled without breaking.
- ✗ Lower strength joint
- ✗ Often not a leak proof joint

Permanent joints:

- ✗ Cannot be **dismantled** without breaking the assembled parts.
- ☑ Is useful when the joint is intended to stay fixed for **longer**.
- ✗ **Maintenance** and **repair** as more difficult as parts cannot be disassembled without breaking.
- ☑ Stronger joint
- ☑ Mostly create a leak proof joint

Clips

There are lots of different clip fastenings. These are used to temporarily hold parts together for easy disassembly without tools,. Eg. road works signs

Riveting

Riveting (e.g. pop-riveting) is often a permanent method, but as they are made of a dofter metal and can be drill out, they are referred to as temporary too.

Key words:
Fabrication= joining materials together
Assembly: Putting things together
Disassembly: Taking things apart
Dismantle: take apart into separate pieces.

Metal casting processes Knowledge organiser

The process of pouring **molten** metals into a mould is called **casting.**

Advantages of casting are:

- Large hollow shapes can be produced
- Intricate shapes can be produced
- Little to no waste is produced
- A high quality surface finish can be produced (sand casting)

Keywords:

Molten: the **melted** state of metal

Die: A mould made from high carbon steel used in die casting

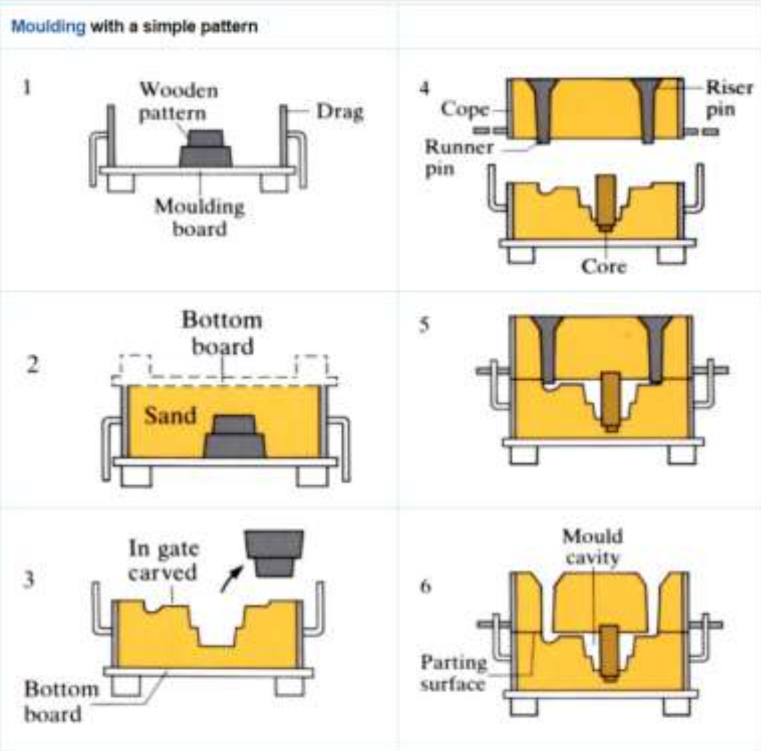
Cavity: empty space

Sprue: Where melted material enters the cavity. This needs to be removed from the finished part.

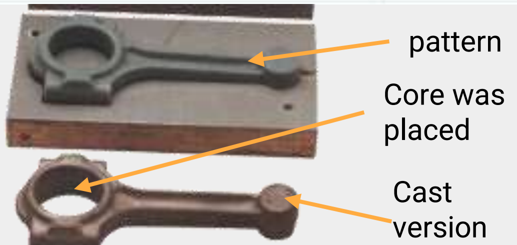
Sand casting

Stock form used: ingots

Material used: *most commonly*



1. A wooden **pattern** is placed inside the **drag**.
2. Fill with **petrabond sand**
3. Turn over and remove **pattern**
4. Place runner and riser pins in the **cope** and fill with **petrabond sand.** Add **core** for hollow parts
5. Place the **cope** on top of the **drag**
6. Remove **runner** and **riser pins**
7. Melt metal and pour into cavity

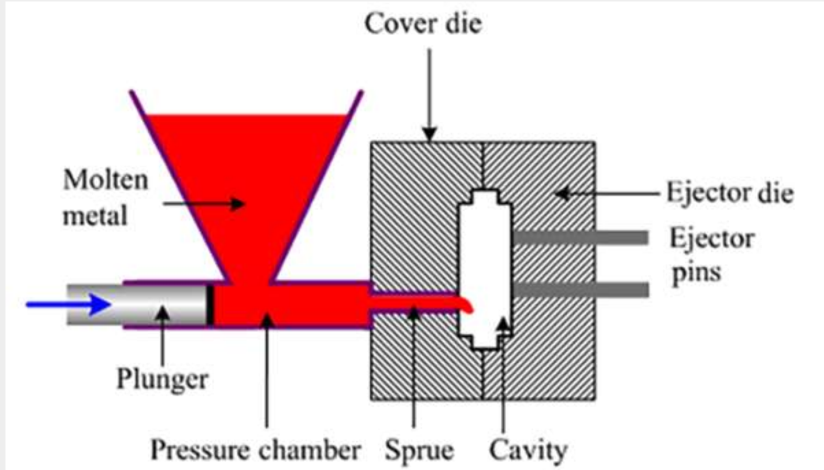


Sand casting is a repeatable process used in batch production, but will leave a textured surface which has to be finished. More suitable for simple, solid parts

Die casting

Stock form used: ingots

Material used: most commonly aluminium



1. A pre-made **die** is fitted on the machine
2. Metal is melted then poured into the hopper
3. A **plunger** pushes the **molten** metal into the **cavity**
4. Mould is allowed to cool
5. **Ejector pins** push the die open and the finished part is removed
6. **Sprue** is cut off.

Die casting is a mass production process which creates **highly detailed** products.

The **die** is made from high carbon steel and produced a self-finished product and can be used repeatedly without losing accuracy, but is **very expensive** to make. This means that dies casting is **cost effective** when used to make large **batches** of a product

Plastic moulding processes Knowledge organiser

Plastics are shaped and moulded in many different ways to create complex shapes. To shape and mould plastics they must be heated until soft then they will harden when they cool.

Plastics are **self-finishing** which means they do not need to be sanded and polished unless they have been cut. The interior surface of the mould used in the process will determine whether the plastic has a textured or smooth finish as well as a gloss or matte finish texture.

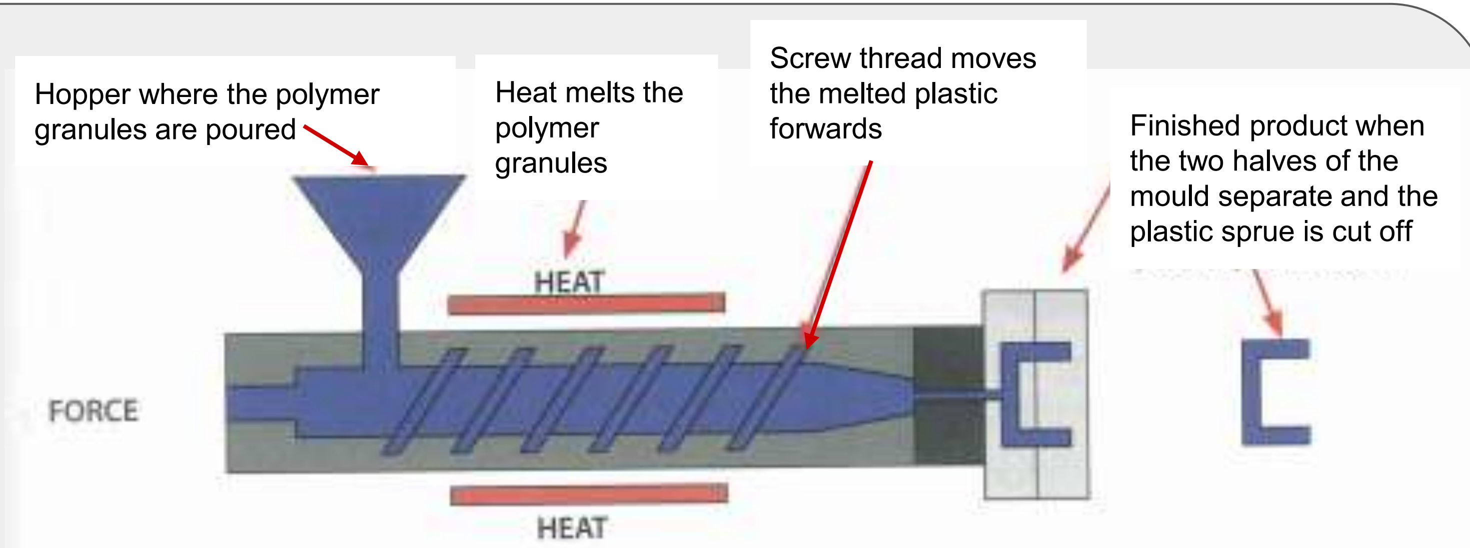
Keywords:
Sprue: the mark on a finished product which shows where the plastic entered the mould

Injection moulding

Stock form used: thermoplastic or thermoset granules or powder

This process involved forcing melted plastic into a mould. This process is **accurate**, good for **high volume production** (e.g. mass production) and produces little **waste.** However it is a very **expensive** process to **set up**.

Products that have been injection moulded need minor finishing, such as trimming the **sprue** or the **'bleed'**(**lines** where the two mould meet).



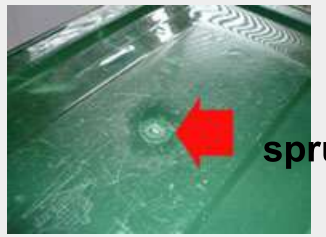
Products made by injection moulding include

Lego blocks

Staplers

Product casings

Identifiers:
- Detailed designs
- Seam line where the moulds halves met
- Varying wall thickness
- Feed points or ejector pin marks



Vacuum forming

Stock form used: thermoplastic sheets

1.

Suitable former is manufactured

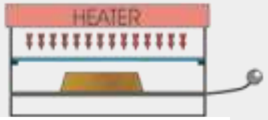
2.

The former is placed in the vacuum former

3.

Plastic sheet is placed above the former and clamped securely

4.



The heater is turned on to heat the plastic sheet

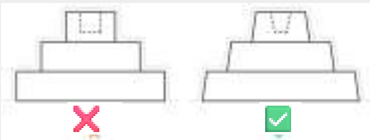
5.

The plastic becomes flexible

6.

The air is pumped out of the area below the plastic and former

The former used for vacuum forming must have angled side (draft angles)to allow it to be easily removed from the finished plastic shape



Products made by vacuum forming include:

Car dashboards

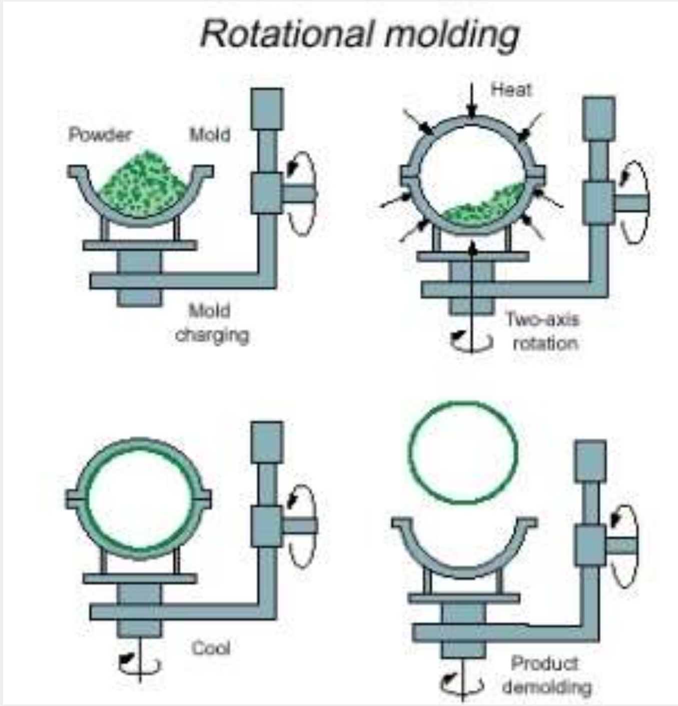
Packaging

Suitcases

Vacuum forming is an inaccurate, low setup and running cost, low-volume process

Rotational moulding

Stock form used: thermoplastic granules or powder



Rotational moulding is inaccurate, low running cost, high set up cost and good for larger objects.

Identifiers:

- Hollow objects
- Seam line where the moulds halves met
- Thicker walls

Products made by rotational moulding include:

Bins and containers

Cones and barriers

Toys

Engineering Design

Renewable Energy

Non-renewable energy is made from fossil fuels. These are non-renewable resources which are burnt to create energy. They cannot be remade once they've been used. Coal, oil and natural gas are all examples of fossil fuels.

Fossil fuels

- ✗ Creates pollution when burned which harms the environment
- ✗ Will eventually run out
- ☑ Cheaper running cost
- ☑ Reliable and consistent source of energy

Renewable energy

- ✗ Expensive set up cost
- ✗ Can be noisy and unattractive for residents (e.g. wind farms)
- ☑ Energy source will not run out
- ☑ Does not cause long term environmental impact

Types of renewable energy

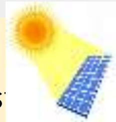
Geothermal power

- ✗ Expensive to create
- ✗ Difficult to find suitable locations (volcanic land)
- ☑ Clean resource (steam)
- ☑ The hot reservoirs within the Earth are naturally replenished, making it both renewable and sustainable.

Wind power

- ✗ Expensive to maintain
- ✗ Can be noisy and unattractive for local residents
- ✗ Is reliant on windy weather
- ☑ Minimal impact on the environment
- ☑ Makes good use of a renewable energy source
- ☑ Can be placed out at sea or on land

Solar power



- ✗ Expensive set up cost
- ✗ Do not work at night
- ✗ Requires good air quality
- ☑ Can absorb normal daylight on a cloudy day but most efficient in sunlight
- ☑ Minimal impact on the environment
- ☑ Makes good use of a renewable energy source
- ☑ Wear out very slowly

Hydro power

- ✗ Can negatively impact on wildlife habitats and fish migration
- ☑ Predictable water levels
- ☑ Reliable = very efficient source of energy

Key word	Definition
Fossil fuels	A fuel formed naturally which is non-renewable e.g. coal, oil and natural gas.
Renewable	A resource which can be replenished naturally
Non-renewable	A resource which cannot be replenished naturally
Energy source	Where electricity and energy is sourced from. This can be a renewable or non-renewable source.
Raw materials	Materials taken and converted into usable material forms
Sustainability	Meeting the needs of the present without affecting future generations
Landfill	An area of land for waste. It is either piled up or buried underground.
Slag	Waste material that is left behind when melting or refining metals
Biodegradable	Materials that can be broken down by microorganisms, such as bacteria and fungi.

Product life cycle is the impact that a product has on the environment throughout its life, from sourcing the materials to when it is finished being used

Extracting raw materials
Renewable/ non-renewable resources
Human and wildlife impact of mining materials?

Refining raw materials
Renewable/ non-renewable energy use to refine materials into usable forms. Pollution from transporting them?

Manufacturing parts
Waste material from manufacturing. Energy type used, pollution from factories

Assembling parts
Fair working rights for workers? Pollution from transporting parts?

Using the product
Single use product? Designed to be repaired by the user? Unnecessary packaging?

End of product life
Recycled? Landfill? Biodegradable?

Existing and future engineering materials and processes

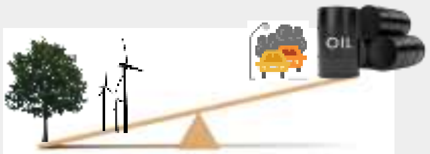
Engineers all over the world are constantly looking to develop new materials and processes that are more **efficient**, **cost effective** and **better for the environment.**

- **Sustainable concrete** is made from fewer materials by using crushed glass, wood chips and **slag** to bulk it out
- **Pollution absorbing bricks** can be used for construction and they act as air filters for the air around the building to reduce air pollution
- **Bioplastics** instead of using crude oil to make plastic. Bioplastics are made from organic materials such as sugar cane, algae or cornstarch. They are 100% biodegradable so that they don't affect the environment when disposed of.
- **Photovoltaic surfaces** are an advanced use of solar panels. The can be in the form of a thin film and be applied to glass to make skyscrapers self-powering
- **Self-healing materials** use carbon in the atmosphere to repair themselves when broken. They are still in the early stages of development but could be used for medical, structural and aeronautical materials
- **Smart factories** use computer-integrated manufacturing and robotics to adapt and change processes through live monitoring, without human input.

Sustainable engineering

➔ Creating products that are made from **sustainable sources**


➔ Creating products using **minimal or renewable resources** during manufacture and transport



➔ Creating products that can be recycled fully

Recycling

- Millions of tonnes of materials are used every year to produce products, from building materials to plastic packaging
- Many materials end up in a **landfill** or thrown into the **ocean** into being **reused** or **recycled**
- **ISO 15270:2008** deals with what percentage of plastics have to be recyclable for all new products (it is international law for all manufacturing companies)

Recycling logo (mobius loop) This shows if a product or part of the product **can be** recycled (plastic products, packaging)

Forest stewardship council® (FSC) Show that a forest product (e.g.wood or paper) is responsibly sourced.

Euro Ecolabel shows if a product has conformed to the European standards for sustainability (for products manufactured in Europe)

<u>Recycling plastics:</u>

- Most plastics **can be recycled**
- It takes **a lot of energy**
- It is **difficult to do**

Plastic types have to be stamped onto the product:

<u>Recycling metals:</u>

- Metals are **100% recyclable and reusable** (except for corroded/rusted parts)
- Metals can be **repeatedly recycled** without changing their properties
- Steel is probably the most commonly recycled material.

Anthropometrics and Ergonomics Knowledge organiser

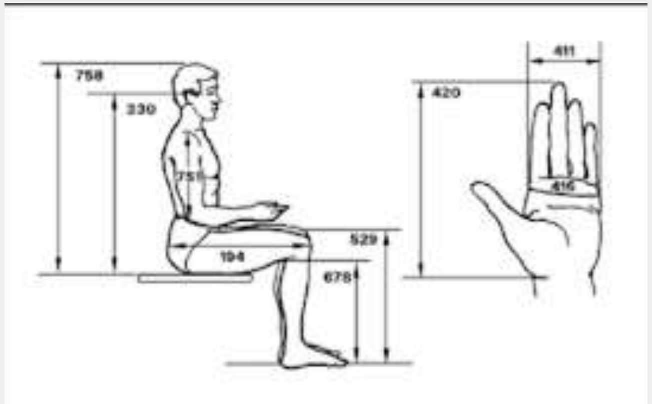
Anthropometrics is data on **human** body size and shape

Ergonomics is any way that a user **interacts** with a product.

Anthropometric data is used in the design of products to improve the ergonomics and make the product more comfortable for the user, e.g. average data on feet lengths are used to ensure that stairs are deep enough to put you feet on.

Anthropometric Data

Anthropometric data is human body sizes and shapes. Thousands of measurements from humans in a set group (e.g. adult males) are used to calculate a **mean**, which is used for designing.



Ergonomics

If it's comfortable to use
E.g. buttons in natural hand positions

Easy to control *e.g. not too heavy for the user or unbalanced*

How it smells *e.g. high quality leather*

Easy/ comfortable to lift

How it feels/ texture (soft, high quality, warm etc)
E.g. metal handles may feel cold to the touch

Intuitive design
E.g. Standard use of colours, buttons in obvious positions etc

User feedback *e.g. lights, vibrations, etc tell the user that they have pressed a button*