

GCSE ENGINEERING 2025 REVISION LINKS

Unit 3 Solving Engineering Problems
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WJEC LEVEL 2 ENGINEERING

REVISION BOOKLET FOR THE UNIT 3 EXAM.

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Name

Teacher Name

Learning Outcome 1: Effects of engineering achievements

Introduction to engineering industry

Engineering is a very exciting, creative and interesting subject to study. There is much to learn but most of this can be covered through practical designing and making activities. Engineering involves:

- Designing products, through drawing, modelling and testing
- Selecting the materials to be used
- Planning making activities
- Making products using a wide range of different equipment, ranging from hand tools, to machine tools, to automated equipment.

There are many different types of engineering industry today ranging from chemical engineering to automotive and electrical, however, to simplify things down this course requires you to look at three different sectors in detail.

Structural Engineering	Mechanical Engineering	Electronic Engineering
• Buildings • Bridges • Dams	• Vehicles • Cranes • Aircraft	• Mobile phones • Personal Computers • Televisions
• Arup • Balfour Beatty • Skanska AB	• Airbus • Ford • BMW	• Apple • Samsung • Dyson

Environmental Issues

In the past the engineering industry has contributed significantly to pollution and environmental damage. One of the main reasons for this is that we, as a society, placed more importance on our needs for material progress rather than environmental issues. This means that we were more concerned with having larger cars, mobile phones and the comforts we associate with modern life than the environmental impact of making, using and disposing of these products. Engineering companies were more concerned with generating profit than reducing environmental impact. Another reason is that we may not have been fully aware of the environmental impact of our manufacturing activities.

As environmental issues have become more pressing, their relative importance to society has increased. This has placed increasing moral and legal responsibilities on engineering companies. A number of different approaches are being used to minimise the impact of their activities on the environment. These include:

- Modifying the design of products
- Recycling materials and components at the end of the products useful life
- Reducing energy requirements to make the products

The 6 Rs of Sustainability		
Reduce Using less material and energy	Repair Extend the life of products rather than disposal	Recycle Reduce use of resources and energy by reprocessing
Reuse Don't dispose of a product if it could be used to fulfil the same use again or a different use	Rethink Review if the need is necessary and the features of the design	Refuse Decline to use products that are not environmentally friendly ²

Reducing material usage and energy consumption

Engineered products are made from materials and components bought from suppliers in standard shapes and sizes. The production of these materials uses both energy and raw materials. For example, most metals are made from metal ores mined from the ground and plastics are made from oil, both of which are finite materials. Changing the form of these raw materials into useful products uses a lot of energy to power the manufacturing processes.

Designing products that use less material or reduce the amount of materials or components needed in a product can help to reduce environmental impact. Products that use electrical systems to operate are designed to be more energy efficient. In addition industries can use more recycled materials in their products, which can help reduce energy consumption as not as much power is required to process recycled materials compared with producing materials from raw materials.

Extending product life

Many products have a limited life span and are usually more expensive to repair than to buy a new product. This means that manufacturers protect their future sales by designing built-in obsolescence into their products.

Extending product life can be achieved by using materials with improved properties. For instance, using coatings to improve the corrosion resistance of products that are exposed to the elements or extremes in temperatures extends their life span. The ability to repair a product can also extend the products life as worn or damaged parts can be replaced.

Disposal

All engineered products today must comply with strict environmental legislation to reduce their environmental impact. For example, the End of Life of Vehicles Directive came into force in Europe in 2000. It gives legal targets for what proportion of a vehicle has to be reused or be suitable for recycling. These targets meant that by 2015, 85% by weight of the materials used in the car had to be suitable for recycling. The responsibility for achieving this target is placed on the company producing the vehicle.

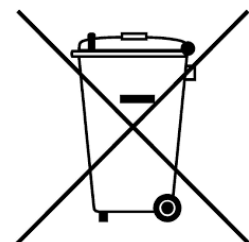
Reuse

Using a component again is preferable to recycling as no energy is required to change the form of the part. Scrap yards are a well established source of parts to repair cars. This is because it is cheaper to buy parts second hand than to buy them new.

Recycling

Recycling involves breaking down or melting material and changing it into a different shape so that it can be used for a different application. Recycling applies to both products at the end of their useful life and to waste generated during the manufacture of the product. Metals, glass and different types of plastic are routinely recycled and are usually marked to indicate which material they are.

Recycling products made from just one material is fairly straightforward, however, most products contain several different materials that need to be taken apart before they can be recycled. Many products can be difficult to separate, which makes recycling difficult. For example, composite materials are a very fine mixture of two or more different types of material that are not normally suitable for recycling.



Energy use in engineering

Engineering industries use large amounts of energy during the production and transportation of their products. Much of this energy is generated by burning fossil fuels such as oil, gas and coal which in turn releases carbon dioxide and contributes to global warming. To reduce their environmental impact many engineering companies have tried to adopt some of the following strategies:

Increasing process efficiency to reduce the amount of energy actually used by powering down or turning off electrical equipment when not in use. This can include machines, computers and lighting. Replacing old machines with more efficient new machines. Insulating the facilities used to heat-treat products, which can reduce the energy needed to heat them by 20%.

Switching from non-renewable energy sources to renewables such as solar, tidal or hydroelectric power. Investing in carbon capture schemes which are designed to offset the carbon produced by planting trees.

Learning Outcome 2: Properties of Engineering Materials

When choosing engineering materials or components it is important to consider the mechanical or physical properties to ensure that the materials will perform their task. The table below shows the most common properties you need to know and their application.

Property	Description & Application
Tensile Strength	The ability to withstand stretching forces. Structural steel is used in many modern buildings to provide a framework for other building materials.
Hardness	Resistance to scratching, cutting, denting and wear. High speed steel is very hard and so is suitable for use in high speed machining operations.
Toughness	Resistance to sudden shock without breaking or deforming. Many plastics are very tough that is why they are used to produce products such as wheelie bins, classroom chairs and buckets.
Malleability	The ability to be permanently deformed in all directions without fracture. Precious metals like silver and gold can be formed into shape by hammering and beating .
Ductility	The ability to be stretched and permanently deformed without breaking. Mild steel is used in the production of car bodies as it can resist the stretching involved in forming processes.
Conductivity	The ability to conduct electricity and heat. Copper is used to produce electrical wiring and water pipes as it is an excellent conductor.
Corrosive resistance	Resistance to oxygen and water in the air. Tinplate is used to package beans and other food products as it is resistant to corrosion.
Environmental degradation	The ability to withstand environmental conditions. Zinc is used as coating on steel buckets, screws and roofing sheets as it is extremely resistant to corrosion from moisture and other environmental conditions.
Elasticity	The ability to regain its original shape after it has been deformed. Plastic or rubber based materials are used on handles as they provide a comfortable grip on sporting products.

Industrial Material Testing

Before selecting materials for use with engineering products it is important to know if they are suitable for the environment they will be used in and if they are suited to the function they have to perform. Tyre companies such as Michelin will run tyres on vehicles to establish wear-rates in use.

Destructive Testing

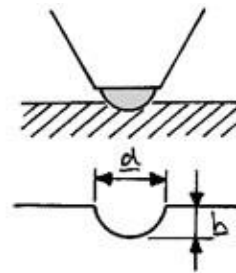
Destructive Testing refers to a range of tests that ultimately results in the destruction of a standard size piece of material. Hardness test pieces will have small indentations after testing, while impact testing will cause test pieces to bend or break completely.

Hardness Tests

Hardness is the ability of a material to resist abrasive wear, indentation or deformation. Hardness is a by-product of strength, so generally the stronger the material the harder it is. Opposite are two basic tests that are used for testing hardness:

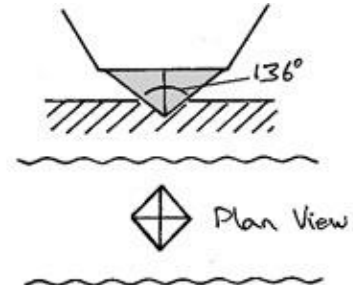
The Brinell hardness test forces a steel ball into the material's surface by means of a suitable load. The surface area of the indent is measured and used to calculate the hardness number.

The Vickers test uses a diamond pyramid to indent the material. This is again measured using a microscope to give the hardness value.



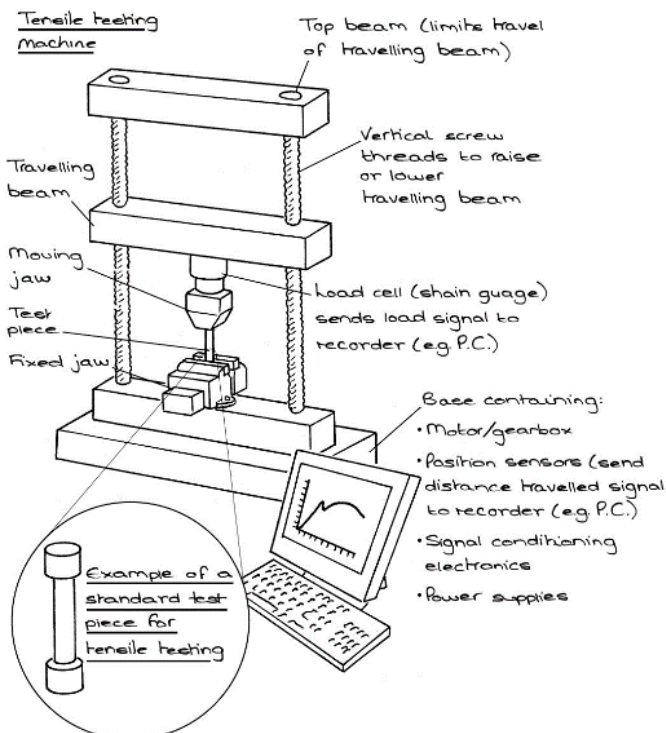
Brinell hardness test

A hardened steel ball indenter is used. Diameter d and depth b are measured and used to calculate a hardness value.



Vickers pyramid hardness test

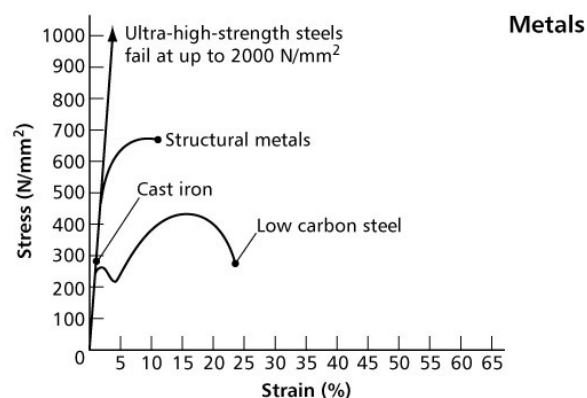
A diamond pyramid indenter is used. The surface area of the indent and the load are used to calculate a hardness value.



Tensile Tests

Tensile testing involves putting material under tension by stretching to provide information regarding tensile strength, elasticity and plastic properties, such as ductility and malleability.

A standard test piece is held between two grips. One of the grips is fixed and the other is moved at a constant speed by a motor until the material either breaks or stretches beyond the elastic limit of the machine. A number of materials are tested in this way including rubber, steel and fabric. The rope making industry tests the strength of the fibres used in their ropes and in the clothing industry test the strength of their fabrics.



Impact Tests

Impact tests indicate the toughness of a material and, in particular, its resistance to mechanical shock. There are three main methods of impact testing:

- Izod test
- Charpy test
- Hounsfield test

Test pieces are standardised for each test and the more the test piece absorbs the impact the tougher the material is.

Wear Resistance

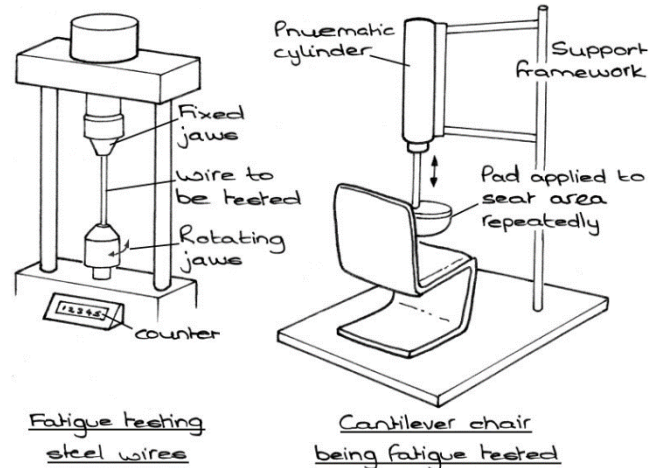
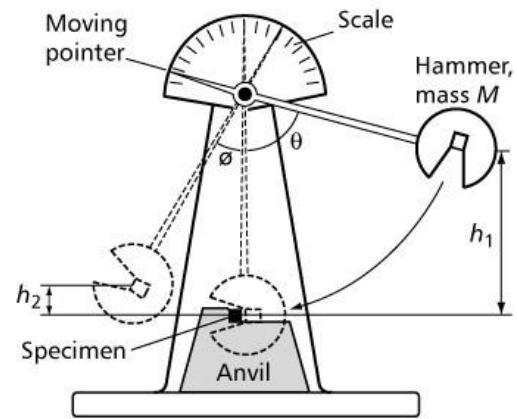
Materials that need to resist constant wear can be tested by weighing a sample piece before and after the test, which involves rubbing the material with an abrasive. The difference in weight is used to determine the materials resistance to wear.

Fatigue Testing

Two methods of testing fatigue are shown opposite. The first involves twisting steel wire in different materials over time until the sample breaks.

Chairs can be tested by repeatedly applying a force or weight to the seating area representing a person sitting on the chair.

Izod/charpy impact test equipment



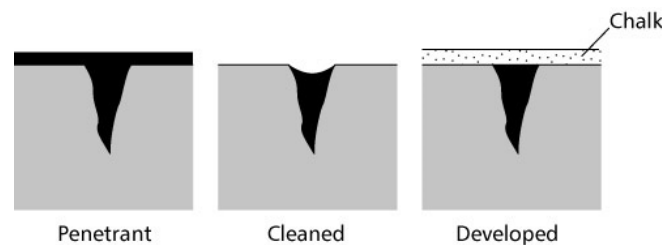
Non-destructive Testing

These tests use methods that do not damage or destroy the material or product. They are usually used on the final product to test for surface or near surface faults or flaws. Welded joints on car chassis and engine castings in the car industry are tested in this way.

Surface Crack Detection

A simple way of testing for surface cracks is to visually check the surface. Touch can also be used to sense any faults directly on the surface of the product.

Ring testing is used in the casting and pottery industries to test for faulty products as a bell cannot ring if it is cracked.



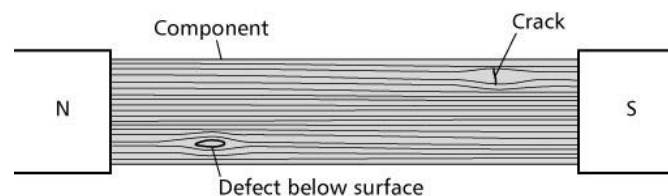
Crack detection

Liquid Penetrant

In this process a liquid is sprayed onto the surface of the product. Once the excess has been removed only the penetrant in the cracks will remain. To make the cracks clearer a light dusting of chalk is applied.

Magnetic Testing

A component can be magnetised in an electromagnetic circuit. Iron particles are dusted over the area and highlight where the magnetic lines of force are broken by a defect. It is particularly useful when trying to find defects just below the surface.

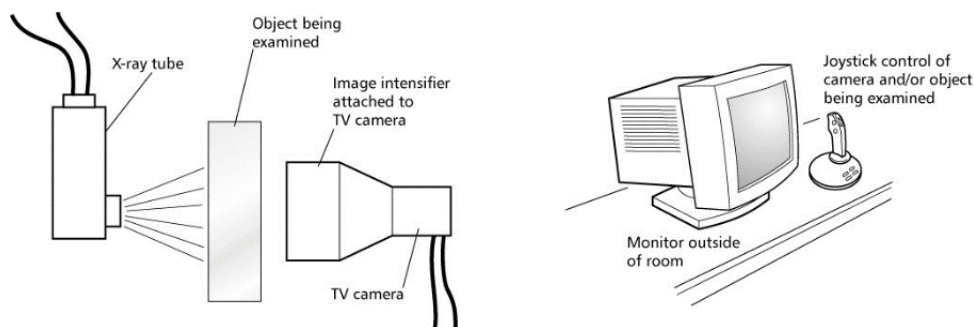


Component within a magnetic circuit

Internal Defect Detection

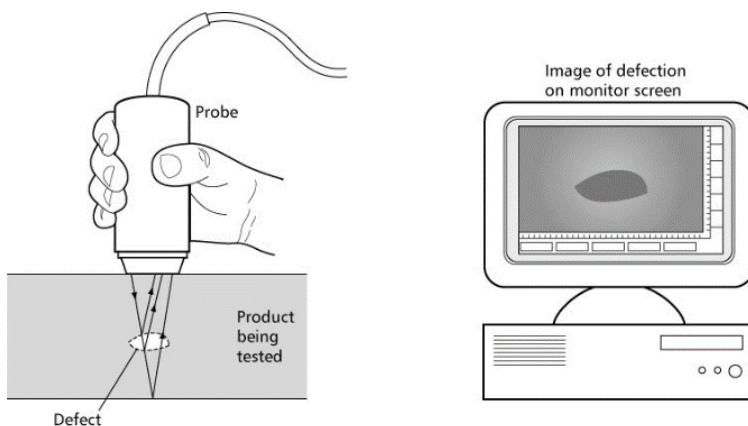
X-ray Testing

X-rays are used to detect defects under the surface of a product or material. An x-ray tube emits radiation through the product and forms an image through an image intensifier and camera to a monitor. As x-rays travel faster through cavities they produce a darker image on the screen. This is useful for detecting if products have been formed together correctly.



Ultrasonic Testing

Very high frequency sound vibrations can be used to precisely locate internal defects. A probe is passed over the component transmitting the high frequencies. Under normal conditions the vibrations pass through the material and are reflected back through the bottom surface of the material. The probe receives this and an amplifier converts the vibrations into blips on a monitor. This process is ideal to test sheet, plate and strip materials making it ideal into the inspection of aircraft and pipelines.



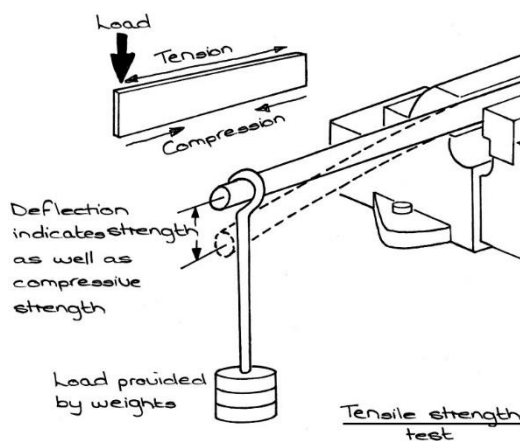
Example Question

You have been asked to measure the ability of a length of steel bar to resist bending.

Describe using notes and sketches how you could perform a simple test in a workshop to measure the steel bar's ability to resist bending.

As each weight is added, the sample is reviewed and comments recorded.

As the sample weight reaches 1Kg a reading is taken using a metal rule.



Engineering Materials

Metals

Metal ores are mined from the ground and the metal is extracted from the rocks, this is a finite resource, so has to be managed carefully. All metals can be recycled, however, which should reduce the demand on raw materials. There are three main types of metal: ferrous, non-ferrous and alloys.

Ferrous metals consist of iron, carbon and other elements. Most ferrous metals are prone to rusting and are magnetic. Non-ferrous metals do not contain any iron, so they are not magnetic and do not rust when exposed to moisture. However, they do tarnish and oxidise. Alloys are metals that contain two or more elements which are combined to enhance the properties of the material. For example, improving the strength to weight ratio in vehicles or improving resistance to corrosion.

Stock forms/types

Metals used in industry are generally available in standard forms as they are easier to handle and transport, in addition they are cheaper than special sizes as they can be manufactured in large quantities.

Construction beams are used in the construction industry to carry large loads across a gap. The most common is the I beam which has large flanges to spread load over larger areas. Other beams are shown below and are used in different applications.



Bar has a solid cross-section and is available in square, round, hexagonal, flat, angle and channel. It is used in general purpose construction work.

Sheet comes as flat sheets ranging in thickness from 0.6-3mm and is used to manufacture washing machine casing and radiators among other products. Plate is sheet metal with a thickness greater than 3mm and is used in heavy duty work, for instance building ship hulls.

Pipe and tube has a hollow section and is available in square, rectangular, round and hexagonal. It is used in general construction work where reduced weight is important.



Ferrous Metals		
Name	Description	Application
Cast Iron	- Re-melted pig iron with some small quantities of other metals - Typically 93% iron with 4% carbon - Very strong in compression, but brittle	- Metal work vices and machinery bases - Brake discs and drums - Car cylinder blocks
Mild Steel	- Iron mixed with about 0.3% carbon - Ductile and malleable with a high tensile strength - Rusts very quickly if exposed to moisture	- Nuts and bolts - Car body panels - Gates and girders
Tool Steel	- Known as medium or high carbon steel - Up to 1.5% carbon content - Strong and very hard	- Hand tools - Garden tools and springs
High Speed Steel	- Contains a high content of tungsten, chromium and vanadium - Brittle but resistant to wear - Used in high speed machining operations	- Drill bits - Lathe tools - Milling cutters
Stainless Steel	- An alloy of iron with 18% chromium and 8% nickel - Very resistant to wear and corrosion	- Kitchen sinks - Cutlery and teapots - Surgical equipment

Non-Ferrous Metals		
Name	Description	Application
Aluminium	- A light grey colour that can be polished to a mirror-like appearance - Light in weight, ductile and malleable - Can be anodised to protect the surface and give it colour	- Cooking foil and packaging - Saucepans - Window frames - Ladders
Copper	- Reddish brown, but can turn green after exposure to oxygen - Ductile and malleable - An excellent conductor of heat and electricity	- Plumbing and electrical components - Domed roofs (copper covered)
Tin	- Bright silver in colour - Ductile and malleable - Resistant to corrosion - Tinplate is steel with a tin coating	Used as a coating on food cans and packaging
Zinc	- Very weak - Extremely resistant to corrosion from moisture	Used as a coating on steel buckets, screws and roofing sheets (galvanized steel)
Gold and Silver	- Precious metals - Very ductile and malleable - Silver tarnishes, but gold isn't affected by oxidation	- Jewellery - Plated onto electrical wires to improve contact and reduce resistance

Alloys		
Name	Description	Application
Brass	• A hard yellow material • An alloy of 65% copper and 35% zinc • Often cast and machined, then chromium plated	• Decorative metal work, like door handles and boat fittings • Plumbing accessories
Pewter	• A lead-free alloy than can be easily cast as it has a low melting point • An alloy of 92% tin, 6% antimony and 2% copper • Polishes to a bright mirror-like finish	• Drinking tankards • Jewellery • Picture frames
Casting Alloy	• Mainly aluminium with 3% copper and 5% silicon • Looks like pure aluminium but far easier to cast	• Die casting and sand casting processes
Duralumin	• An aluminium alloy with 4% copper and 1% manganese and magnesium • Almost as strong as steel but only 30% of the weight	• Aircraft bodies • Car body panels

Heat treatment

The crystalline structure of a metal affects how it reacts to working and cutting. The size of the grains is important and can be changed by annealing or softening the metal. By hardening and annealing metals we can make them malleable enough to form into shapes or hard enough to cut all other metals.

If a metal becomes deformed by working (hammering or bending) it becomes work hardened and continuing to work the metal will make it brittle. If the metal is annealed the heating allows the grains to re-form. On cooling the metal will have returned to its original condition and working can continue.

When a ferrous metal is annealed it becomes very soft and workable. It can be annealed in the following way:

- 1) Heat it to bright cherry red (725°C) and soak it in the heat for a few minutes.
- 2) Cool it very slowly to allow the grains to grow.

A non-ferrous metal can be annealed in the following way:

- 1) Heat it to dull red (500°C).
- 2) Either quench in cold water or allow it to cool slowly.

The scale or oxide on the surface of the metal can be cleaned off with acid or an abrasive.

Hardening

If high carbon or tool steel is hardened, it is at its maximum hardness and able to cut other steels. Steel can be hardened in the following way:

- 1) Heat the metal to cherry red (720°C).
- 2) Soak the metal in the heat for a few minutes.
- 3) Quickly quench it in water or oil.

Tempering

Hardening makes steel very hard, so it will not wear away, but it leaves it brittle and liable to crack. Tempering reduces the hardness a little until a workable balance is found between hardness and brittleness (toughness).

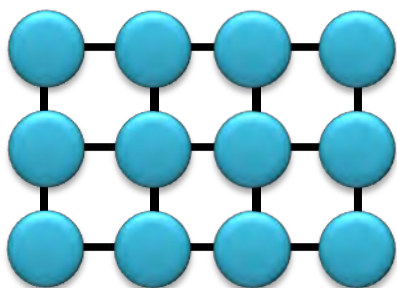
- 1) Clean the metal so its colour can be seen
- 2) Reheat the steel until its between 230°C and 300°C depending on the toughness you need for the metal (see the colour chart below).
- 3) As soon as the correct colour is seen, stop the heating and quench the metal.

Mild steel doesn't have enough carbon in it to be hardened, but it can be case hardened. This involves giving a thin outer layer of hardened steel by soaking it in a bed of red hot carbon for several hours at 950°C.

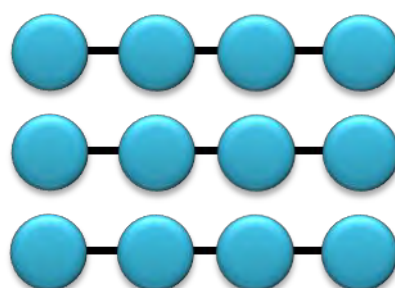
Colour	Hardness	Temperature	Application
Pale straw	Hardest	230°C	Lathe tools and scribes
Straw		240°C	Drills and milling cutters
Dark straw		250°C	Taps and die punches
Brown	Tough and hard	260°C	Plane irons, shears and chisels
Brown/purple		270°C	Scissors and knives
Purple		280°C	Cold chisels and saws
Dark purple		290°C	Screwdrivers
Blue	Toughest	300°C	Springs, spanners and needles

Polymers

Polymers are the most widely used materials in commercial production. They are created from two main sources. Natural polymers include materials such as amber, which is fossilised tree resin and latex which is a form of rubber. Synthetic polymers are chemically manufactured from carbon-based materials, such as crude oil, coal and natural gas. Synthetic polymers are manufactured using a process known as polymerisation.



Thermosetting Polymer Bonds



Thermoplastic Polymer Bonds

Stock forms/types

Plastics used in industry are generally available in a variety of different forms depending on the process they will be used in, for instance when injection moulding, plastic granules are used and sheet materials are used when vacuum forming. They can also come in a variety of other forms similar to metals. There are two different types of plastics:

Thermosetting Polymers are heated and moulded into shape. They can't soften if heated because the polymer chains become interlinked during the moulding process. Individual monomers are joined together to form a massive polymer.

Thermoplastic Polymers soften when they are heated and can be shaped when hot. The plastic will harden when it is cooled, but can be reshaped if heated again.

Thermosetting Polymers

Name	Description	Application
Melamine Formaldehyde MF	- Heat resistant polymer - Used as a surface finish on manufactured boards	- Tableware - Electrical installations - Decorative work tops
Epoxy Resin ER	A resin and a hardener mixed to produce a casting	- Castings - Printed circuit boards(PCBs) - Surface coating
Polyester Resin PR	- Polymerises at room temperature - A resin and hardener mixed together - Often reinforced with GLASS FIBRE	- Laminated to form GRP (Glass Reinforced Plastic) castings - Car bodies and boat hulls
Phenol Formaldehyde	- Hard, brittle plastic with dark colour - Glossy finish - Resists heat	- Electrical fittings - Parts for domestic appliances, e.g. kettle and saucepan handles
Urea Formaldehyde	A colourless polymer with artificial pigments to produce a wide range of different colours	- Door and cupboard handles - Electrical switches and fittings

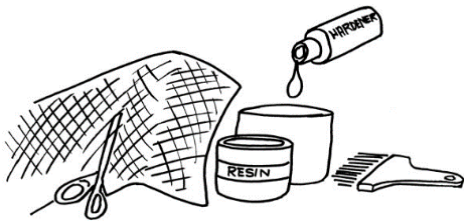
Thermoplastics		
Name	Description	Application
High Density Polythene HDPE	- Stiff and strong plastic - Softens at 120-130°C	- Pipes and bowls - Milk crates - Buckets
Low Density Polythene LDPE	- Weaker and softer and more flexible than HDPE - Softens at 80°C	- Packaging and film carrier bags - Toys - Detergent bottles
Polypropylene PP	- High impact strength - Can be flexed many times without breaking - Softens at 150°C	- Bottle crates - Medical equipment and syringes - Food containers
High Impact Polystyrene HIPS	- Light but strong plastic - Widely available in sheet - Softens at 95°C	Outer casings of products
Nylon	- Hard material- good resistance to wear and tear - Solid nylon has low friction qualities and high melting point.	- Combs - Clothing - Gear wheels and bearings
Rigid Poly Vinyl Chloride PVC	- Stiff and hard wearing - Plasticiser can be added to create a softer more rubbery material	- Air and water pipes - Chemical tanks - Window frames
Acrylic Polymethyl-methacrylate	- Trade name – Perspex - Glass like transparency or opaque - Can be coloured with pigments - Hard wearing, will not shatter	- Display signs - Baths - Roof lights - Machine guards
Acrylonitrile butadiene styrene ABS	- Excellent impact strength - Lightweight - Hard and durable	- Computer casings - Mobile phones - Safety helmets - Car bumpers
Styrofoam™ Extruded polystyrene	- Lightweight and buoyant - Good insulator - Easily shaped	- Fast food packaging - Insulation - Modelling material

Composite Materials

Composites are produced by mixing together two or more different materials providing enhanced properties for the final composite material. For example, by adding strands (fibres) of glass to polyester resins, a very tough, rigid, lightweight material can be produced, fibre glass.

Composite materials have gained popularity (despite their generally high cost) in high-performance products that need to be lightweight, yet strong enough to take harsh loading conditions such as:

- Aerospace components (tails, wings, fuselages, propellers)
- Boat and scull hulls, bicycle frames and racing car bodies. Other uses include fishing rods and storage tanks.



A resin being added to a glass fibre Mat.



Arrangement of Kevlar fibres

Composites

Name	Description	Application
Glass-reinforced Plastic GRP	• Polyester resin reinforced by the addition of strands of spun glass fibres • Light weight, hard wearing and durable • Corrosion resistant	• Car body building • Boat hulls
Carbon Fibre	• A very high strength to weight ratio • Impact resistant • Expensive to produce	• High performance vehicles • Aircraft • Sports equipment
Kevlar	• A very high strength to weight ratio • High toughness and cut resistance • Flame resistant and self extinguishing	• Bullet proof vests and helmets • Sports equipment • Run flat tyres
Reinforced Concrete	• Cement mixed with water, sand and aggregates and reinforced by adding steel bars • A dense material that is very strong under compression but also flexible to resist tensile forces	• Construction industry • Buildings • Bridges

Smart Materials

Smart materials react to outside stimuli and change their properties as a result, for instance they become different shapes or colours. They are often integrated into or onto products in the form of a coating or finish.



Shape Memory Alloy used in spectacle frames



Phosphorescent Pigments used in safety signage



Thermochromic Pigments used in a child's thermometer

Smart Materials

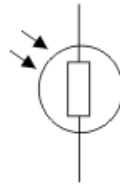
Name	Description	Application
Shape Memory Alloys SMA	- Made from nickel-titanium or copper-zinc-aluminium alloys - Use heat to return to their original shape	- Spectacle frames - Triggers or switches - Bioengineering and surgical procedures
Polymorph	- Tough polymer material - Softens at 62°C and becomes easy to mould - Hardens on cooling	Model making and prototyping
Thermochromic Pigments	- React to changes in temperature - Combined with polymers during moulding	- Temperature indicators on electrical products - Baby feeding products
Phosphorescent pigments	- Replaced radioactive materials - Absorb large amounts of light - Re-emits light energy over a period of time - Available as a powder which can be mixed with paints	- Emergency warning signage - Watch faces
Quantum Tunnelling Composite QTC	- A flexible polymer which contains tiny metal particles - Normally an insulator but if it is squeezed it becomes a conductor.	- Membrane switches - Pressure sensors - Speed controllers

Electronic Components

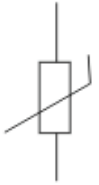
Electronic components are used in electronic devices to make them work, from switches to microcontrollers. You need to know some basic components for your course, however, further research is recommended to increase your understanding of how a number of electronic components and devices operate.



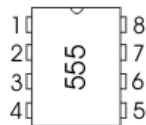
Push to Make Switch
Allows current to flow through it when pressed.



Light Dependent Resistor
Has a resistance that changes depending on the light level, e.g. street lights.



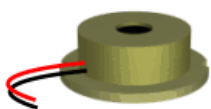
Thermistor
Has a resistance that changes depending on the temperature, e.g. home central heating.



Microcontroller
A small computer on an integrated circuit that can be preprogrammed to provide functionality such as timing, counting and decision making.



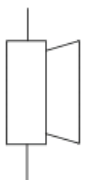
Resistor
Limits the flow of electrical current in a circuit, used to protect delicate components, e.g. LED.



Buzzer
Produces a buzzing sound when current flows through it, e.g. audible warnings.



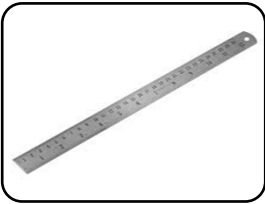
Light Demitting Diode (LED)
Produces light when current flows through it, e.g. home lighting and visual warnings/notifications.



Speaker
Turns electronic signals into sounds.

Measuring & Marking

There are a number of tools used in engineering for measuring and marking out. You will need to be able to identify and know how to use them for practical tasks to ensure accuracy in your work.



Steel Rule

A steel rule is used to measure lengths and to set odd-legs and dividers

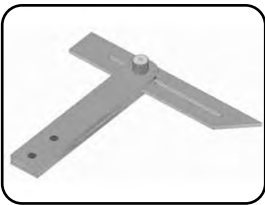


Engineering Square

An engineering square is used to:

Mark lines at 90° from the edge of the material

To check square components or corners



Engineering Bevel

An engineering bevel is an adjustable angle marker that can be set to any angle.



Surface Plate

A surface plate is a very flat surface used to accurately mark out materials.



Surface Gauge

A surface gauge is used with a surface plate to accurately mark parallel lines on materials.



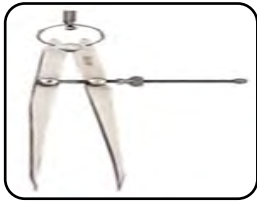
Scriber

A scribe is a sharp tool used for marking accurate lines on metals and polymer materials.



Odd-Leg Callipers

Odd-Leg Callipers are used to scribe lines parallel to a straight edge. The notched leg slides along the edge of the metal while the scribe point marks a line.

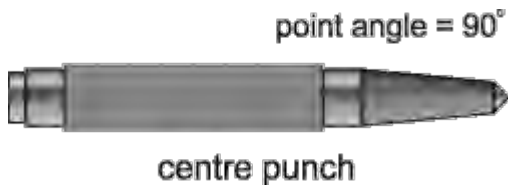


Dividers

Dividers are used to mark circles or arcs. One point digs into the material whilst the other point scribes a line into the surface of the material.

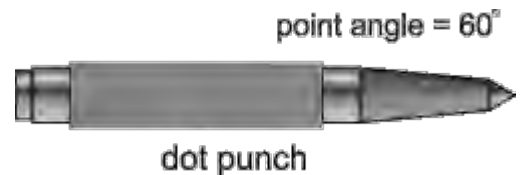
Dot Punch

A dot punch has a conical point ground to 60° that is used for marking the positions of drill holes.



Centre Punch

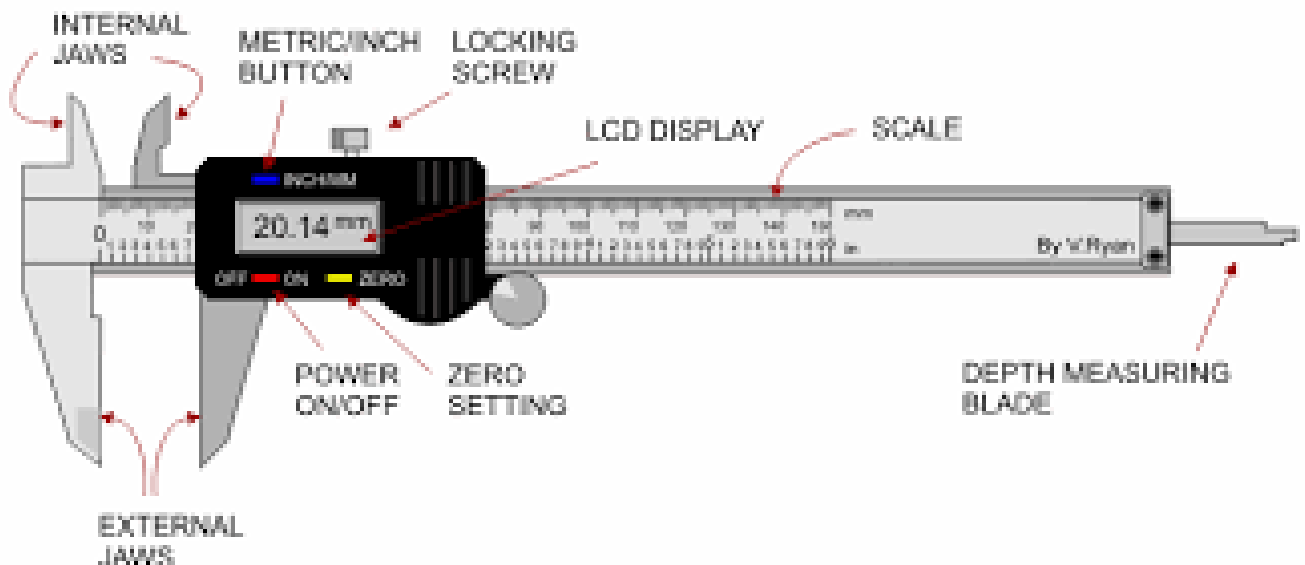
A centre punch has a conical point ground to 90° that is used for marking the centre of holes for drilling.



The Digital Vernier Calliper

The Vernier Calliper is a precision instrument that can be used to measure internal and external distances extremely accurately. The example shown below is a digital Vernier calliper as the distances are read from an LCD display.

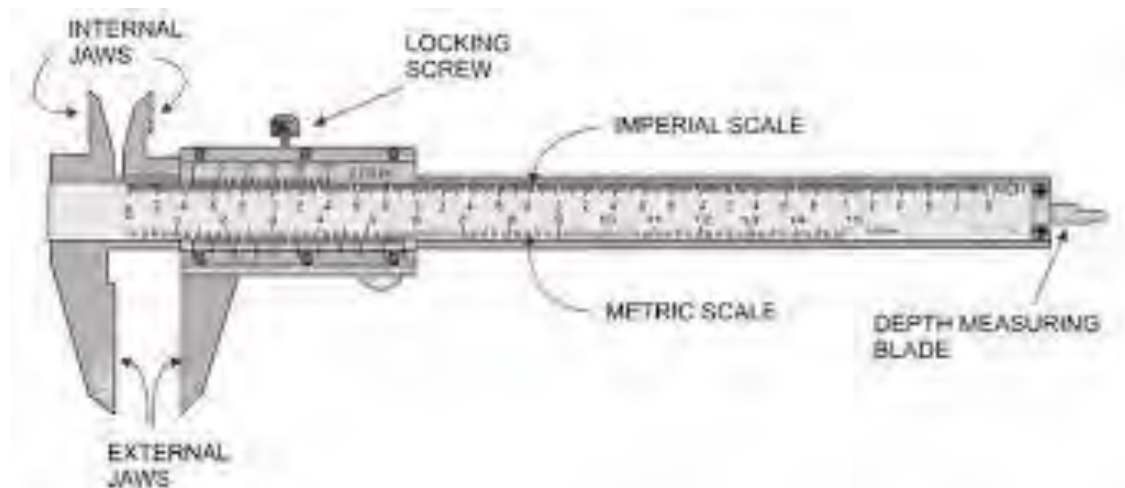
Digital Vernier callipers are easier to use as the measurement is clearly displayed and also, by pressing the inch/mm button the distance can be read as metric or imperial.



The Vernier Calliper – Manual Version

The Vernier Calliper is a precision instrument that can be used to measure internal and external distances extremely accurately. The example shown below is a manual calliper. Measurements are interpreted from the scale by the user. This is more difficult than using a digital Vernier calliper which has an LCD digital display on which the reading appears. The manual version has both an imperial and metric scale.

Manually operated Vernier callipers can still be bought and remain popular because they are much cheaper than the digital version. Also, the digital version requires a small battery whereas the manual version does not need any power source.



How to read a measurement from the scales

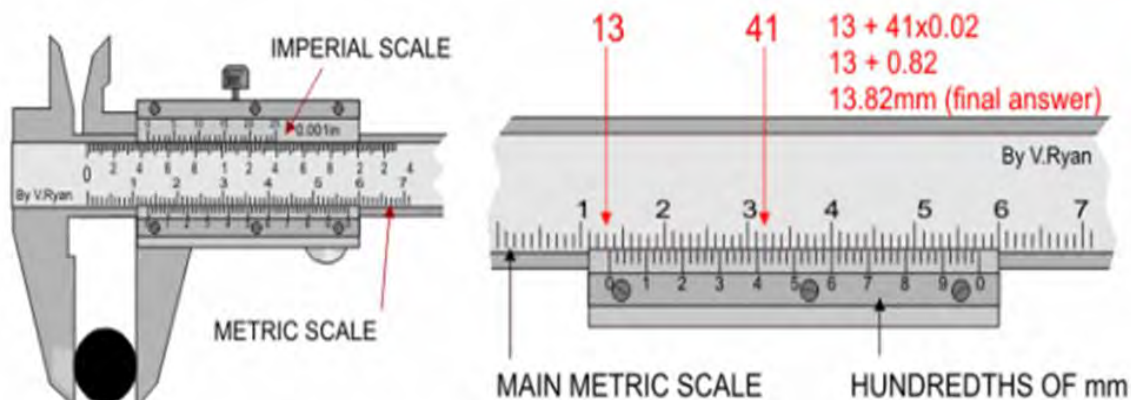
The external measurement (diameter) of a round section piece of steel is measured using a Vernier calliper, metric scale.

A. The main metric scale is read first and this shows that there are 13 whole divisions before the 0 on the hundredths scale. Therefore, the first number is 13.

B. The 'hundredths of mm' scale is then read. Only one division on the main metric scale lines up with a division on the hundredths scale below it, whilst others do not. In the example below, the 41st division on the hundredths scale lines up exactly with a division on the metric scale above.

C. This 41 is multiplied by 0.02 giving 0.82 as the answer (each division on the hundredths scale is equivalent to 0.02mm).

D. The 13 and the 0.82 are added together to give the final measurement of 13.82mm (the diameter of the piece of round section steel).



Measuring Internal Distances

The example below shows a Vernier callipers being used to measure the internal diameter of a piece of copper tube. The internal jaws are adjusted carefully until they touch the internal 'sides'. The locking screw is tightened so that an accurate measurement can be made even if the jaws are 'knocked' against the sides as the jaws are removed from the hole. The measurement is shown on the LCD display.



Measuring Depths

Measuring the depth of a hole can be very difficult. However, using a Vernier calliper makes this task easy. The base of the Vernier calliper rests on the top of the hole and the depth measuring blade is adjusted until it touches the bottom of the hole. The locking screw is tightened and the measurement can be read on the LCD display.



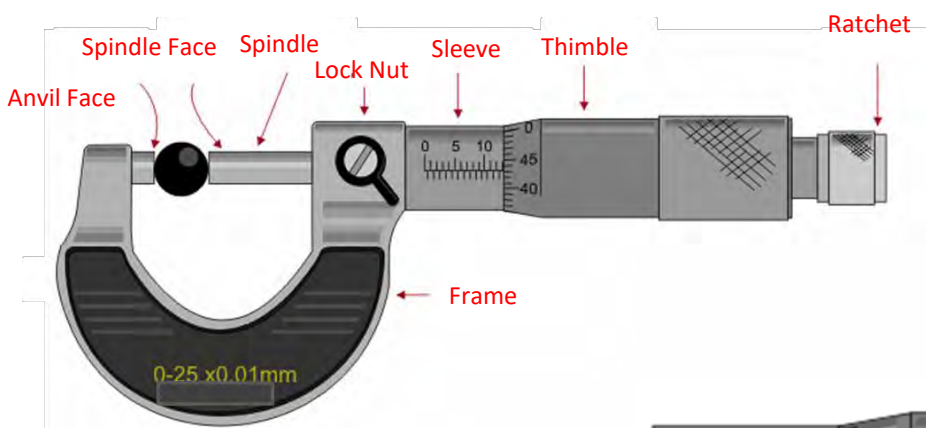
The Micrometre

The micrometre is a precision measuring instrument, used by engineers. Each revolution of the ratchet moves the spindle face 0.5mm towards the anvil face. The object to be measured is placed between the anvil face and the spindle face. The ratchet is turned clockwise until the object is 'trapped' between these two surfaces and the ratchet makes a 'clicking' noise. This means that the ratchet cannot be tightened any more and the measurement can be read.

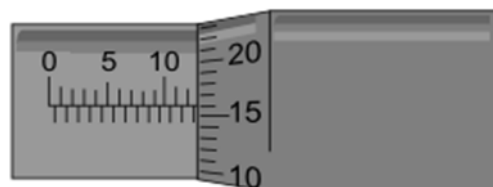
How to read a measurement from the scales

1. Read the scale on the sleeve. The example clearly shows 12 mm divisions.
2. Still reading the scale on the sleeve, a further $\frac{1}{2}$ mm (0.5) measurement can be seen on the bottom half of the scale. The measurement now reads 12.5mm.
3. Finally, the thimble scale shows 16 full divisions (these are hundredths of a mm).

The final measurement is $12.5\text{mm} + 0.16\text{mm} = 12.66$



Sleeve Reads full mm = 12.00
Sleeve Reads $\frac{1}{2}$ mm = 0.50
Thimble Reads = 0.16
Total Measurement = 12.66mm



Joining Metals

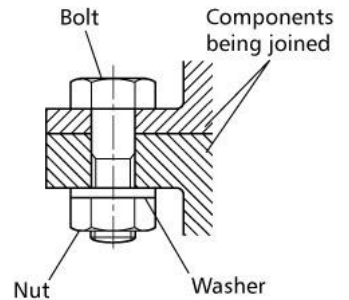
All materials can be joined using either temporary or permanent joining processes. Temporary fixings allow components to be disassembled whereas permanent joining processes do not usually allow for disassembly.

Temporary Fixings

Nuts and Bolts

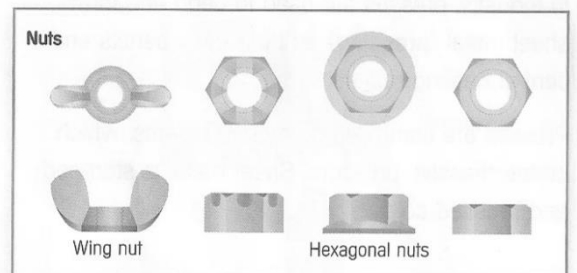
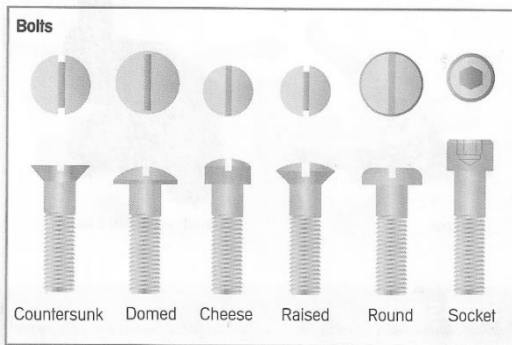
There are many different types of nuts, bolts and washers. Bolts are made with different heads for use in different applications. Countersunk and cheese head screws are tightened with a screwdriver. Hexagonal heads are tightened with a spanner and socket heads are tightened with an allen key.

Nut and bolt assembly



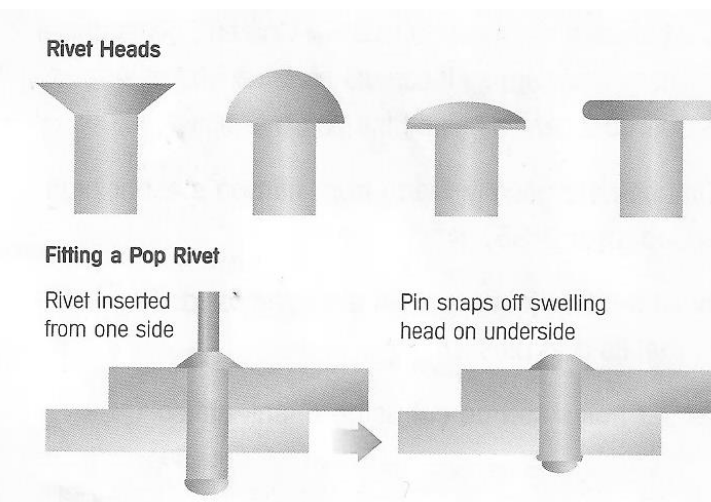
Threads also vary in size, but metric threads are mostly used today. They are available in many lengths, typically 20-100mm. Smaller bolts are called machine screws and have the thread over the entire length. Nuts need to match the same thread as the bolt. Wing nuts are tightened by hand and are useful for temporary joints. Hexagonal heads are tightened with a spanner.

A washer is used under the nut to spread the pressure and protect the surface of materials being joined together. These are usually plain ring washers, although spring washers are used to stop the nut vibrating loose.



Rivets

Rivets are used to make a more permanent joint than nuts and bolts. They hold the material together by forming a head on both sides of the material. Pop rivets are fitted using a rivet gun from one side of the material. They come with a variety of heads and are normally made from mild steel, copper or aluminium.

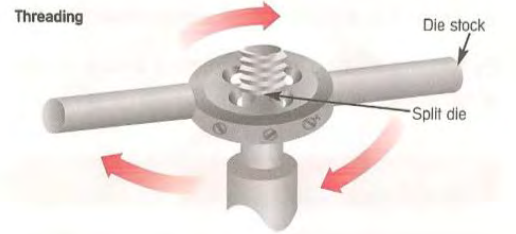
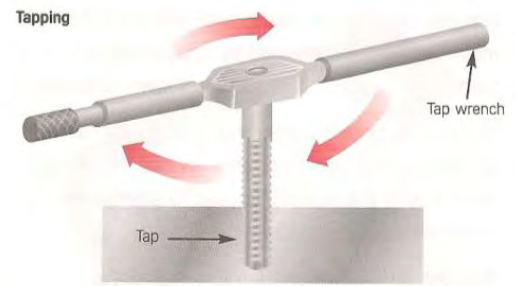


Tapping and Threading

Screw cutting can be carried out on most metals. A tapping hole, smaller than the thread, must be drilled in the metal before an internal thread can be cut.

Internal or female threads are usually cut with a tap, held in a tap wrench. A tap is a very hard steel tool which makes its own thread as it's twisted into a hole drilled into the material.

Threading is the cutting of an external or male thread. The tool is called a split die and is held in a die stock so that it can be turned.



Permanent Processes

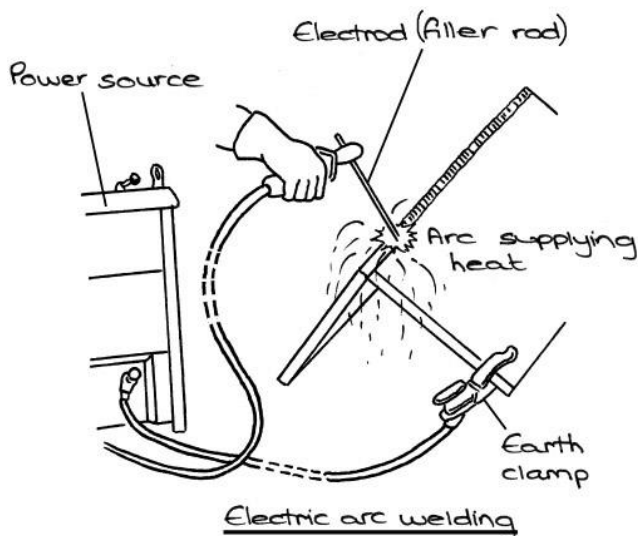
Heat can be used to join metals together. Welding uses heat to melt the edges of the metals being joined. This forms a pool of molten metal that when cooled forms the joint. Soldering uses a bonding alloy to form a joint and the parent metals do not melt. The surface is cleaned with flux and heat is applied using a gas torch. The solder is applied, which melts and runs between the two parent materials.

Welding

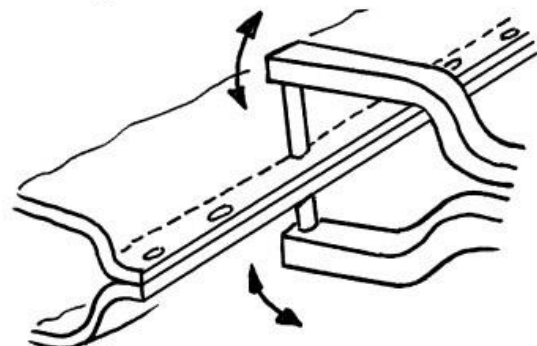
Gas welding uses an acetylene torch to heat up the joint. A mixture of acetylene gas and oxygen produces a very small, hot flame which melts both the filler rod and the surrounding metal.

Metal Inert Gas (MIG) welding is another method where an electrical spark creates the heat by arcing between the electrode and the work-piece. The electrode melts and is fed in from a roll of steel wire. The area is cooled with a gas mixture of argon and carbon dioxide. Tungsten Inert Gas (TIG) welding is used to weld non-ferrous metals. It's like MIG welding, but the electrode doesn't melt.

Spot welding is a form of resistance welding and is used for melting thin sheet steel together, e.g. car body panels. Copper electrodes sandwich the metal together and a current is passed between them. The resistance creates the heat to bond the two metals in a tiny spot.



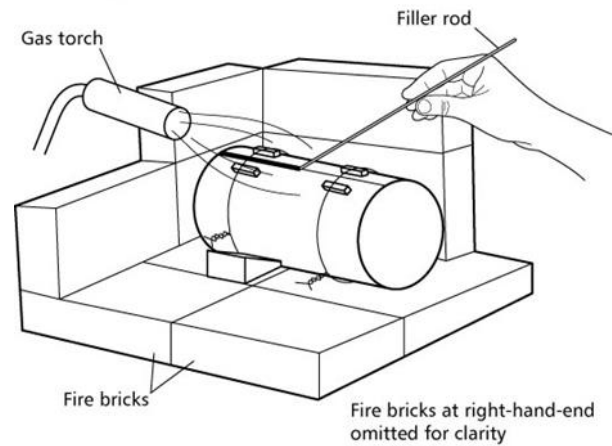
Using spot welding to join sheet metals



Soldering

Soft soldering joins metal parts together using a lead free alloy. It is used for light applications, e.g. electrical connections and plumbing joints. Flux is applied to the joint to clean it, the fluxed joint is heated using a gas torch or metal soldering bit. Hard soldering or brazing is used for heavier applications as the joint is much stronger. The brass bonding alloy (spelter) melts at a much higher temperature than soft solder. Its used for joining mild steel and copper. Silver soldering is like brazing but it uses a silver based alloy. Its used on brass, copper and gilding metal as the silver alloy melts at a lower temperature than brazing spelter.

Soldering



Cutting metal

Shearing and bending

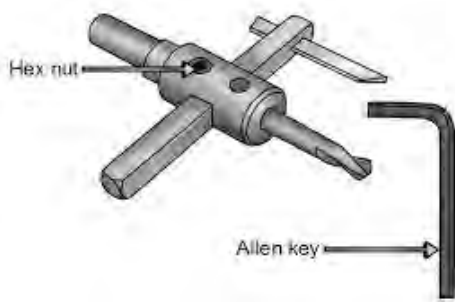
Sheet metal fabrication is used in many engineering industries for and machine processes. Cutting sheet metal is usually achieved by using a shearing action. Two methods include using tinsnips to cut small pieces of sheet metal and using bench mounted shears for thicker sheets as they provide greater leverage. Sheet metal can also be bent using either folding bars or bending machines.



Tinsnips



Bench-mounted shears



Tank Cutter

Drilling

Drill bits are usually made from carbon steel or high speed steel. Twist drills or jobber drills are used for drilling holes in metals and polymers. Larger holes can be cut using a tank cutter or a hole saw.

Sawing

Sawing is one of the oldest methods of cutting materials. Teeth are triangular and shaped so that they remove a small amount of material on the forward stroke. Metal cutting saws have small teeth on a blade supported in a frame.

The hacksaw is the main saw used for cutting in engineering. Teeth are available in different teeth per inch (TPI) with 20 TPI being usual for bench work. The blade is tensioned by turning a wingnut and can be changed when worn down.

For thin metals a junior hacksaw is used. Teeth are usually 32TPI and the blade is tensioned by the spring in the steel frame. A piercing saw is a very fine toothed saw is normally used in jewellery making.



Junior Hacksaw



Hacksaw



Powered Hacksaw

Machine saws use the same action as a manual version but are more accurate as the material is clamped in position.

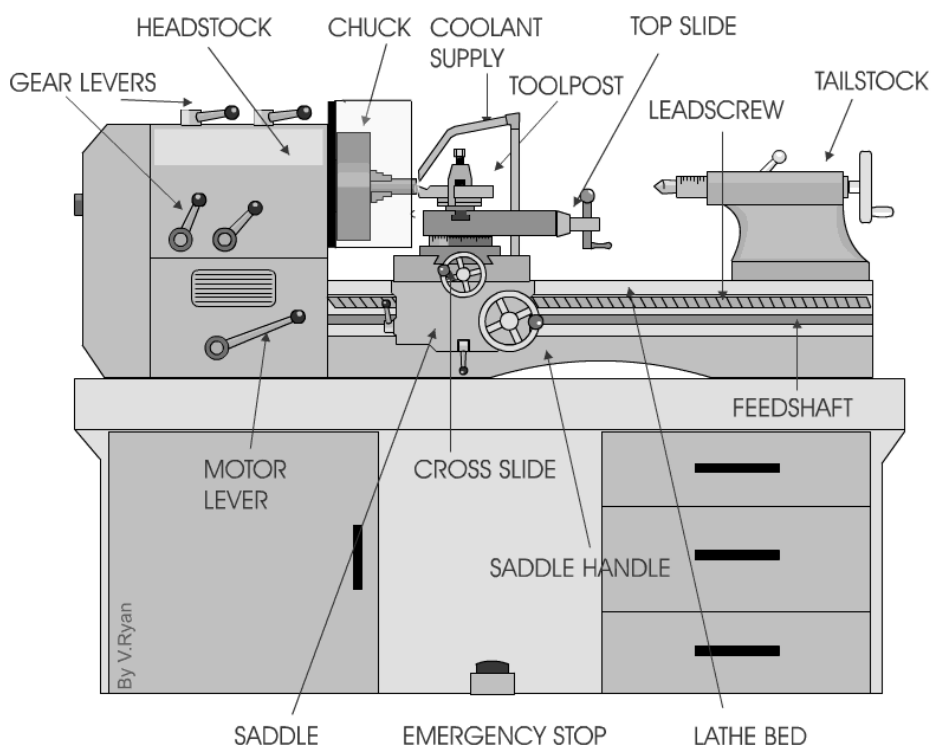
Laser and plasma cutting are used to cut metals and polymers when larger volumes and accuracy is required. They are both driven by design produced using computer aided design packages.



Turning

A centre lathe is used to produce parts by holding the work in a chuck and rotating the work towards the cutter. The cutter can be moved left and right (X axis) and forwards and backwards (Y axis). A variety of tools can be used to create the desired shape in the work and the tailstock can be fitted with a drill chuck for drilling holes into the end of the material.

A manual lathe is shown below. When producing large volumes of identical parts computer numerically controlled (CNC) lathes are used which produce parts following instructions from a CAD programme. This is extremely accurate and is much faster than a manual operator.



Turning Operations

Facing

The tool is moved at right angles to the axis, facing the end surface.

Parallel Turning

The tool is moved parallel to the axis to form a cylinder while reducing the diameter.

Taper Turning

The tool at an angle to the axis to produce a taper.

Parting

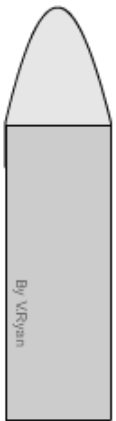
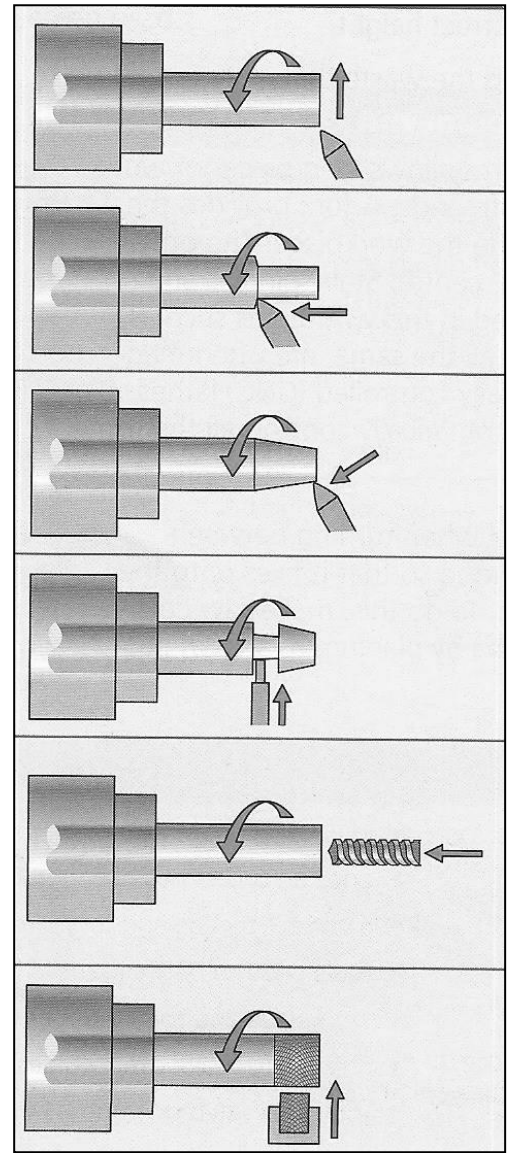
A narrow tool is fed into the work to trim to length or part off work from stock bar.

Drilling

The tail stock is used to hold a chuck into which a drill can be placed; as work rotates the drill is fed into the work.

Knurling

A hardened steel wheel is pressed into the rotating work to produce a straight or diamond pattern.



ROUGHING
TOOL



RIGHT



LEFT



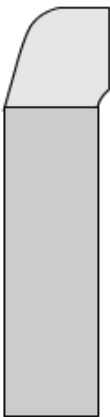
RECESSING
TOOL



PARTING
TOOL



RIGHT



LEFT

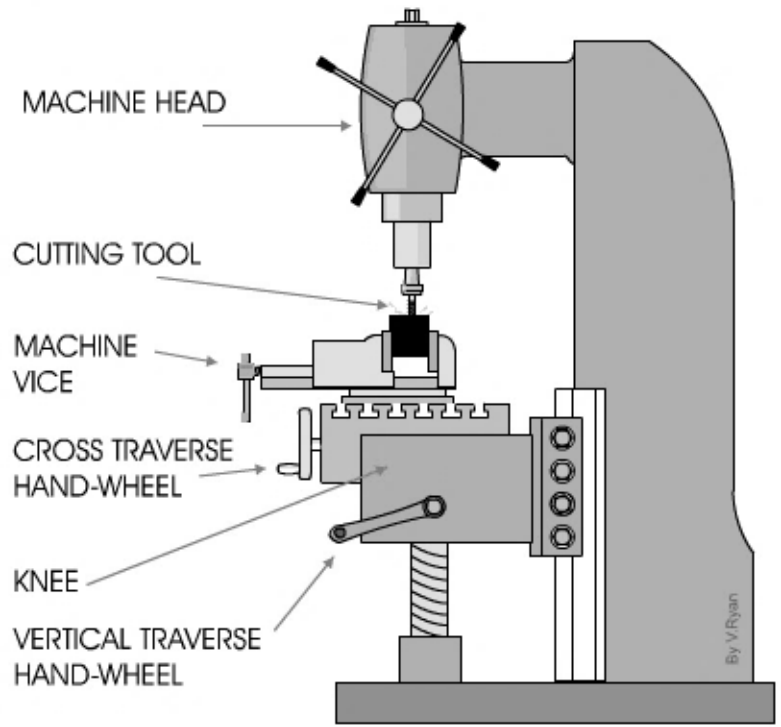
TURNING TOOLS

KNIFE TOOLS

Milling

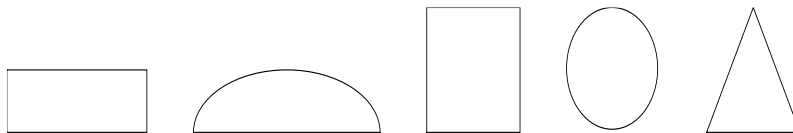
A variety of engineering materials can be shaped using a revolving, multi-toothed cutter which moves over the material. A manual machine can be moved left and right (X axis) and forwards and backwards (Y axis). A variety of tools can be used to create the desired shape in the work.

A manual milling machine is shown below. When producing large volumes of identical parts computer numerically controlled (CNC) millers are used which produce parts very accurately following instructions from CAD programmes.



Surface Finishes

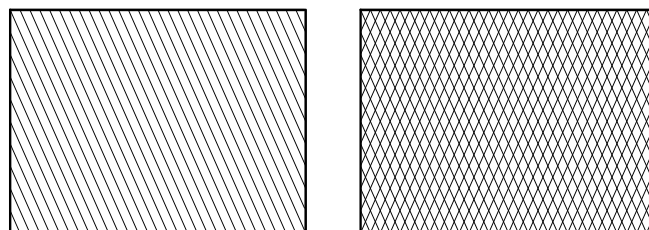
Files are used to smooth and shape the surface of metals and hard plastics by pressing and dragging the hundreds of small teeth on the file across the material. They are made from hardened and tempered cast steel, so they will cut other metals. Files come in a variety of shapes flat, half round, square, round and three square.



Hand Flat Half Round Square Round 3 Square

Files also have different sized teeth and are used depending on the amount of material to be removed. Different techniques are used:

- Cross filing removes metal quickly with the file moving from end to end to bring the rough material to shape.
- Draw filing involves moving from side to side which removes less material and leaves a finer surface ready for abrasives.



Single Cut

Double Cut

Abrading

To make abrasive paper, small chips of abrasive material are glued onto a paper or cloth backing sheet. The abrasive material is usually silicon carbide or emery. Each sheet is numbered, with the lowest number being the coarsest sheet. Emery cloth is used on metals and polymers and can be used in a two handed manner or wrapped around a flat file. A finisher (sanding machine) can also be used.

Polishing

Metal polish is always slightly abrasive because it relies on cutting away the surface of the metal until its very smooth. Metal polishes can be used in liquid form, which is applied with a cloth or as a wax bar applied to a buffing wheel.

Coatings

Plastic dip-coating

Polythene is the most common thermoplastic powder used for dip-coating. It is commonly used on dishwasher racks, coat hooks and tool handles.

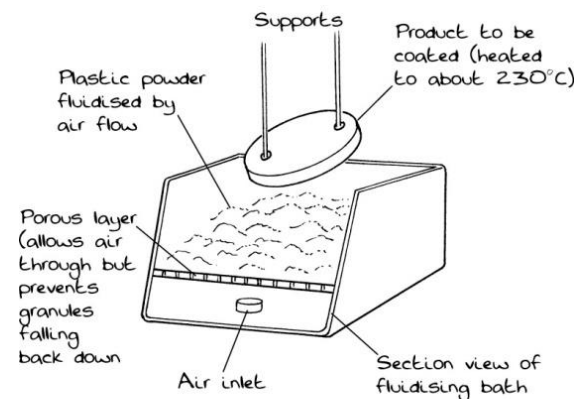
- Air is blown through the powder to make it behave like a liquid.
- Metal, pre-heated to 180°C , is dipped in the fluidised powder.
- The metal is returned to the oven where the plastic coating melts to form a smooth finish.

Powder coating

Powder coating is an industrial finish that is a more sophisticated version of dip-coating. The powder is sprayed onto the products which then pass through an oven.

This process provides a very hard paint-like finish and is available in all colours as well as translucent.

This finish makes the products very durable and is suited to those that are exposed to the environment, such as outdoor furniture and wheel trims.



Plastic dip coating

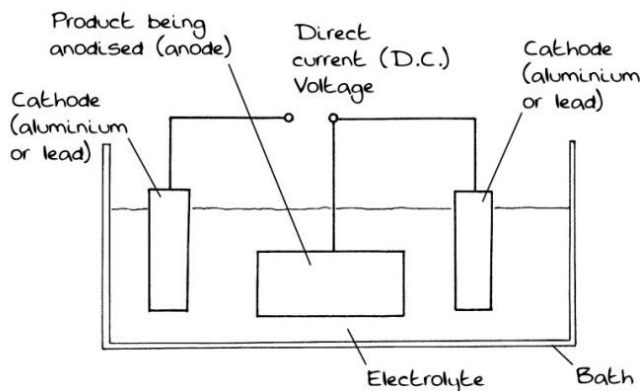


Diagram showing anodising

Industrial Surface Finishes

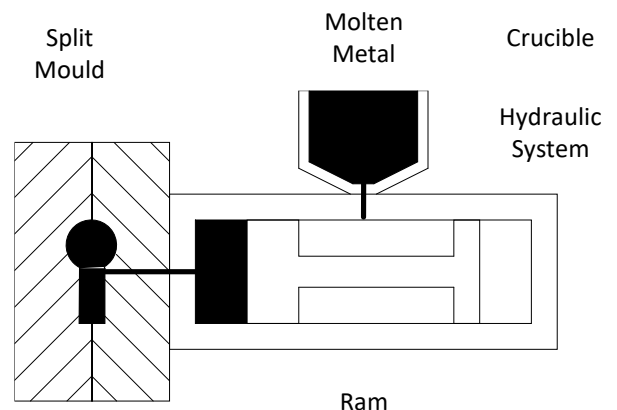
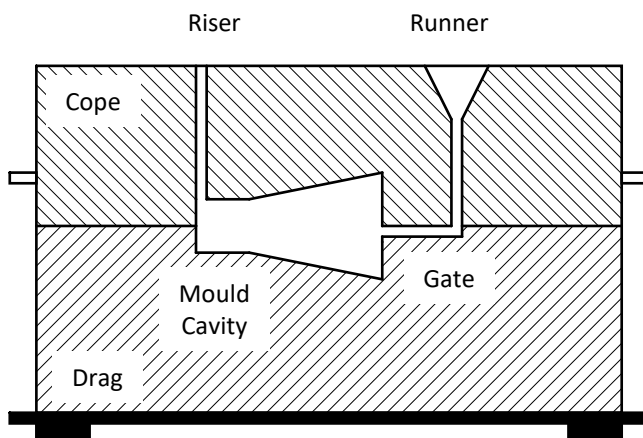
Anodising is used on aluminium to provide a durable, corrosion resistant finish. It involves electrolysis, which involves acids and electric currents. Sports equipment, window frames and electrical products are often anodised.

Plating also uses electrolysis. There are many forms, although chromium plating is the most widely recognised. The thin layer of metal on the surface provides a durable finish that is corrosion resistant.

Galvanising involves dipping the metal (usually mild steel) into a bath of molten zinc. Although it isn't very attractive, the zinc provides a very corrosion resistant surface. Car body panels are usually galvanized prior to further paint finishes being added.

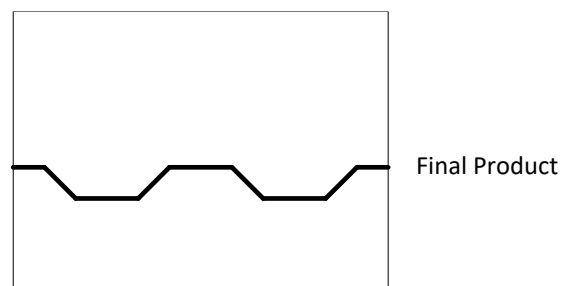
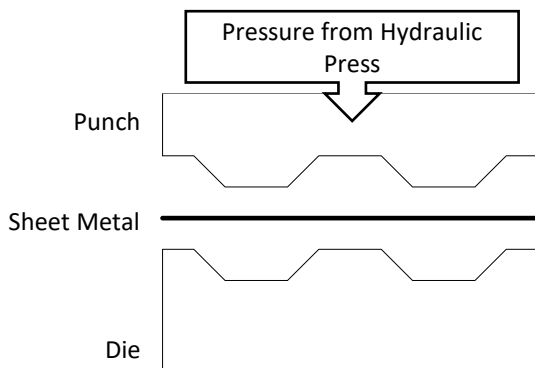
Industrial Processes

Sand Casting	Die Casting
Sand casting is used to shape metals, e.g. cast iron, aluminium and brass. It is not used to produce very large quantities of products. 1) A pattern is made from wood or MDF in two halves and attached to a board. 2) The pattern is sandwiched between open boxes called a cope and drag. 3) A special oil-bound sand is used to fill each box. One of the boxes also contains two tapered wooden pegs or sprues, which form the pouring spout (runner) and the riser to let the air out. 4) The pattern is removed and the space left is filled with molten metal. 5) Once cooled further machining is normally carried out before the final product is complete.	Die casting is very similar to injection moulding and is used to manufacture large quantities of metal products. Alloys with a low melting point, e.g. pewter, aluminium and zinc alloys can be used. The mould is created by a spark eroding the form required into two blocks of steel. These moulds are water cooled to control the temperature. 1) The metal is heated in a crucible until molten. 2) A hydraulic ram pushes a quantity of the molten metal into the mould. 3) Pressure is maintained until the metal has cooled enough for the mould to be opened.



Pressing

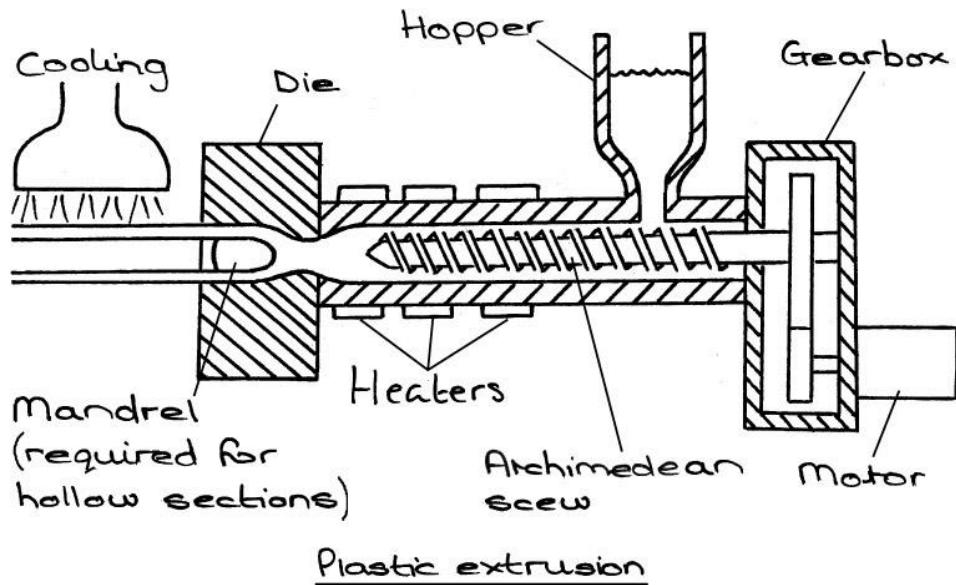
In industry presses are used to bend and form sheet metal to make car body panels and radiators for example. Presses are controlled by hydraulic rams, which create massive pressure. Sheet metal is stamped and pressed cold.



Extrusion

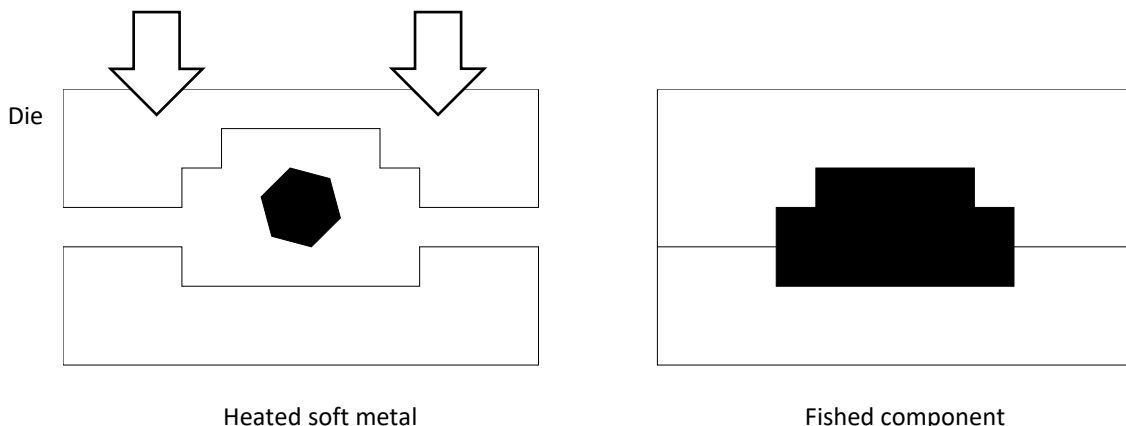
Extrusion is a process that produces material in a continuous section, for example making plastic drain pipes or metal tubes. Typical polymer materials include polythene, PVC and nylon, whereas aluminium alloys, copper and steels are used as they are ductile.

- 1) The material to be extruded is fed into the rotating screw and is heated at the same time.
- 2) The molten material is forced through a die in a continuous stream to create long tube or sectional extrusions.
- 3) The extrusions are passed through a cooling chamber and then cut to the required length.

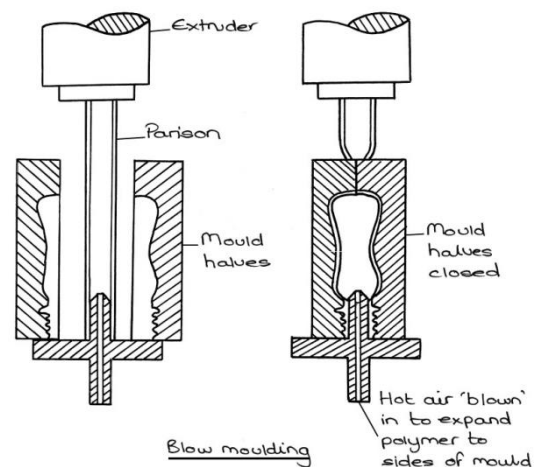
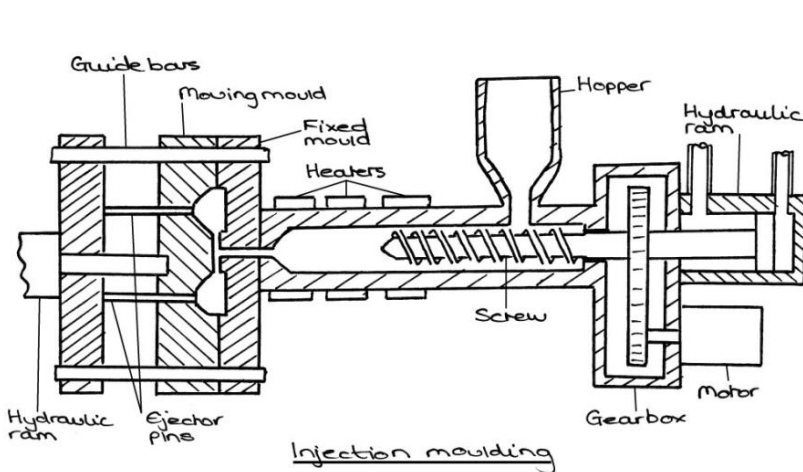


Drop Forging

Forging has been done for hundreds of years by blacksmiths. To produce large quantities of metal products, however, drop forging is used. This involves a piece of white hot metal being placed between two dies. A very large force is applied in a single blow by a mechanical hammer. This process improves the strength of the metal which cannot be achieved through casting or machining. Components are used in agriculture, transportation, defence, mining and other industries.



Injection Moulding	Blow Moulding
Injection moulding is used to manufacture products such as electrical casings, storage containers and bottle tops. Typical materials include polythene, polystyrene and polypropylene. 1) Plastic powder or granules are fed from the hopper into a hollow steel barrel. 2) The heaters melt the plastic as the screw moves it along towards the mould. 3) Once enough melted plastic has collected, the hydraulic system forces the plastic into the mould. 4) Pressure is maintained on the mould, until it has cooled enough to open.	Blow moulding is most often used to produce drinks bottles from materials like low density polyethylene, high density polyethylene, polyethylene terephthalate and polypropylene. 1) Heated plastic is injected into the moulding through a process very similar to injection moulding. 2) The split mould closes and air is blown in, forcing the plastic to the sides of the mould. 3) The mould is cooled and then opened to remove the product.

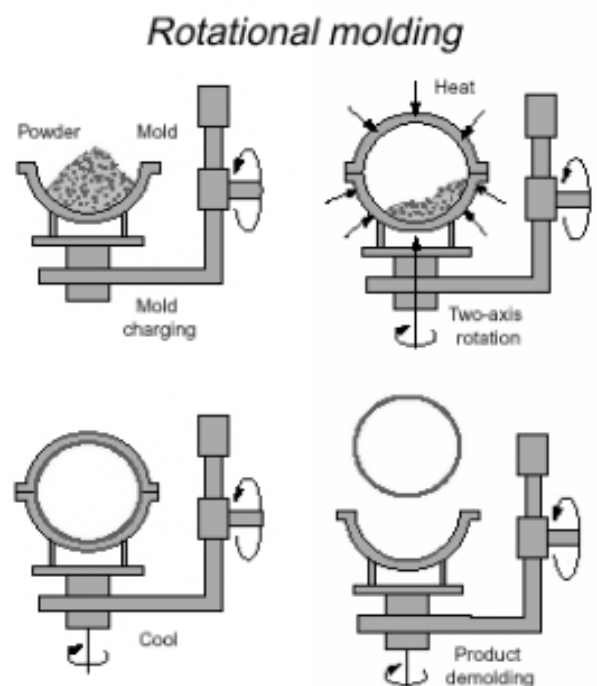


Rotational Moulding

This process can be used as an alternative to injection moulding or blow moulding if making an enclosed object, e.g. a ball or plastic wheel.

A rotational moulding machine has arms fixed at the same point. Moulds are attached to each arm and rotated continuously with heated thermoplastic powder inside. The mouldings are made from polythene, which can have fire retardant and vandal resistant qualities.

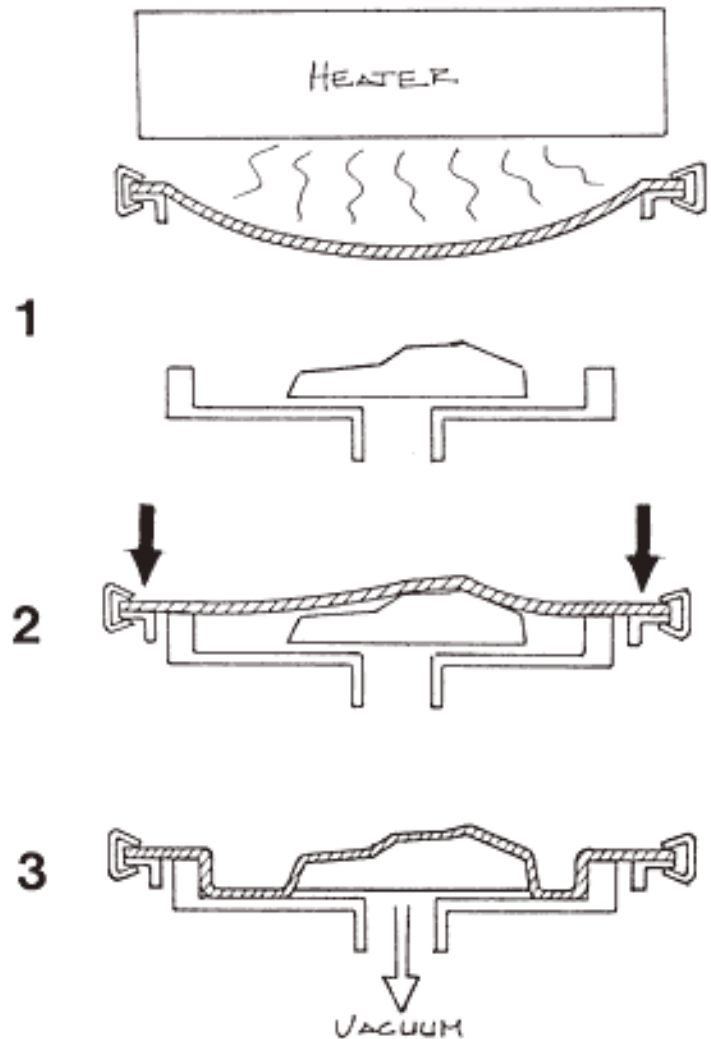
- 1) The mould splits apart and the plastic is poured in.
- 2) Heat is applied while the mould is rotated. The plastic is thrown outwards to the inner surface of the mould.
- 3) On cooling the mould is opened up and the product is ejected.



Vacuum Forming

This process is commonly used to make packaging from thermoplastic sheets that can measure up to 1.8m x 1.5m. The most popular material is high-impact polystyrene, which is cheap and is easy to form. Heated plastic is sucked onto the shape of the former required. A former can be a wooden mould around which the softened plastic will be held by the vacuum until it has cooled.

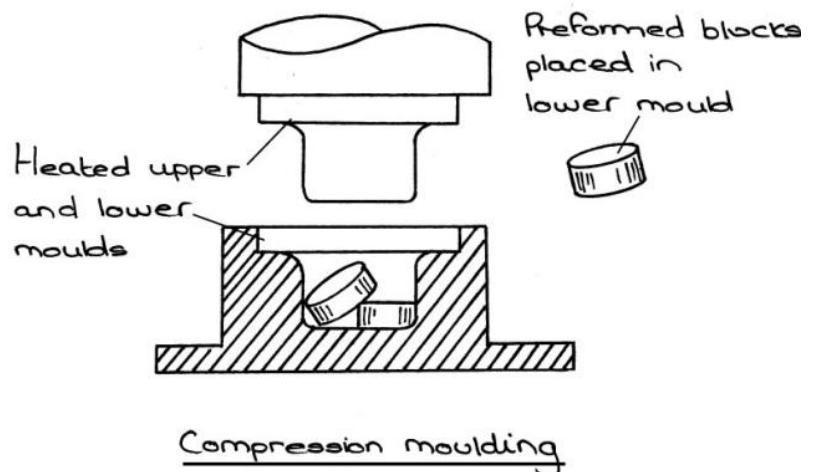
- 1) The mould is placed on the plattern and the plastic is clamped in position. The plattern is dropped and heat is applied to the plastic.
- 2) Once the material has softened the heat is removed and the mould is brought up into the material, which drapes over the mould.
- 3) Air is removed to form a vacuum causing the material to form a rigid impression of the mould.
- 4) The vacuum pump is switched off, the material is unclamped and the mould is released. The formed material is then cut to the required shape.



Compression Moulding

Thermosetting plastics are moulded using compression moulding. Once formed, they can't be reformed. Phenol, urea and melamine formaldehyde are plastics that are moulded in this way.

A large force is used to squash a cube of polymer into a heated mould. The cube of polymer is in the form of a powder, known as a slug.



Computer Aided Design

The use of computer software to produce designs for products is called Computer Aided Design (CAD). The designs can be 2D drawings or 3D models, which can be virtually tested prior to development.

The main advantages of CAD include:

- CAD is extremely accurate, often more accurate than drawing designs by hand.
- It is easier to modify or revise an existing design.
- Storage space is reduced as the files are electronic.
- Files can be shared around the world very quickly, or imported into presentations.
- 3D models can be rotated and viewed from different angles.
- Designs can be simulated to see how well they function. This will allow potential problems to be spotted early in the design process.
- Designs can be exported to CAM equipment for manufacture.

The main disadvantages of CAD include:

- Some CAD packages are expensive to buy, so there can be a high initial setup cost.
- There needs to be access to appropriate ICT hardware to run the software. Thus usually needs to be a computer with a very good specification, which can be expensive.
- Some designers may not be familiar with how to use CAD software, so time and money must be spent training them. In addition they must also regularly update their skills.



CAD Designer



Solid Modelling

Computer Aided Manufacturing

The use of computer software to control machine tools to manufacture products is called Computer Aided Manufacturing (CAM). Examples of CAM equipment include laser cutters, vinyl cutters and 3D printers.

The main advantages of CAM include:

- Complex shapes can be produced much more easily than when manufacturing by hand.
- There is consistency of manufacture as every product produced is exactly the same.
- It enables high levels of precision and accuracy.
- There is greater efficiency as machines can run 24 hours a day, 7 days a week.
- It increases the speed of manufacture, especially when producing products in large volumes.

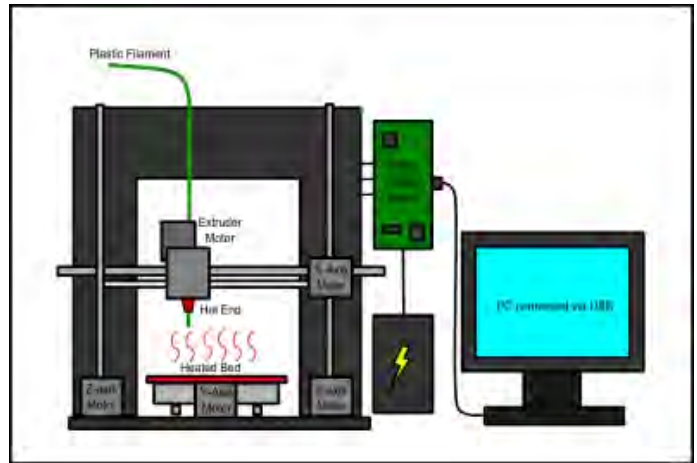
The main disadvantages of CAM include:

- As with CAD initial setup costs can be high. CAM machines are usually very expensive, although their cost is reducing with time.
- Operators must be trained to use the equipment, which adds time and cost.
- For one-off products, CAM can actually be slower than if the product was produced by hand.

3D Printing

3D printing is a process that replicates a CAD drawing by slicing the CAD model into thin layers using specialist software, allowing intricate items to be made.

This has tended to be a very expensive process, however *Additive 3D Printers* have made the process more affordable. They build models by extruding very thin layers of heated polymer, usually ABS or PLA onto a heated bed fusing each layer together until the model is complete. They are used to produce a small number of identical parts for use in projects or to model designs for testing.



Laser Cutting

Laser cutters use high-powered lasers to cut a wide range of materials including acrylic, paper, wood and metal. Laser cutting acrylic is an ideal process as it finishes the edge as it cuts the material from a sheet.

Laser engraving is often used on acrylic and laser engraving laminates for signage or to enhance the text or an image on the surface of the material. This process is more accurate than engraving by hand, however, the equipment cost of laser engraving can be expensive.

Vinyl Cutting

Vinyl stickers can be cut using a CNC plotter cutter directly from a CAD file allowing colour and text to be added to the surface of a polymer. A sticker requiring different colours is made up by repeating the process on different coloured vinyl and overlaying each layer to form the image or text. Vinyl stickers are commonly used to create signage as well as creating advertising wrap designs on buses and cars. Care needs to be taken when positioning stickers and they may peel off in some circumstances.



Laser engraved acrylic



Vinyl cut graphic

Learning Outcome 4: Solve engineering problems

Measuring

When measuring component parts in the workshop we use millimetres as they are more accurate than centimetres. Most components will be measured using a steel rule, however, you may need to use a **Vernier Calliper** or a **Micrometre** for some components. These measuring tools use hundredths of a millimetre and are very accurate.

Remember!

1mm	=	0.1cm	To convert mm to cm $\div 10$
10mm	=	1cm	To convert cm to mm $\times 10$
50mm	=	5cm	
57mm	=	5.7cm	
100mm	=	10cm	

Mathematical Techniques

Mean

The mean is the most common measure of average. To calculate the mean add the numbers together and divide the total by the amount of numbers:

$$\text{Mean} = \text{sum of numbers} \div \text{amount of numbers}$$

Median

If you place a set of numbers in order, the median number is the one in the middle.

Mode

The mode is the value of the number that occurs most often.

Example

The following set of data shows the number of parts made by nine engineering students in a week.

8	4	4	6	3	7	3	2	8

The mean is $45 \div 9 = 5$.

You work this out by (the total number of parts) $\div$ (the total number of students).

Use of formulae: Ohm’s law

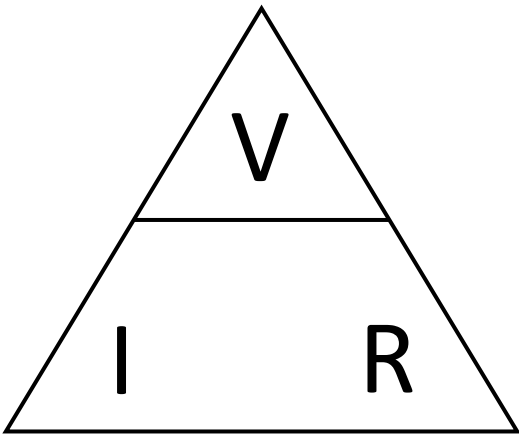
Ohm’s law is used to describe the relationship between Voltage (V), Current (I) and Resistance (R). If you know any of two of these values it is possible to calculate the third. Ohm’s law can be arranged in the following three ways depending on what you want to calculate.

$V = I \times R$
 $I = V / R$
 $R = V / I$

Note: V = Voltage in Volts, I = Current in Amps, R = Resistance in Ohm’s

The Ohm’s law triangle

A very useful tool that can be used when doing one of the above calculations is the Ohm’s law triangle shown below. The triangle is used by covering the item which you wish to calculate. The two items that are not covered will then be left in the arrangement required to calculate the covered item. For example if you want to calculate R you would cover that item. The two remaining items are arranged as V/I. This is the formula to calculate R.



Complete the calculations below using the examples above:

Voltage			
Question 1	I = 5 Amps	R = 1 Ohm	
Question 2	I = 3 Amps	R = 4 Ohm	
Question 3	I = 2 Amps	R = 3 Ohm	

Current			
Question 4	V = 5 Volts	R = 1 Ohm	
Question 5	V = 12 Volts	R = 4 Ohm	
Question 6	V = 24 Volts	R = 12 Ohm	

Resistance			
Question 7	V = 5 Volts	I = 5 Amps	
Question 8	V = 3 Volts	I = 6 Amps	
Question 9	V = 50 Volts	I = 10 Amps	

Use of formulae: Efficiency

The definition of efficiency is the ratio of the useful work performed by a machine or in a process to the total energy expended or heat taken in. For example, "the boiler has an efficiency of 45 per cent." Engineers at BMW would use this to work out how efficient their vehicles can be by using different engines and materials.

Efficiency =

Useful energy

Total energy in

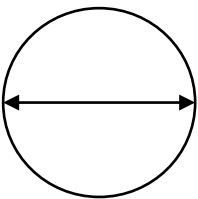
For example, a street lamp uses **100 joules** of **electrical energy**.
75 joules of this are wasted as **heat energy** and only **25 joules** are converted into **light** (the useful energy).

Efficiency = 25/100 = 0.25 or 25% efficient

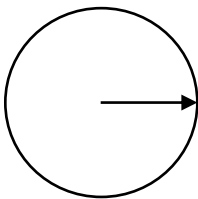
Complete the calculations below using the efficiency cards provided:

Appliance	Energy in	Waste energy	Useful energy	Efficiency
Street lamp	100 J	75 J	25 J	25J/100J = 0.25
	Electrical	Heat	Light	25% Efficient
iPhone				
	Electrical	Heat	Light	
Lamp				
	Electrical	Heat	Light	
Torch				
	Electrical	Heat	Light	
Microwave				
	Electrical	Heat	Light	
Matches				
	Electrical	Heat	Light	

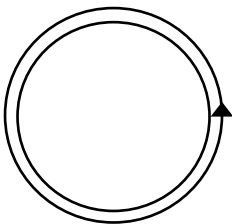
Areas and volumes of geometrical shapes



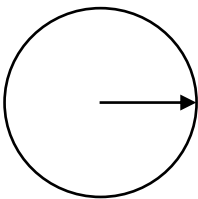
Diameter
 $\varnothing$ or D



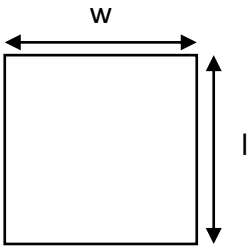
Radius
R



Circumference
 $C=2\pi r$

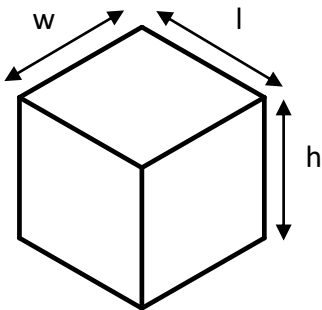


Area
 πr^2

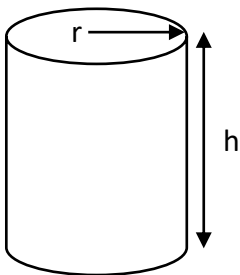


Area
length x width

$\pi = 3.142$



Volume
length x width x height

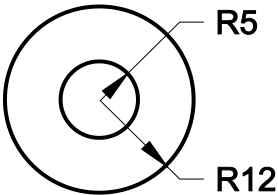


Volume
 $\pi r^2 h$

1 Use $A = \pi r^2$ to find the areas of circles with these radii.				
14cm	35mm	2.6m	62mm	28cm

2 A metal washer has the dimensions shown in the diagram.

Calculate the area of the washer.

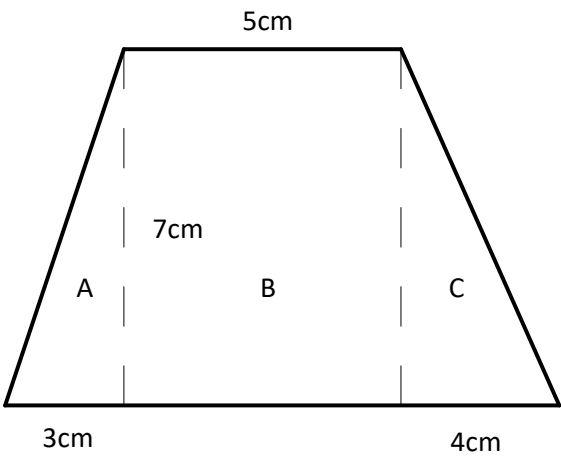


Area of complex shapes

Remember!

Area of a rectangle = length x width ($A = l \times w$)

Area of triangle = $\frac{1}{2} \times \text{base} \times \text{height}$ ($A = \frac{1}{2} \times b \times h$)



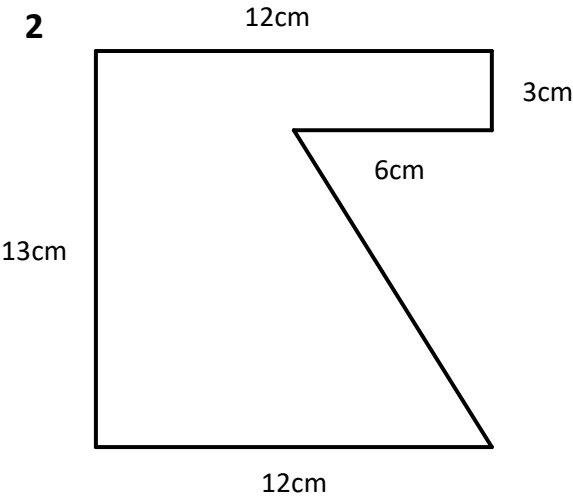
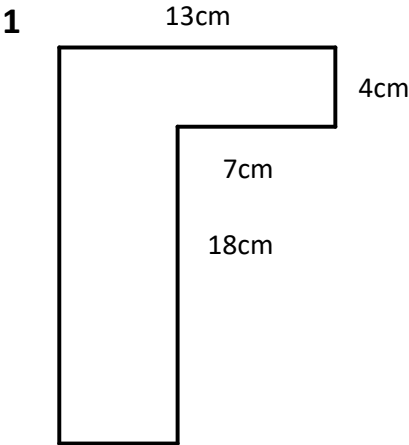
Example

Work out the area of the rectangle and each of the triangles separately and then add them together to find the area of the whole shape.

Area of shape = area of triangle A + area of rectangle B + area of triangle C

$$\begin{aligned} & \frac{3 \times 7}{2} + 5 \times 7 + \frac{4 \times 7}{2} \\ & 10.5 + 35 + 14 \\ & = 59.5\text{cm}^2 \end{aligned}$$

Find the area of each of these profiles that must be cut from a piece of sheet steel.



Volume of complex shapes

Working out the volume of cuboid shapes is shown opposite.
It is possible to find the volume of shapes made from cuboids by breaking them down into smaller parts.

Example

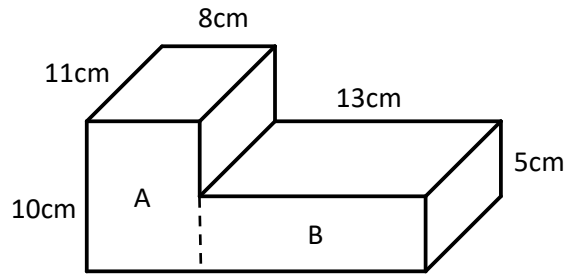
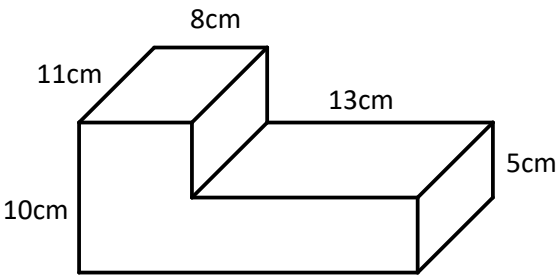
Find the volume of this shape

Solution

This shape can be broken into two cuboids **A** and **B**.
Work out the volumes of these two cuboids and add them together to find the volume of the whole shape.

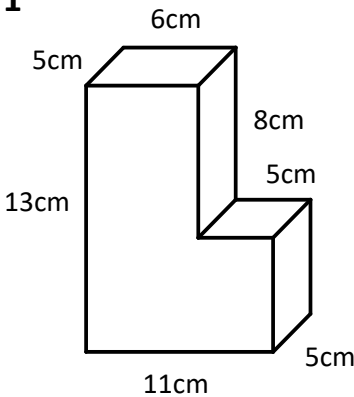
Volume of shape = volume of **A** + volume of **B**

$$\begin{aligned} &8 \times 11 \times 10 + 13 \times 11 \times 5 \\ &880 + 715 \\ &\mathbf{1595\text{cm}^3} \end{aligned}$$

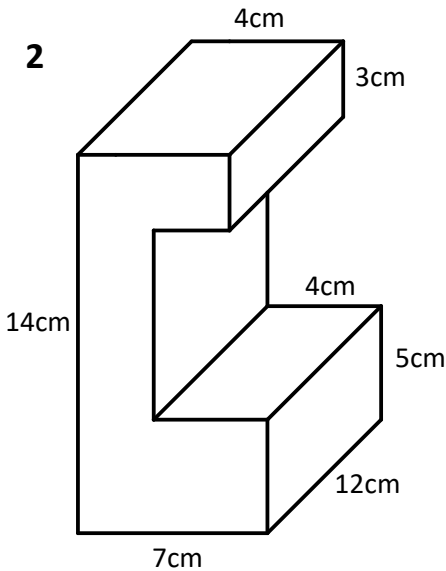


Find the volume of concrete required for each of these components.

1



2



Volume of a cylinder

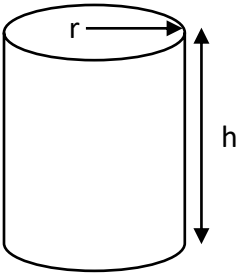
To work out the volume of any cylinder you multiply the area of the circle by the length or height.

Example

Find the volume of a cylinder with radius 13cm and height 50cm.

Solution

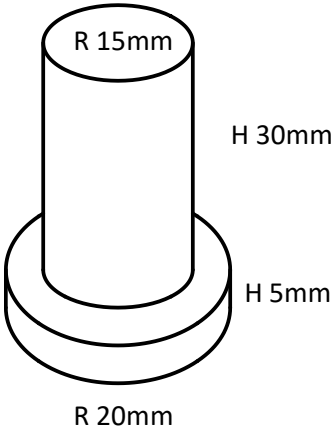
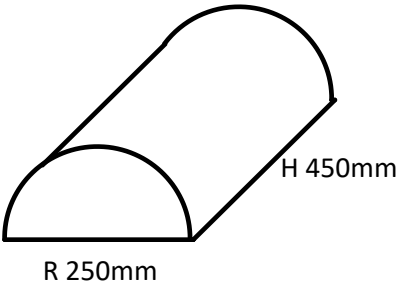
Volume $\pi r^2 h$
 $3.142 \times 13^2 \times 50$
26 549.9
26 550cm³



Volume
 $\pi r^2 h$

Use Volume $\pi r^2 h$ to work out the volumes of the following cylinders.				
Radius 8cm Height 35cm	Radius 14cm Height 42cm	Radius 25mm Height 6mm	Radius 3m Height 25m	Radius 5.8m Height 3.5m

1. Find the volume of concrete required for the capping stone below.
2. Find the volume of aluminium required to cast the component below.



Describing engineering developments

How have engineering developments impacted the following three areas:

Structural design – Development of bicycles

Developments in new lightweight materials have improved the efficiency of bicycles by reducing weight and increasing structural strength. The use of composite materials has allowed for improved streamlining. Further developments in tyre and gear technology have all impacted on the cycling world in both professional sports and daily use.

Mechanical design – Focus on theme parks

The engineering developments in theme parks have allowed the creations of far more immersive and challenging experiences for users. The integration of sophisticated mechanical animatronics combined with more mechanically advanced motions on rides and digital content have revolutionised theme parks.

Electronic design – Mobile phone technology

The developments in mobile phone technology are fast paced and evolve on a regular basis. The introduction of more connectivity to smart home devices, the inclusion of more control of our surrounding home environment, from geo tagging to camera and screen development, have revolutionised mobile phones and their use.

The effects of engineering developments

How has the impact on engineering products been impacted by:

Materials – New materials have impacted directly on engineered products in a variety of ways. Improved strength and reduced weight has had a dramatic impact, as has the development of new alloys and smart materials. Developments in plastics and textiles have also allowed for more diverse products and garments to be developed.

Smart technology – The growth in smart home integration has driven smart technology developers to focus on more integrated products and services. As more products incorporate Bluetooth and WiFi connectivity, the overall outcome is improved quality of living for people both at home and at work.

Electronic and microelectronic components – Continued miniaturisation of components has allowed electronic products to become smaller and faster with increased storage capacity, making devices more efficient and reliable. Improved screen technology and the way in which we interact with technology has changed considerably in recent years. Considerations should be given to identify both the positive and negative aspects of the above developments when discussing the individual topics.

How environmental issues affect engineering

How engineering applications and products have an environmental impact.

Materials development – The improved use of sustainable materials and the way that recycling has improved has had a positive impact on the environment. The development of new plastic polymers is reducing the dependency on petroleum-based plastics.

Costs – The improvement of more efficient manufacturing techniques has helped to reduce the overall cost of producing some materials. Some raw material prices are volatile due to changing prices of oil and ores.

Transportation – The impact of the need to move products globally and the effect that emissions have on our environment.

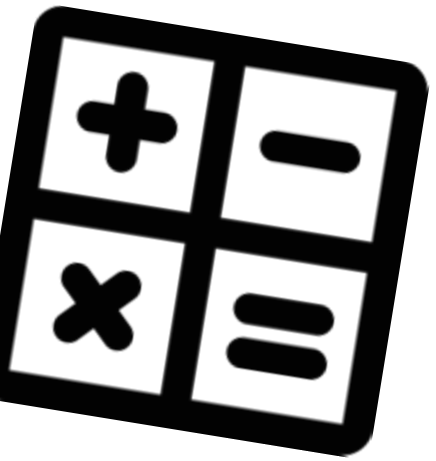
Usage – The impact that end users have on products by the way that they are disposed of at the end of life. The different ways in which countries approach sustainability and recycling.

Disposal – How do different countries dispose of products when they fail or reach their obsolescence?

Recycling – What strategies are available for recycling products? Are these successful and are there any obvious failures?

Sustainability – What strategies exist for managing sustainable development of products and resources?





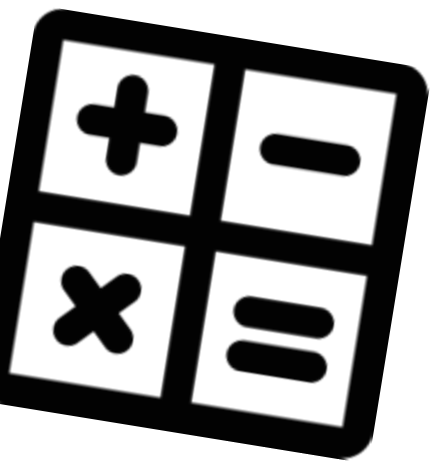
WJEC UNIT 3 - EXAMINATION

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Slide 14	AC1.2 Understand how changes in engineering have impacted society, industry and the home.
Slide 20	AC1.3 Environmental impact of products.
Slide 25	AC2.1 Material properties. Understand how structures are designed to be strong. Mechanical systems, e.g. gears, bearings, linkages etc.
Slide 34	AC2.2 Testing processes.
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Slide 45	AC3.1 Manufacturing processes.
Slide 53	AC3.2 Finishing processes.
Slide 56	AC4.1 Mathematics.
Slide 63	AC4.2 Technical drawings, including the industry standards for drawings.
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Slide 70	AC4.4 Be able to design products and show ideas through drawings and writing.
Slide 72	Additional useful information



When you see this symbol click the image in the digital version to watch a video.



WJEC UNIT 3 – AC 1.1

STRUCTURAL ENGINEERING

Architectural structures fill the world around us. Buildings are often designed using a frame or shell structure. Many structures make use of triangulation to give the form strength.

Frame structures

A frame structure is made up of multiple parts joined together.

Most large buildings are built this way using structural steel joists.



Shell structures

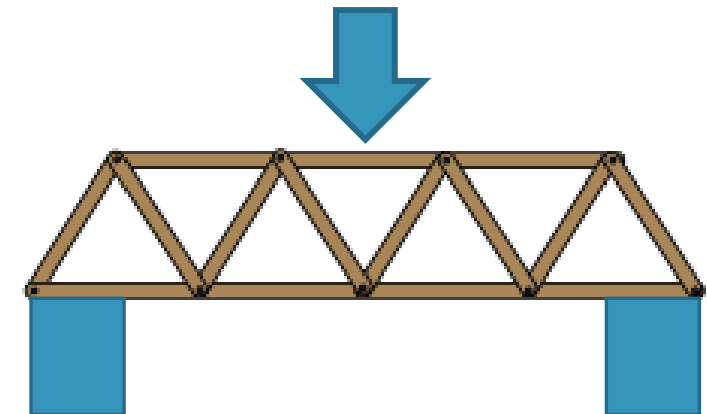
A shell structure is one surface, and gains strength from its form.

This structure is often found in nature, but also in a number of man made products, the Sydney opera house and coke cans are good examples.



Triangulation

Triangulation involves the use of triangular shapes to give stability to structures. Triangles are particularly good at resisting force applied to compress them.



VEHICLE STRUCTURES

Ladder chassis

This is the simplest form of chassis. Mechanical running gear is mounted onto a chassis system which is separate from the vehicle's body. The overall weight of the vehicle is higher than the other 2 methods.



Space frame chassis

Space frame vehicles use a complex frame of welded metal bars to provide the structure. The running gear is mounted within this frame, and body panels are secured to the outside. This type of chassis is very strong and lightweight and is used in motorcycle, off road and some sports car applications.



Monocoque chassis

The majority of modern vehicles have a monocoque chassis. The body and chassis are one unit made of various panels secured together. The design reduces additional unnecessary weight while maintaining body rigidity and strength. Assembly can be largely automated.



STRUCTURAL — FORCE DEFINITIONS

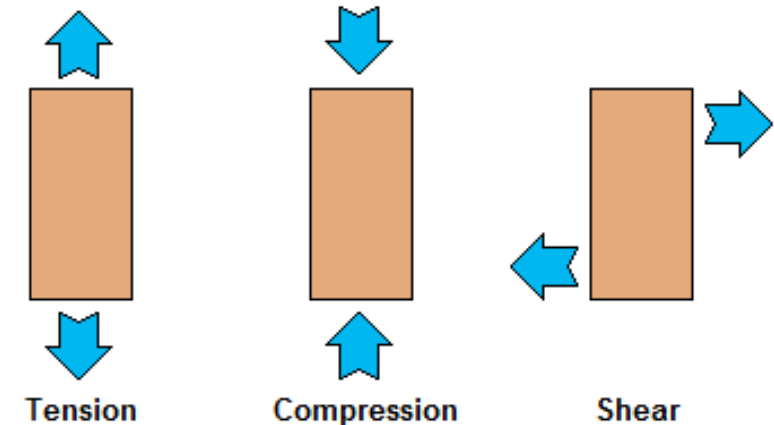
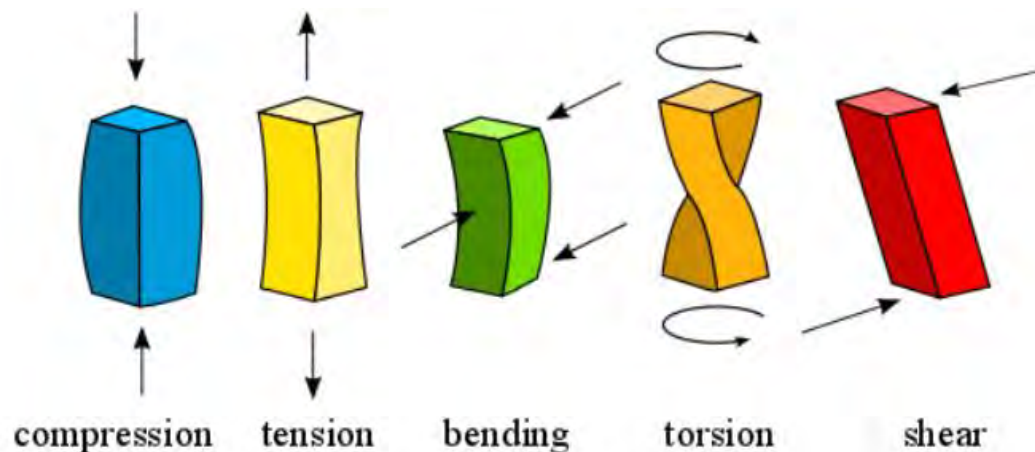
Compression is where an object is put under pressure making it smaller.

Tension is where a stretching force is being applied which tries to make the object longer.

Bending is where a force is applied to the middle of an object to distort it.

Torsion is a twisting force applied to an object.

Shear is where two forces are applied in opposite directions across an object.

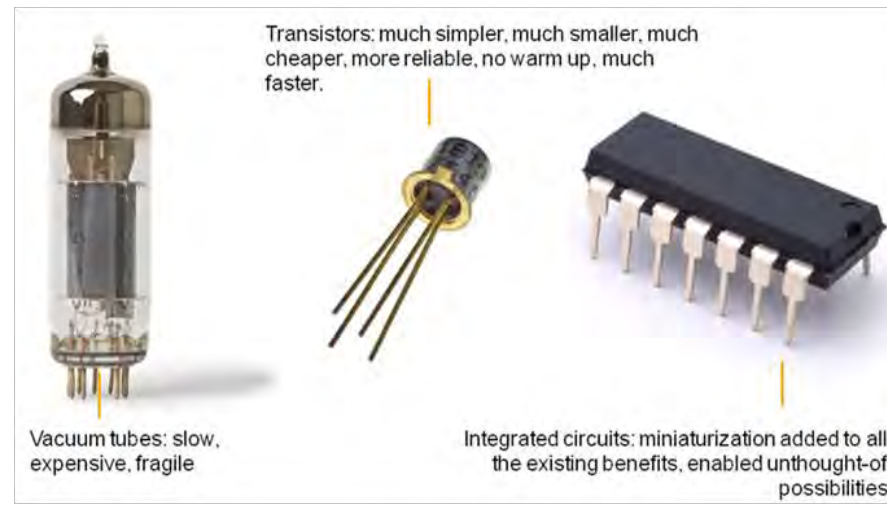
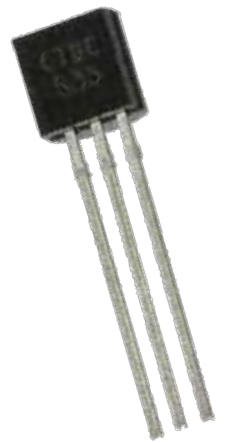


ELECTRONICS

Few areas have developed as quickly as electronics.

In 1965 Gordon Moore made an observation that electronic components were becoming more powerful while costs were dropping, this observation has become known as Moore's Law

“Moore's Law is that the number of transistors on a chip doubles every two years while the costs are halved. Moore's Law predicts that this will continue into the foreseeable future.”



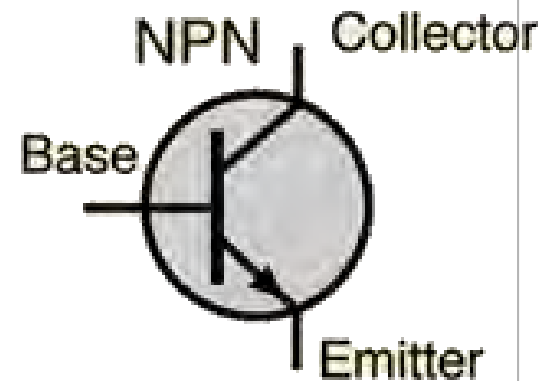
ELECTRONICS - TRANSISTORS

Transistors can be considered electronic switches, but rather than requiring a physical press they are switched via a small electric current. When a small current is applied to the **Base** electricity passes through the **Collector** to the **Emitter**.

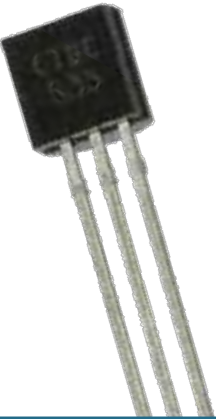
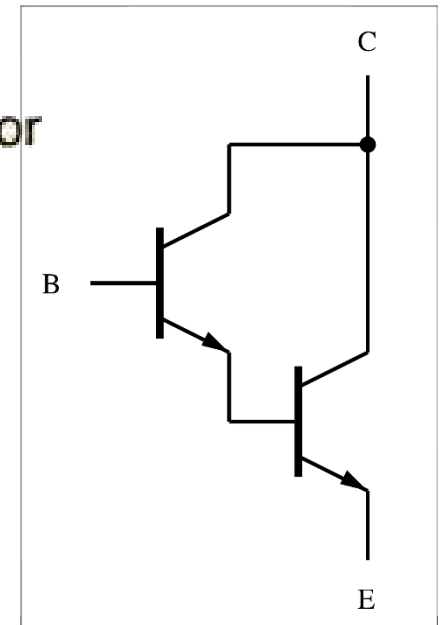
Key features:

- They can handle a large current between **Collector** and **Emitter**.
- They only require a small current to the **Base** to switch, because of this they are often used to amplify current.
- The output current is proportional to the input current.
- For a larger increase in current two transistors can be arranged in what's known as a Darlington Pair. When the first switches on it applies a larger current the **Base** of the second transistor, allowing more current to pass from it's **Collector** to **Emitter**.

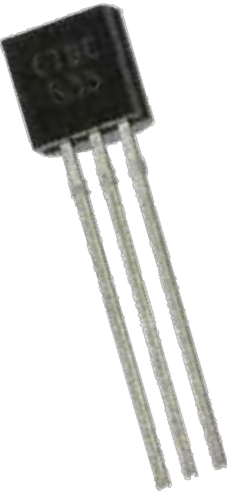
NPN Transistor



Darlington Pair



ELECTRONICS — BATTERY TECHNOLOGY



Battery technology has also developed a huge amount over time.

Advantages of the newer batteries:

- Lighter — Cars, drones etc can travel further.
- More capacity — Batteries last longer.
- More power — Batteries can store more energy.
- More shape options — They can fit a larger range of products.
- Minimal ‘memory’ — Older batteries would develop a ‘memory’ where if recharged from say 30% rather than 0% they wouldn’t discharge beyond 30% next time.

Battery timeline

Lead Acid batteries
NiCD — Nickel-cadmium
NiMH — Nickel-metal hydride
Lithium ion batteries

Older - Newer

ELECTRONICS — SCREENS

Advantages of the newer screens:

- Smaller — This enables them to be fitted to more products.
- Require less energy — Batteries will last longer.
- Higher quality.
- Thinner — Overall product thickness can be reduced.
- Lower cost.



Screen timeline

CRT — Cathode ray tube

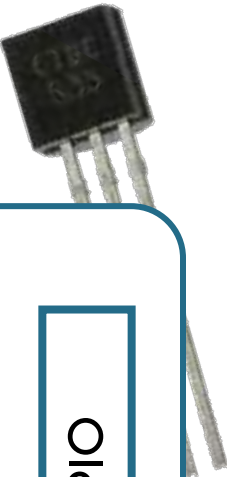
LCD display — Liquid crystal display

Touch screen

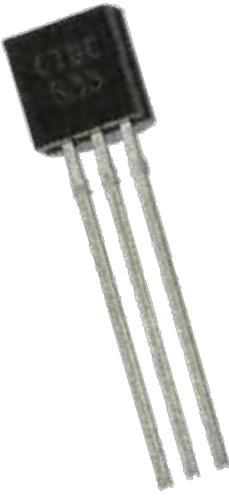
4K display

Flexible displays? (Currently under development)

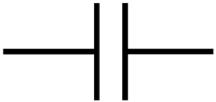
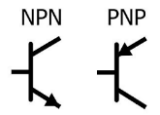
Older - Newer



ELECTRONICS — ELECTRONIC COMPONENTS



These are the essential electronic components you need to be aware of:

Component name	Symbol	Description
LED		Light Emitting Diode. Shines light when a current flows through it.
Resistor		A passive component that resists an electric current.
Push to make (PTM) switch		A switch that has to be pressed to complete a circuit. The circuit is broken upon release.
Capacitor		An electronic component that stores an electric charge.
Transistor		A switch that operates with the application of a small electrical charge.
Variable resistor		A resistor whose resistance can be changed.

ELECTRONICS — CIRCUIT BOARDS

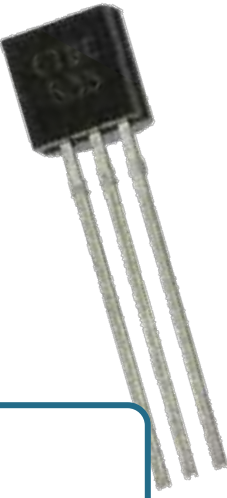
Manufacture — PCB Engraving

The material between tracks is physically removed with a sharp engraving tool on a CNC mill.



Manufacture — PCB Etching

The material between tracks is removed in an acid bath. The tracks are protected with a film.



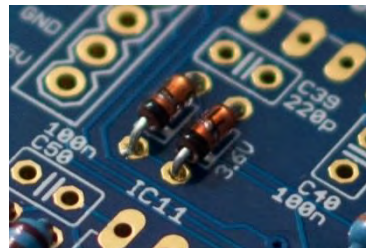
Population of PCB — Pick and place

Modern circuit boards are populated automatically by **Pick and Place** machines. They rest the **Surface Mount Components** on top of pre-soldered tabs. The whole board is heated to melt the solder and make the connection.



Population of PCB — Through hole technology

Older boards, simpler boards, rely on **Through Hole Components** these boards are drilled, the components fitted through the holes and soldered on the underside.



5 KEY INFLUENTIAL ENGINEERS

Henry Ford

Born: 1863 Michigan USA

Key achievements:

- Founded the Ford motor company.
- Credited with applying assembly lines to automotive production, this revolutionised the car industry and made automobiles far more affordable.



Henry Ford
1863–1947



Elon Musk

Born: 1971 South Africa

Key achievements:

- Founded SpaceX who design and manufacture aerospace equipment.
- CEO of Tesla the world leaders in electric vehicle production.
- Founded The Boring Company who are looking to revolutionise city transport via a network of tunnels.



Elon Musk



Leonardo Da Vinci

Born: 1452 Italy

Key achievements:

- Influential Scientist, Artist and Engineer during the Italian Renaissance.
- Conceptualised many inventions including the helicopter, parachute, calculator as well as many material testing machines.
- Painted 'The last supper' and 'Mona Lisa'



Leonardo da Vinci
1452–1519



James Dyson

Born: 1947 England

Key achievements:

- Founded Dyson
- Designed the cyclone vacuum cleaner.
- Continues to develop household appliances including air purifiers, heaters and hair dryers.



James Dyson



Isambard Kingdom Brunel

Born: 1806 England

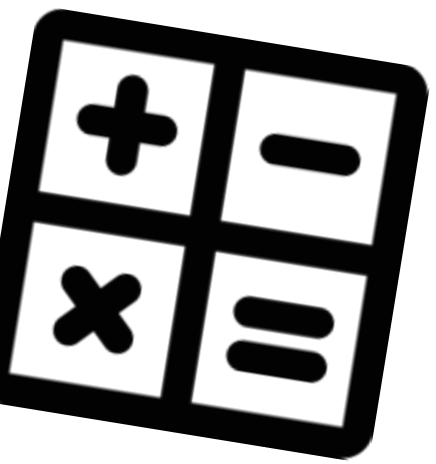
Key achievements:

- Developed the SS Great Britain, the first ocean going iron ship.
- Assisted in the construction of the first tunnel under the Thames.
- Set the standards by which railway networks are built.



Isambard
Kingdom Br...
1806–1859





WJEC UNIT 3 – AC 1.2

IMPACT OF ENGINEERING DEVELOPMENTS - HOME

The Unit 3 examination will usually include an engineered product found in the home. Try to consider the following 2 questions when answering.

- How does this improve a user's quality of life?
- What are the specific differences, and what impact will they have on the user's experience.

For example stating that the modern vacuum works autonomously (by itself) won't achieve full marks. Adding a little more detail by saying this allows the home owner to get on with something else should secure more marks.

2. The world of engineering is greatly influenced by developments in technology. One area that has seen many changes is the development of household products.

Below are two vacuum cleaners. The one on the left is a basic vacuum cleaner, from the 1970s. The one on the right is a modern hi-tech vacuum cleaner.



1970s cleaner



Modern hi-tech vacuum cleaner

- (a) Describe **two** ways how modern technology has made the modern hi-tech vacuum cleaner easier to use in the home.



IMPACT OF ENGINEERING DEVELOPMENTS - INDUSTRY

Advantages of CAD (Computer Aided Design)

- Designs can be 3D and can be rotated, zoomed and exploded.
- High quality renders can be produced.
- Collaboration is much easier due to E-mail.
- Parts can be analysed before manufacture.
- Links directly to Computer Aided Manufacturing.
- Very easy to modify designs.
- Very precise and accurate designs can be produced.

Disadvantages of CAD (Computer Aided Design)

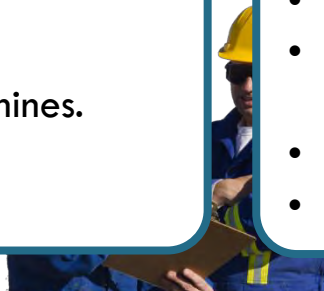
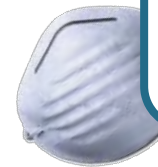
- Workforce needs to be trained to use CAD system.
- High software and hardware costs.
- Potential for computer files to be damaged by viruses / hacking.

Advantages of CAM (Computer Aided Manufacturing)

- Parts can be made faster.
- Systems can be automated.
- Higher level of accuracy.
- One member of workforce can run multiple machines.
- Lower product cost per unit.
- Safer workplace.

Disadvantages of CAM (Computer Aided Manufacturing)

- Less workforce required.
- High machinery costs.
- Remaining employees have higher wages due to increased skill level.
- System errors can quickly become very costly.
- Less employment for the unskilled.



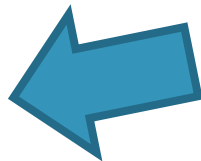
IMPACT OF ENGINEERING DEVELOPMENTS - INDUSTRY

Manufacturing factories can be built in 2 different configurations. Dedicated and flexible systems.

Dedicated System

“A dedicated system is set up to make one product.”

The manufacture of aluminum can is a good example of a dedicated system.



Flexible System

“A flexible system can be adapted to change the products manufactured.”

CNC machinery is an essential part of a flexible manufacturing system.



Note: When discussing the 'advantages and disadvantages' of automation the fact few employees are required could be seen as an advantage for the company, or disadvantage for employees. Make sure you are clear when answering an exam question.

IMPACT OF ENGINEERING DEVELOPMENTS - INDUSTRY

CNC machines are an essential component of flexible manufacturing systems.

CNC machinery

Laser cutter, CNC lathe, CNC milling machine, CNC router, waterjet & plasma cutters (similar to laser cutters but for metals)

Advantages of CNC machines:

- Large amount of flexibility, jobs can be changed quickly.
- High level of accuracy and manufacturing speed possible.
- Can be automated and linked with other machines via robotic arms, conveyor belts etc.
- Few employees required to run machines.

Disadvantage of CNC machines

- Far higher set up cost
- Highly skilled, well paid employees required to set up and service the machine
- Machining errors can be more costly.

Robotic arms

These have multiple joints mimicking a human arm.

Advantages of robotics

- They are very accurate.
- They can repeat a job without tiring.
- They can perform in environments dangerous to humans.
- They can lift heavier weights than humans.
- Products to be made for less money.

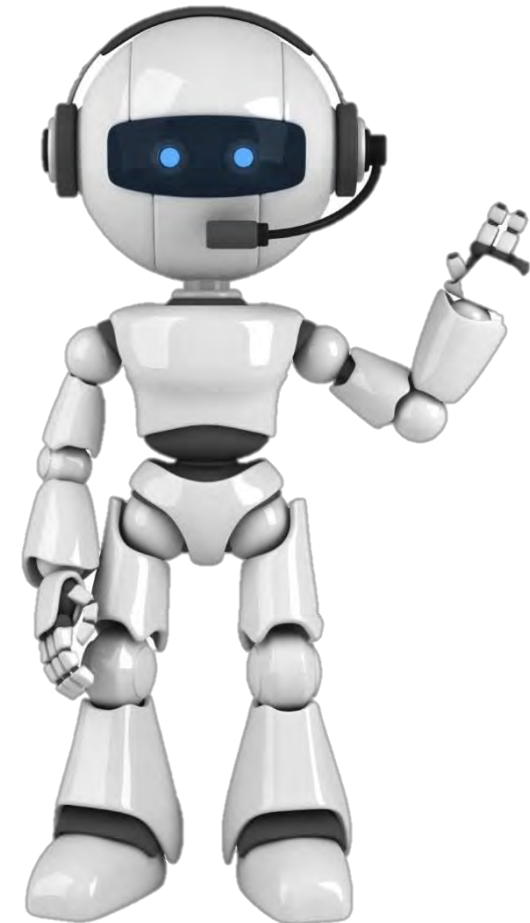
Disadvantages of robotics

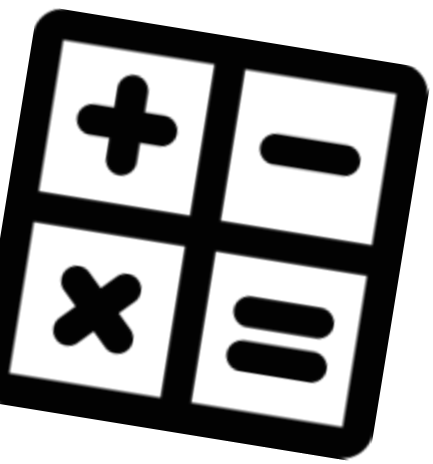
- Very high installation, programming and servicing costs.
- There are less jobs as a result.

IMPACT OF ENGINEERING DEVELOPMENTS - SOCIETY

What will the impact on society be as technology develops? Write down your thoughts on the following areas as you watch this video.

- Jobs
- Employee skill level
- Work / life balance





WJEC UNIT 3 – AC 1.3

Mr Graham

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ENVIRONMENTAL IMPACT OF ENGINEERING

We need to think about the environmental impact of a product at 4 key stages during its life:

- **Manufacture** – Energy consumption at the factory, waste material, noise and heat pollution etc.
- **Delivery** – Distance between manufacturer and consumer. Product weight and the size influence fuel consumption during transport.
- **During use** – The efficiency of the product during its life.
- **End of life** – Can it easily be recycled, repaired or reused?

ENVIRONMENTAL IMPACT OF MATERIALS

The materials a product is made from, and the way it is put together influence how easily it can be recycled. This makes them factors in how large an impact the product will have on the environment.

Materials

Aluminium – Can be recycled repeatedly without losing its properties.

Steel – Steel can be recycled, but this process requires more energy than recycling aluminium. Steel also requires more energy to form than aluminium.

Polymers (Plastics) – Thermoplastics can be recycled, but they must be separated into groups of the same polymer (See AC2.3 for information on the RIC system). Thermoset polymers cannot be melted down.

Composites – These modern materials are often held together with resins, because of this they cannot be broken down into their original materials for recycling.

Designing a product for the end of life

Fixings – The product should be easy to dismantle. Welded or glued products for example are far harder to recycle than a product held together with easily accessible screws or bolts.

Material choice – Products that contain a large number of different materials are more difficult to recycle. Where possible products should be designed so they can be made from one material. Parts made from polymers must have the RIC code stamped in them to allow for easy identification of the polymer type.

Assembly – Products should be designed so they can be dismantled easily. This includes ensuring electronics can be removed from the case as part of the WEEE directive.

ENVIRONMENT —IMPACT OF MATERIALS



The Ferrari F12 on the left is made from aluminium, the one on the right has carbon fibre body panels. Discuss the difference the change in material will have on the environment at each of the 4 stages; **Manufacture, Delivery, During use, End of life.**



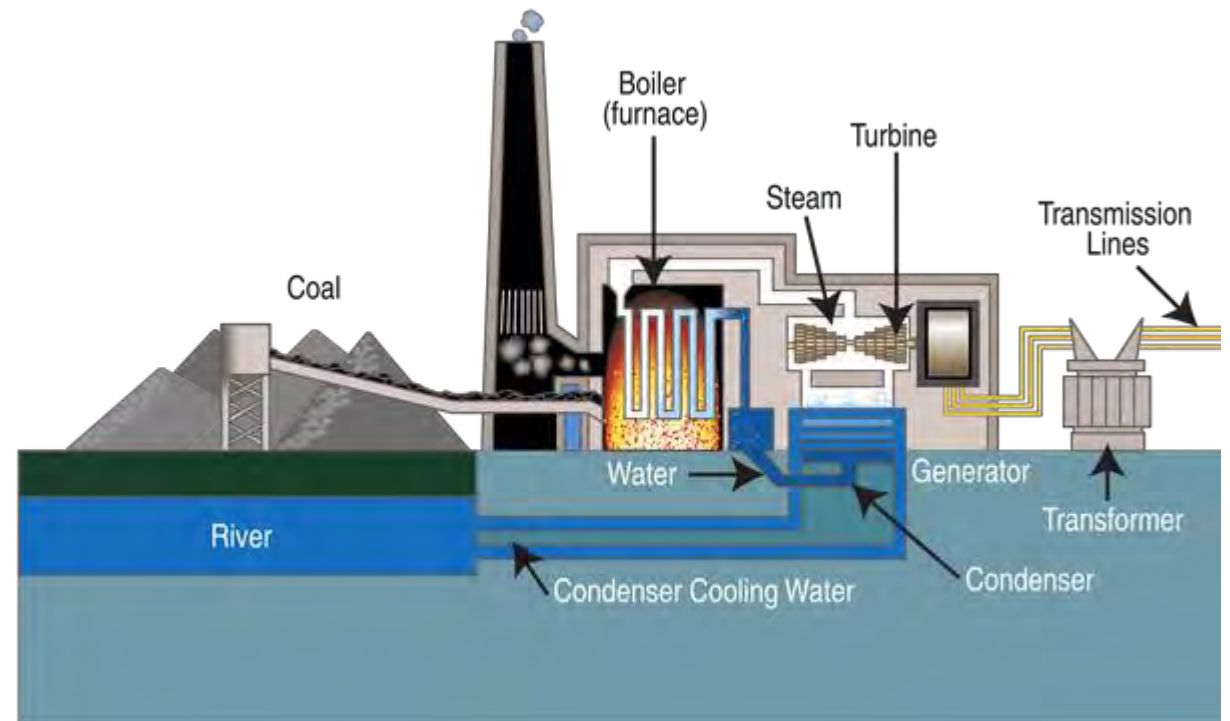
	Aluminium F12	Carbon Fibre F12
Manufacture	Click to remove	
Transport	Click to remove	
During life	Click to remove	
End of life	Click to remove	

Click on the lightening bolt to visit the GridWatch website. Here you can see how the UK's energy is currently being generated

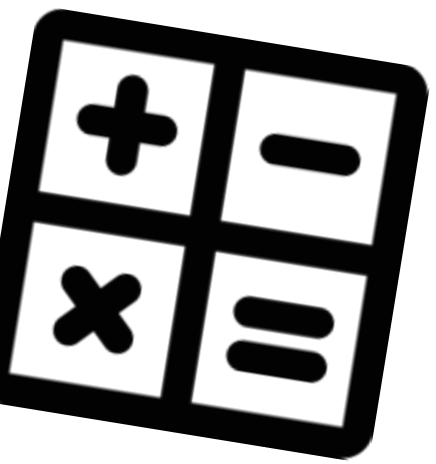


HOW ELECTRICITY IS GENERATED IN A POWER STATION

1. Fuel is burnt to generate heat, this could be a range of fuels. Alternatively the heat can come from nuclear energy.
2. The heat boils water turning it into steam.
3. The high pressure steam is forced over turbine blades causing them to rotate very fast.
4. The turbines are connected to a magnet which rotates inside a stator. This rotation generates the electricity.



Please note, this is a very simple explanation. Not all electricity is generated this way, solar and tidal for example are generated differently.

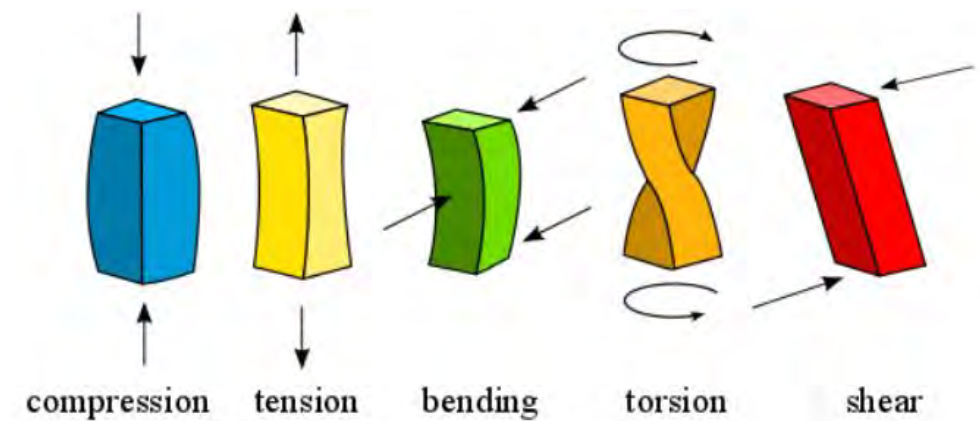


WJEC UNIT 3 – AC 2.1

Mr Graham

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MATERIAL PROPERTIES



Tensile strength – A material's ability to resist tension (Pulling force)

Hardness – resistance to abrasion, denting or bending. Very hard materials, like glass and high carbon steel, tend to be quite brittle.

Toughness – A materials ability to absorb energy without cracking.

Malleability – The ability to deform under compression. Malleable materials are well suited to shaping processes.

Ductility – The ability to be deformed under tension.

Conductivity – The ability to transfer heat or electricity.

Corrosive resistance – A resistance to damaging elements including acids and oxidation.

Elasticity – The ability of a material to resume its normal shape following distortion.

BASIC MECHANICAL SYSTEMS - SPEED VS TORQUE

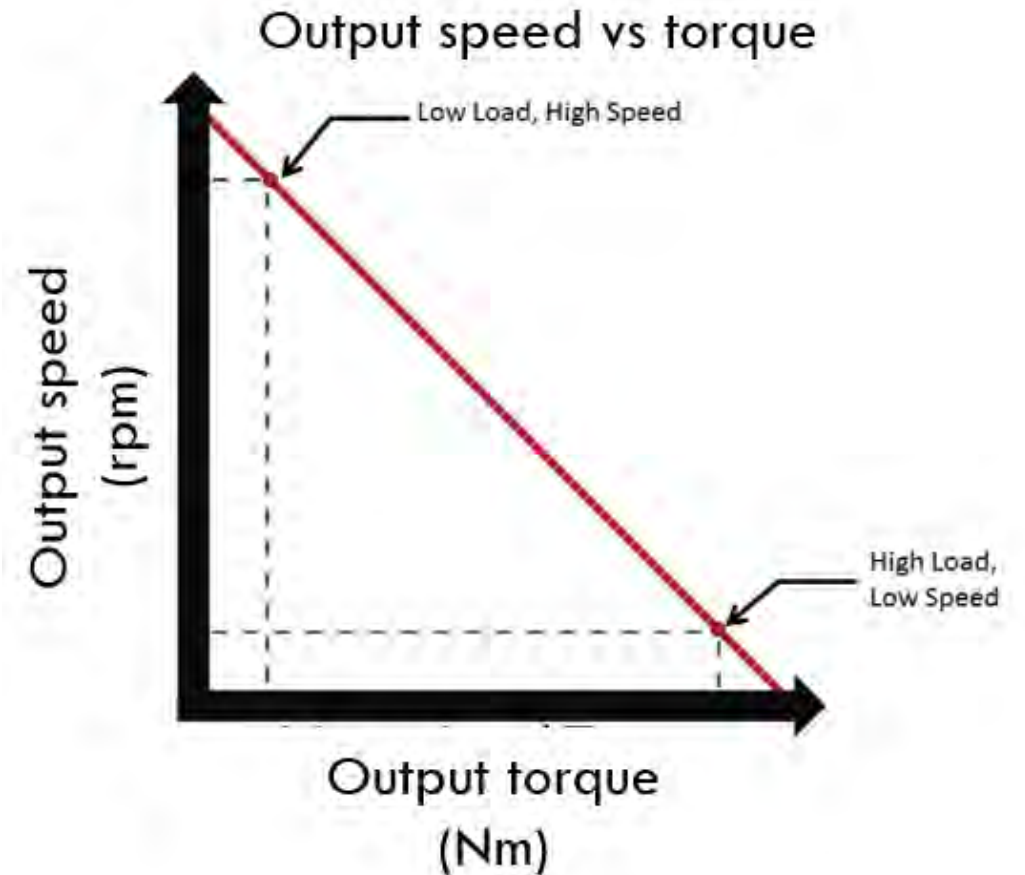
Torque is a measurement of rotational force.

Gears are used to change the output speed from a motor.
The slower the speed the greater the torque.

Examples

Tools that need high speed
+ low torque - An angle
grinder, sander.

Tools that need low speed
+ high torque – An electric
screw driver or wrench.



BASIC MECHANICAL SYSTEMS - GEAR RATIOS

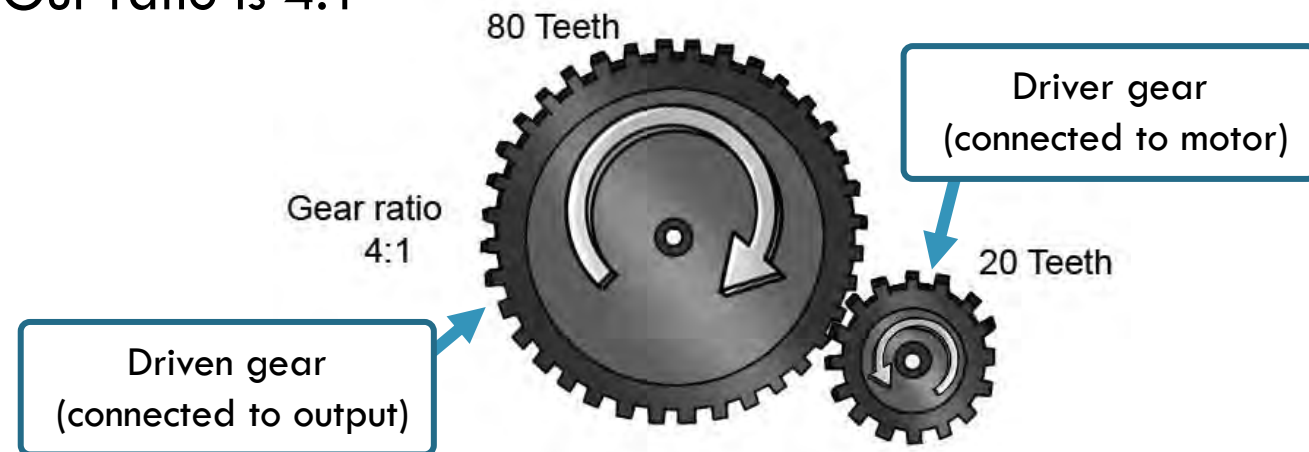
The speed / torque of a motor is changed by gears. The difference in speed between the output speed and original motor speed is determined by the gear ratio.

For example if a motor spins at 1,000rpm and goes through a gear box and ends up spinning at 250rpm that gearbox has a 4:1 ratio. Every 4 revolutions of the motor produces 1 revolution at the output.

In this example the output would have 4 times the torque and $\frac{1}{4}$ the speed of the original motor.

This reduction in speed / increased torque is achieved by the number of teeth on the gears.

The small 20 tooth **driver gear** below is connected to the motor. Every revolution of the **driver** turns the **driven gear** 20 teeth, because the **driven gear** has 80 teeth it only rotates $\frac{1}{4}$ of a turn. The Driver must turn 4 times to rotate the driven gear once. Our ratio is 4:1

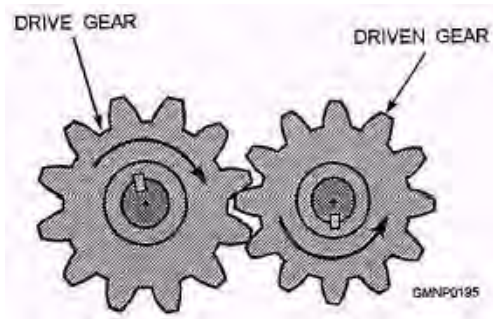


BASIC MECHANICAL SYSTEMS - GEARS

Here are 4 different gear systems used to lower speed / increase torque as well as change the direction / angle of rotation.

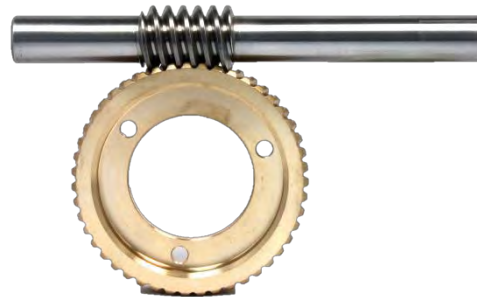
Gear train

This is the most basic type of power transition. It can be used to reverse the direction of the rotation and change speed/torque.



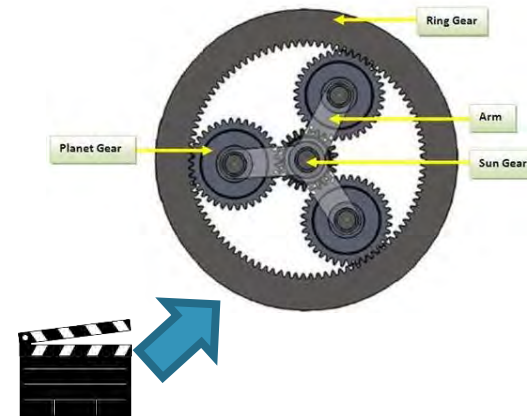
Worm gear

The worm gear provides huge gear reductions in a small space. It also changes the drive direction by 90°.



Planetary gearbox

These gearboxes produce a large reduction in the output speed within a very small space.



Bevel gears

The output rotation is changed by 90 degrees. These gears can also change the speed / torque of the output.



BASIC MECHANICAL SYSTEMS – CAMS & LINKAGES

There are 4 main types of motion. Cams and linkages are used to change one motion type into another.



Linear – Movement in one direction.



Rotary – Rotary movement in one direction.



Reciprocating – Movement back and forth.

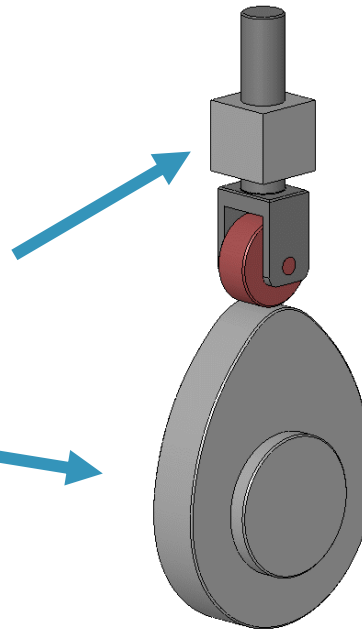


Oscillating – Rotary movement back and forth.

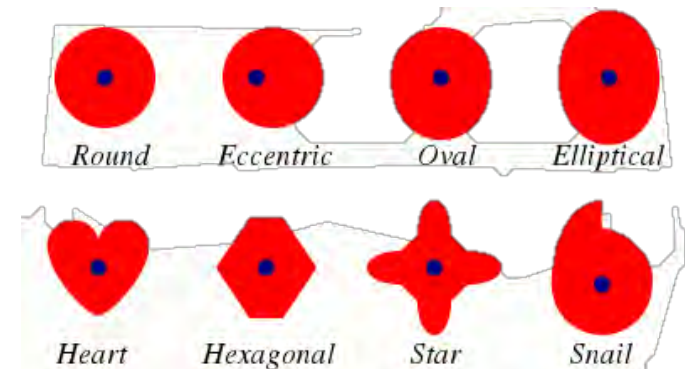
Cams

A cam system consists of 2 parts: a cam and follower.

- The **follower** that follows the profile of the cam and converts the rotary motion into reciprocating motion.
- The **cam** usually moves in a rotary motion



The shape (profile) of the cam changes the motion of the follower.

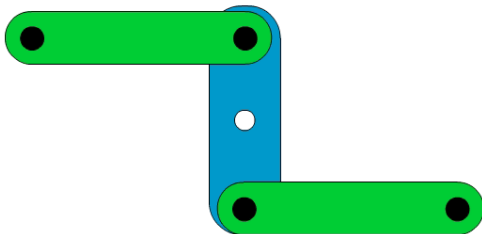


BASIC MECHANICAL SYSTEMS — CAMS & LINKAGES

There are many different types of linkages. Each does a slightly different job, here are 4 to be aware of.

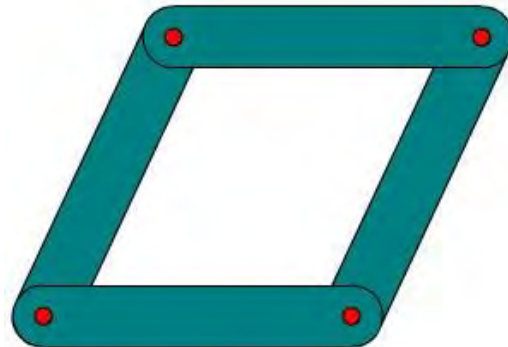
Reverse direction

This linkage reverses the direction. The top bar moves left while the bottom moves right.



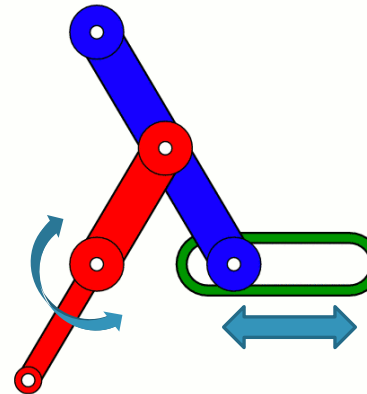
Parallel Linkage

This linkage keeps the bars parallel as it moves.



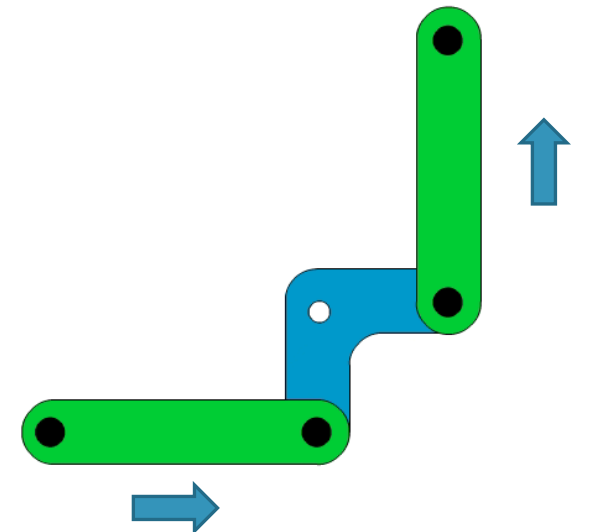
Slider linkage

This linkage changes a rotary / oscillating movement into a reciprocating motion.



Crank linkage

This linkage translates a linear movement by 90 degrees.



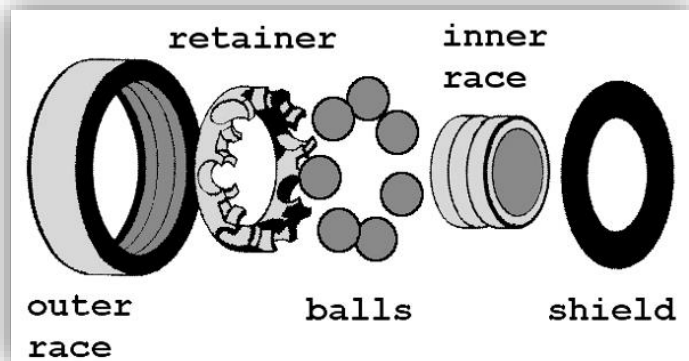
BASIC MECHANICAL SYSTEMS — ADDITIONAL INFORMATION

Bearings

Bearings come in a range of configurations, but are all used to reduce the friction between 2 parts. The majority of bearings reduce rotational friction.

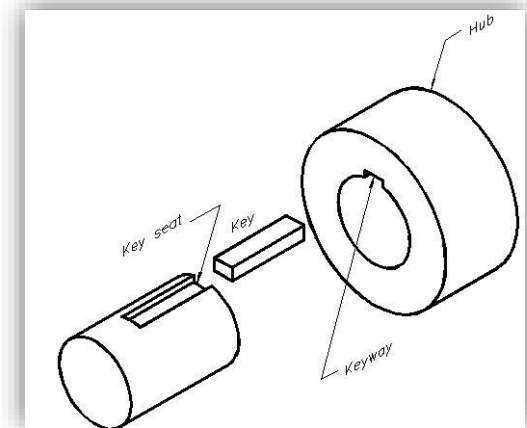
This is how a standard ball bearing works. The bearing has an inner and outer race which move independently of one another. For example:

The **inner race** remains stationary and the **outer race** rotates, or visa versa. Not all bearings work this way, but the majority do.



Keyways

There are a few ways to prevent one cylindrical part rotating inside another. One of the most common is by cutting a 'keyway' in the two parts. A hardened steel 'key' then prevents the two rotating.



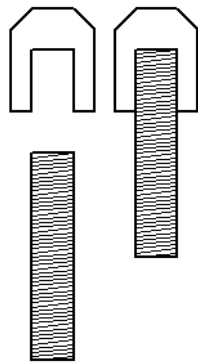
BASIC MECHANICAL SYSTEMS — ADDITIONAL INFORMATION

A keyway prevents rotation, but the parts can still slide along each other (lateral movement).

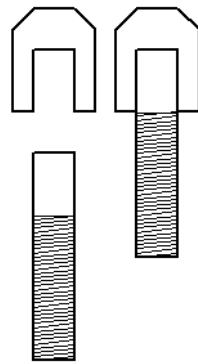
Pictured are some methods to stop lateral movement, while others also stop rotational movement.

METHODS OF SECURING 2 CYLINDRICAL PARTS TOGETHER

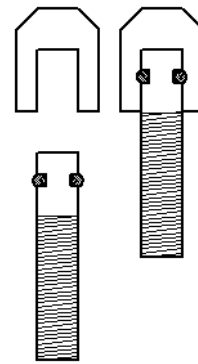
SCREW THREAD



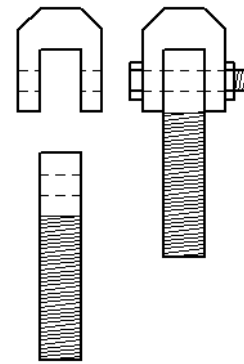
PRESS FIT



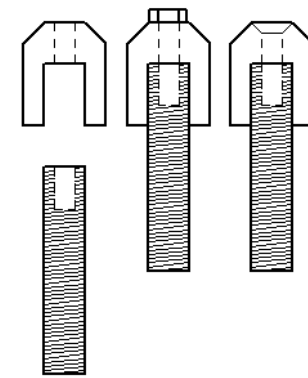
O-RING
PRESS FIT



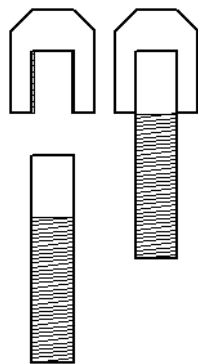
NUT AND BOLT
THROUGH SIDE



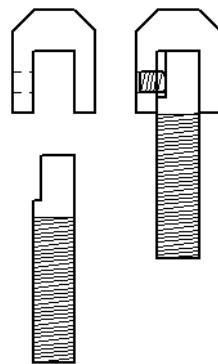
NUT AND BOLT THROUGH
TOP (HEX AND COUNTER-SUNK)



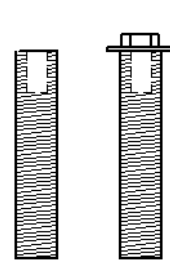
ADHESIVES



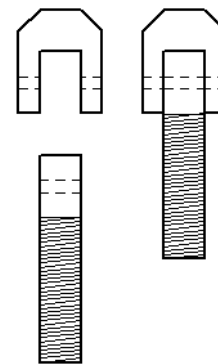
GRUB SCREW



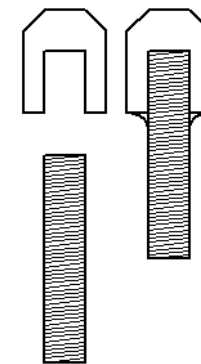
BOLT AND WASHER



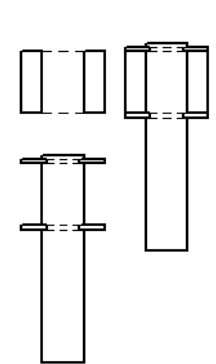
ROLLED PIN

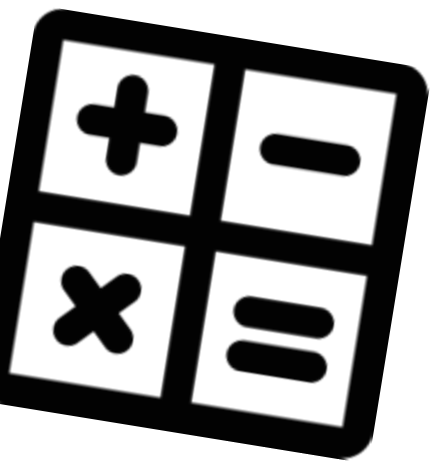


WELDING (MIG)



CIRCLIP (C-CLIP)



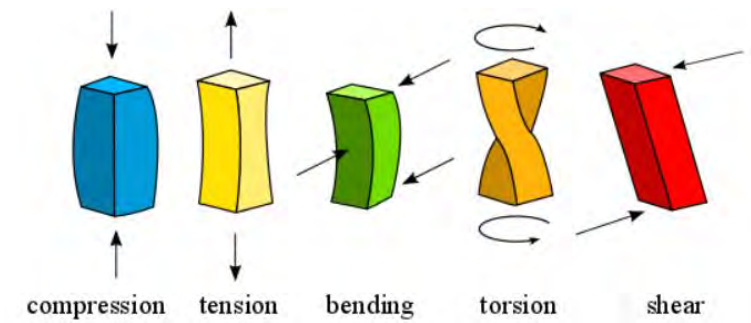


WJEC UNIT 3 – AC 2.2

Mr Graham

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TESTING FOR MATERIAL PROPERTIES



Testing the properties of a material can be divided into 2 categories destructive and non destructive testing.
(The main properties tested can be found in AC2.1)

Destructive testing

As the name suggests this method damages or deforms the material.

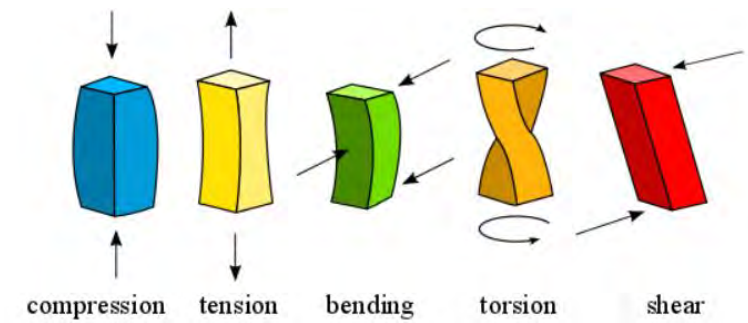
Universal testing machine (Also called a **Tensometer**) – This machine can apply compression, tension or a bending force to a sample piece of material.

Hardness testing – The indentation method is primary method of determining a materials hardness. A very hard diamond, ball or cone is pressed into the surface of the material with a specific force. The distance it is pressed into the material is used to determine how hard that material is.



Vickers (Diamond) Brinell (Ball) Rockwell (Cone)

TESTING FOR MATERIAL PROPERTIES



Testing the properties of a material can be divided into 2 categories destructive and non destructive testing.
(The main properties tested can be found in AC2.1)

Non-destructive testing

These testing methods can be conducted on a finished product as they do not damage the part. Here is a sample of the methods available:

Leak testing – Pressure vessels are filled with air then submerged in water to identify leaks.

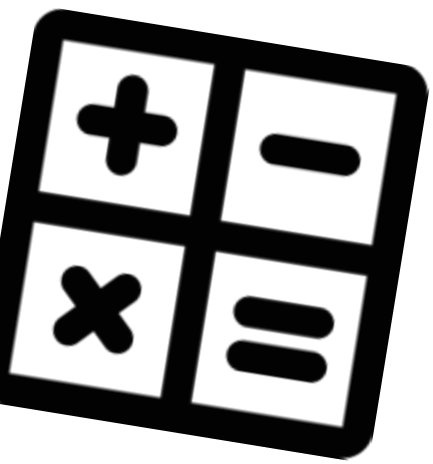
Microwave testing – Microwaves are passed through parts to identify foreign materials or cavities.

Liquid penetrant testing – A thin fluid is applied to a part, a developer then highlights tiny cracks that the fluid finds.

Ultrasonic testing – High frequency sound waves are passed through parts, internal voids, cracks or porosity (air bubbles) can be detected with this technique.

Visual testing – Inspection is conducted with magnifying glasses to identify flaws.





WJEC UNIT 3 – AC 2.3

Mr Graham

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MATERIAL PROPERTIES — METALS

Metals fall into 2 categories, ferrous and non-ferrous.

Ferrous metals

They contain iron, are magnetic and will rust (oxidise) when exposed to oxygen, this is sped up when in contact with water. Stainless Steel is the exception to this rule.

- **Low Carbon Steel**
- **Medium Carbon Steel**
- **High Carbon Steel**
- **Cast Iron**
- **Stainless Steel**



The higher the carbon the harder the steel, but the more likely it is to crack.



Non-ferrous metals

Any metals that does not contain iron (Most metals). Non ferrous metals will not rust, they are non-magnetic and are generally softer.

- **Aluminium**
- **Zinc**
- **Titanium**
- **Copper**
- **Brass**
- **Tin**
- **Pewter**
- **And many, many more!**





MATERIAL PROPERTIES — FINISHING METALS



Ferrous metals need a barrier between the metal and air/water, here are a few methods we can use to achieve this. Some of these can be done to non-ferrous metal to improve aesthetics, and in a few cases add a hard outer layer.

- **Painting**
 - Brushed, sprayed, dipped.
- **Plating**
 - Coating one metal in another by electrolysis.
- **Powder / dip coating**
 - Coating a metal in a plastic either by spraying or dipping in powder.
- **Anodising**
 - Creating a thin, hard oxide layer with acid.

■ **Galvanising**

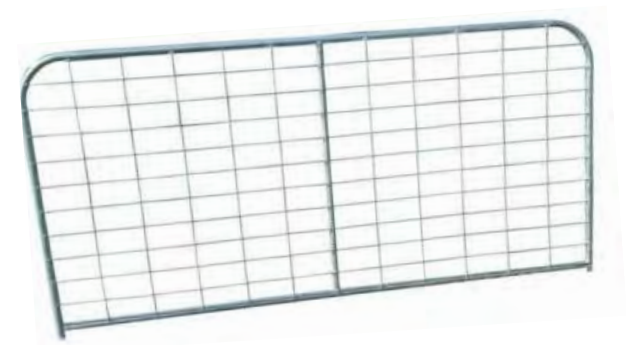
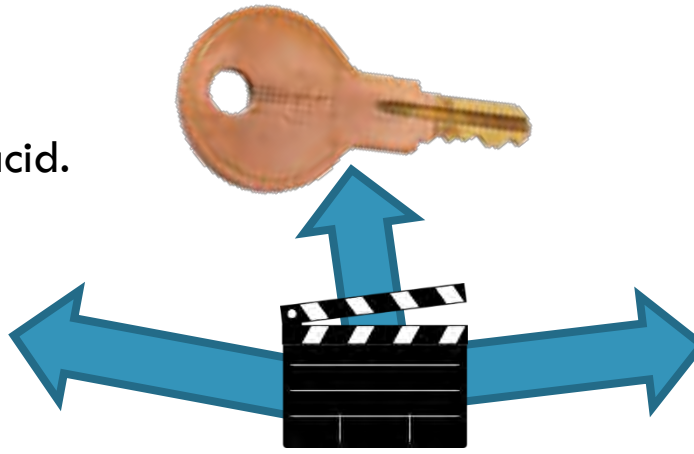
- Coating a ferrous metal in a thin layer of zinc.

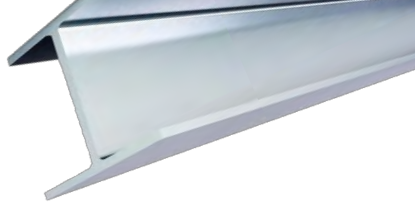
■ **Etching**

- Dissolving metal using strong chemicals.
 - PCB's and for Decorative finishes.

■ **Polishing**

- Removing a small amount of material to smooth a surface. This is achieved with a cloth or buffing wheel.





MATERIAL PROPERTIES — ADDITIONAL INFORMATION

Alloys

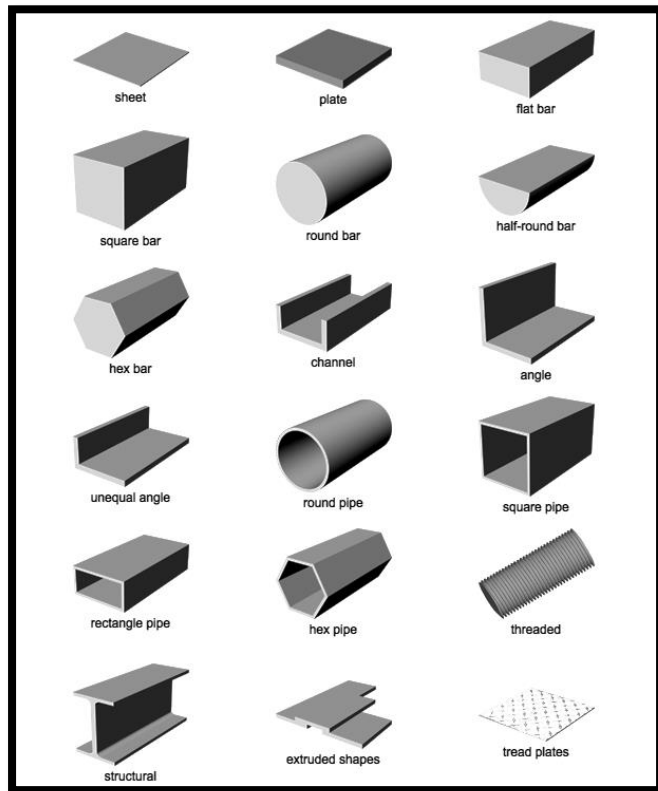
An alloy is a mixture of 2 or more elements, one of which is a metal.
We alloy metals to improve their properties.

Alloy	Components	Typical uses
Brass	Copper (65–90%), zinc (10–35%).	Door locks and bolts, brass musical instruments.
Bronze	Copper (78–95%), tin (5–22%), plus manganese, phosphorus, aluminium, or silicon.	Decorative statues, musical instruments.
Duralumin	Aluminum (94%), copper (4.5–5%), magnesium (0.5–1.5%), manganese (0.5–1.5%).	Automobile and aircraft body parts, military equipment.
Nitinol	Nickel (50–55%), titanium (45–50%).	Shape-memory alloy used in medical items,
Pewter	Tin (80–99%) with copper, lead, and antimony.	Ornaments, used to make tableware before glass became more common.
Solder	Modern solder has 99.25 percent tin and 0.75 percent copper.	Connecting electrical components into circuits.
Steel (general)	Iron (80–98%), carbon (0.2–2%), plus other metals such as chromium, manganese, and vanadium.	Metal structures, car and airplane parts, and many other uses.
Steel (stainless)	Iron (50%+), chromium (10–30%), plus smaller amounts of carbon, nickel, manganese, molybdenum, and other metals.	Jewelry, medical tools, tableware.

Metal profiles

To save money Engineering firms will buy in raw material close to the shape of the product they are making.

This saves: Time, money, wear on the machinery and tools.





MATERIAL PROPERTIES — POLYMERS (PLASTICS)



Thermoplastics

Become flexible when heated, this allows them to be easily recycled.

Examples of thermoplastics : PVC, Polystyrene, PET, HDPE, Acrylic, Nylon, ABS

Thermosetting plastics

These will not deform when heated. This makes them ideal for electrical sockets and worktops.

Examples of thermoset plastics : Melamine, Urea formaldehyde, Silicon, Epoxy



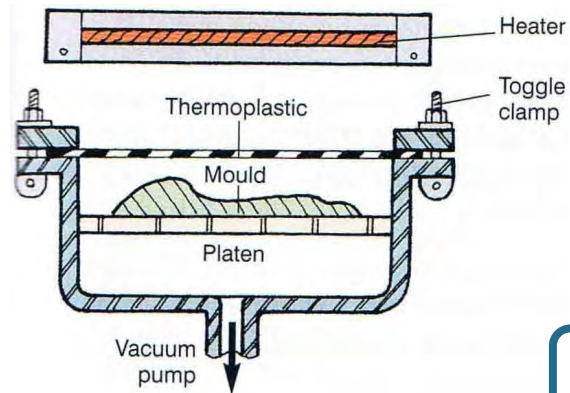
Resin Identification Code (RIC) System

The RIC system is a code stamped into polymer products to identify what material they are made from. To maintain the quality of a polymer the same polymers must be recycled together, the RIC system makes this sorting easier.

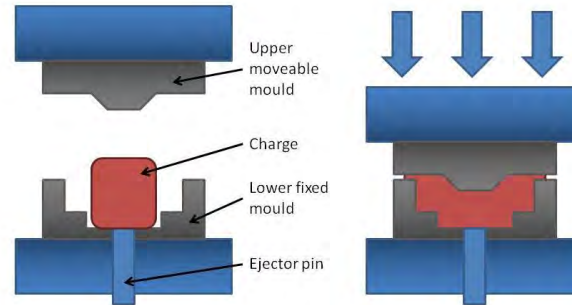


MATERIAL PROPERTIES – POLYMER MANUFACTURING PROCESSES

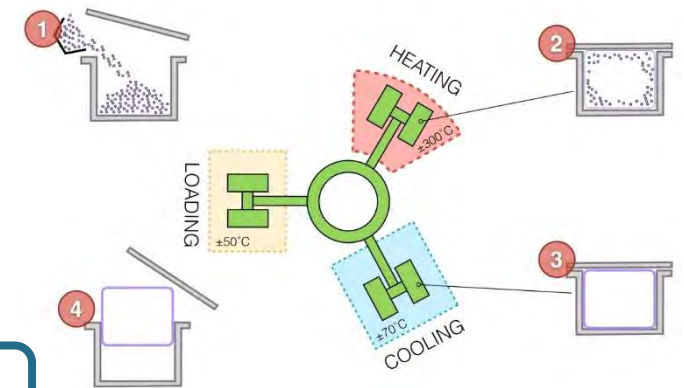
Vacuum forming



Compression moulding (Thermosetting)

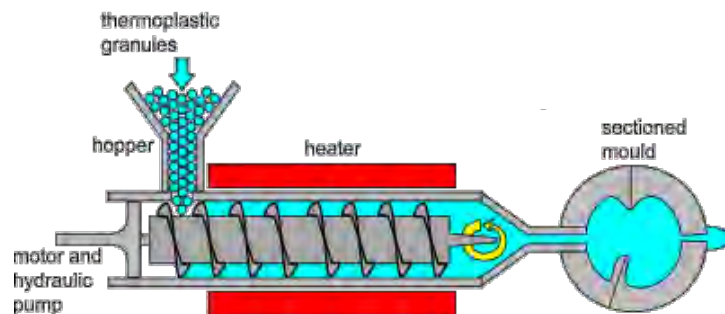


Rotational moulding

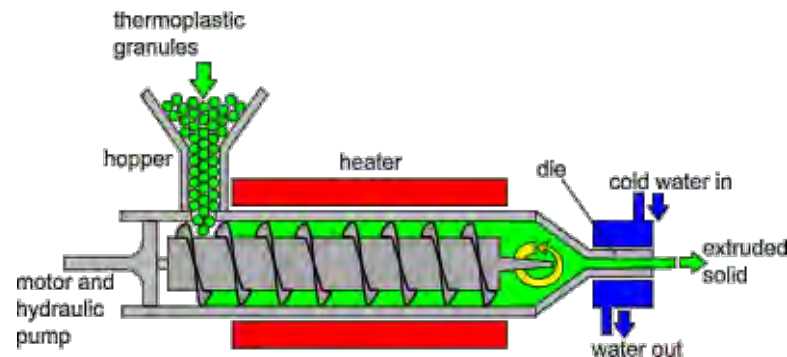


Click any picture for a video explaining the process. Additional information on each process found in 'Additional useful information'

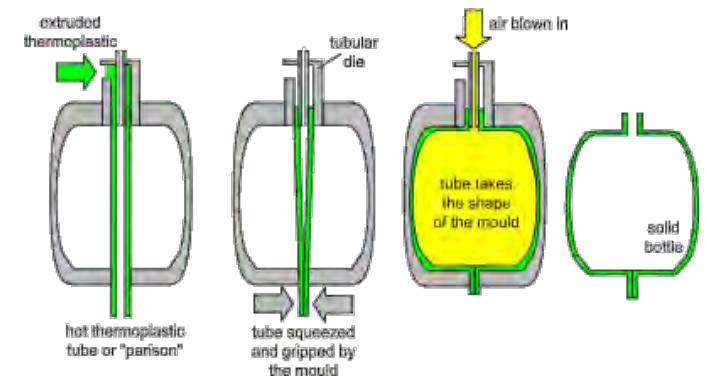
Injection moulding



Extrusion



Blow moulding



MATERIAL PROPERTIES — SMART MATERIALS

“Smart materials can change their properties in response to an external stimulus.”

Thermochromic ink changes colour when the temperature changes.

Photochromic material changes colour when exposed to light.

Hydrochromic material changes colour when in contact with liquid.

Shape memory alloys (SMAs) change shape after exposure to heat.



MATERIAL PROPERTIES — COMPOSITE MATERIALS

“A composite material is made by combining two or more materials. Importantly the materials are not chemically joined but remain physically distinct.”

Advantages : Improved properties over traditional materials. Often this is being stronger, while also being lighter.

Disadvantages : Composite materials generally cannot be recycled.

Reinforced concrete

Concrete has a good resistance to compression, but poor resistance to tension. By running steel reinforcement bars through the wet concrete the end product will withstand compression and tension. This is essential in modern architecture.

Common applications: Carparks, skyscrapers, foundations, bridges.



Fibreglass

Thin fibres of ceramic glass are held together with epoxy resin. The fibres are flexible and can take the shape of complex moulds. Fibre glass often comes in sheets that are layered into the mould and soaked in resin.

Common applications: Boat and hovercraft hulls, kayaks, car panels for kit cars, baths.

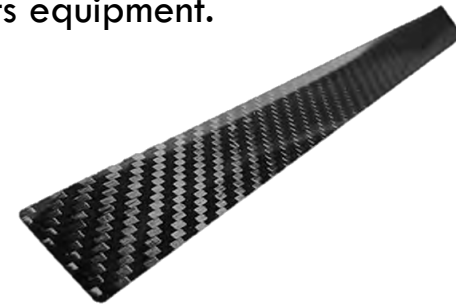


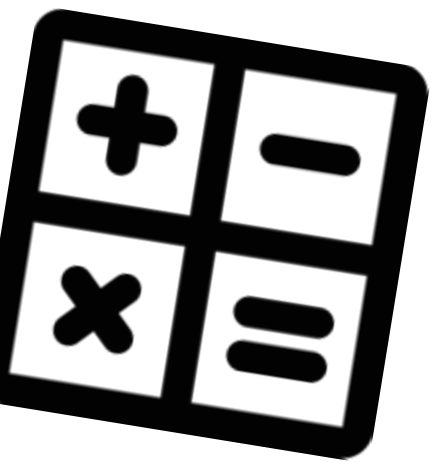
Carbon-reinforced plastic (CRP)

CRP products are stronger than fibreglass components, but the fabrication method is similar.

In the exam make sure you refer to these products as Carbon-reinforced plastic rather than Carbon Fibre.

Common applications: High performance race cars, high end sports equipment.





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ENGINEERING PROCESSES & TOOLS - OVERVIEW

- **Marking out** – Engineers square, scribe, odd legged callipers, steel rule, compass.
- **Cutting** – Hacksaws, metal cutting guillotine, sheet metal stamp, laser cutter.
- **Finishing** – Painting, powder coating, galvanising, electrolysis, buffing, emery cloth + wet and dry paper, anodising.
- **Preparing** – Centre punch, degreasing
- **Shaping** – Bending, rolling, casting and press forming
- **Drilling** – Pillar drill, hand drill or centre lathe
- **Turning** (All completed on the lathe) – Facing (cleaning the end of a bar), turning down (reducing a bars diameter), boring (enlarging a hole)
- **Filing** – hand filing and mechanical grinding.
- **Joining**
 - **Soldering** (Permanent) – Melting solder into a joint to hold the two parts together.
 - **Brazing** (Permanent) – A bronze or brass filler rod is melted between to metal parts to hold them together, similar to soldering but at a higher temperature.
 - **Welding** (Permanent) – Raising the temperature of 2 metal parts to melting point. A filler material is used to replace the melted base metal.
 - Nuts and bolts (Non-permanent)

NON-PERMANENT JOINING

Bolts

Metric threads comply to [BS 2643-1:2007 ISO metric screw threads](#).

They use this naming system. M8 x 1.25 x 50mm

- **M** = Metric thread
- **1.25** = The pitch (Distance between threads)
This information is sometimes missed out.
- **8** = 8mm outer diameter
- x **50mm** = the length of the thread

Primary bolt types

Hex head, Countersunk, Cap head (or Allen key), Coach bolt (Primarily for wood).



Bolt heads

Most bolts will have one of the following head types:

- Hex head
- Slotted
- Phillips
- Pozidrive (Like Phillips, but with 4 additional flutes)
- Torx
- Allen



Nuts

Hex nut – Standard nut.

Nylock – Includes a ring of nylon that the bolt cuts a thread through preventing it from vibrating loose.

Wing nut – Has large 'wings' on the side to allow removal without tooling.



PERMANENT JOINING

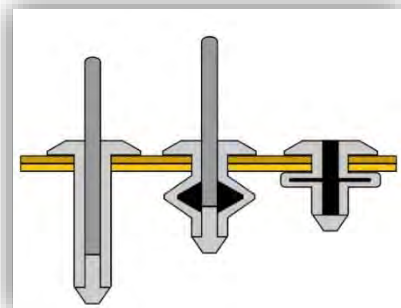
Rivets

Steel pins that are placed through a hole and hammered to deform the end preventing it coming loose. This process can be done with hot or cold rivets.



Pop rivets

A pop rivet is placed through a hole and a rivet gun is used to deform the end.



Soldering

Soldering does not melt the 2 metals together, but heats them to a point where solder melts and can flow between the surfaces. Solder is an alloy of Tin and Lead.

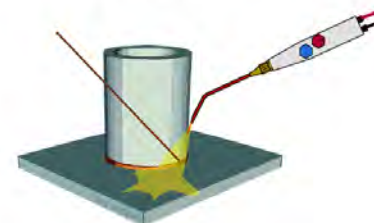
Brazing

Brazing is similar to soldering, but at a higher temperature. Brass or sometimes copper is used.

Brass melts between $900 - 940^{\circ}$

BRAZING

Steel melts at 1370°



Adhesives

Using adhesives on metals is notoriously difficult. Epoxy resin would be the most suitable option. This 2 part glue is mixed together before being applied.



PERMANENT JOINING

Welding

All welding methods raise the temperature of the work pieces to their melting point. A filler material is used to fill the gap between the two parts.

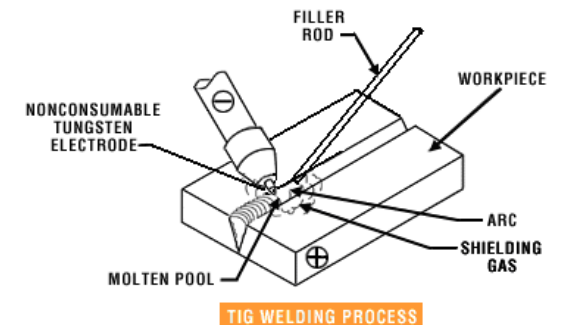
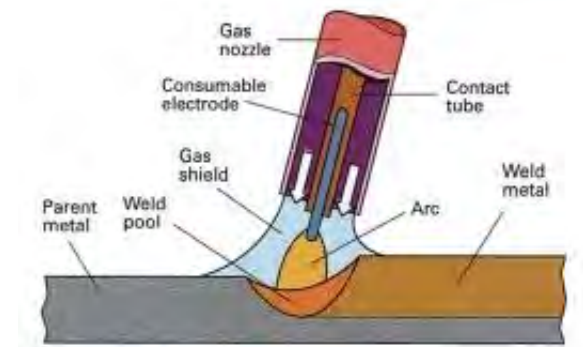
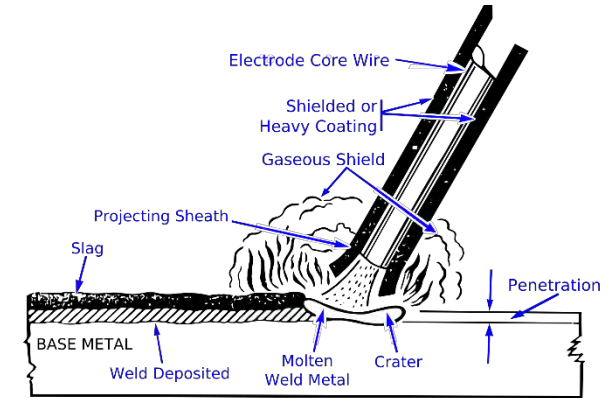
The main problem faced when welding is oxygen entering the weld and weakening it. To overcome this a shield is formed around the hot metal.

Spot welding – A high current charge is passed through 2 thin metal parts fusing them together. No form of shielding is required with this process.

Arc Welding – An electric arc generates the heat and a flux coated filler rod fills the gap. The heat melts the flux which covers the hot metal, preventing oxygen entering.

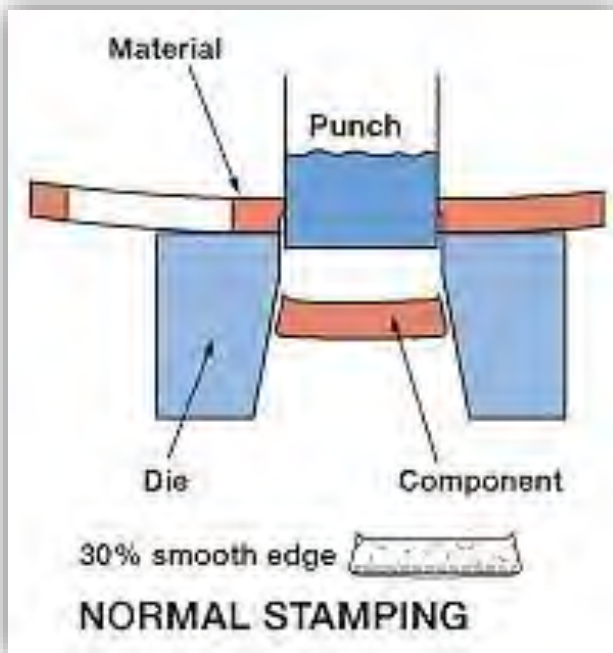
MIG (Metal Inert Gas) Welding – A MIG torch covers the weld puddle with a shielding gas, while a thin steel wire is fed through the torch arcing and melting the work piece.

TIG (Tungsten Inert Gas) Welding – A TIG Torch is held in one hand, and a filler wire in the other. The TIG torch provides the shielding gas and an arc from a tungsten electrode. In TIG welding the electrode doesn't melt, and the filler rod is fed in with the other hand.

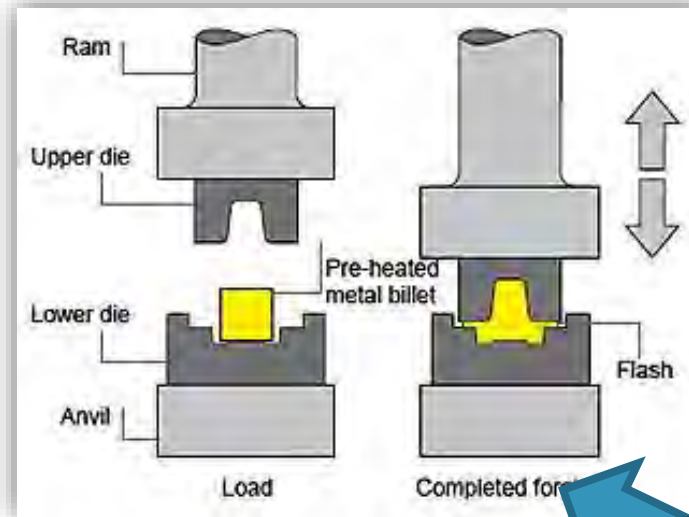


METAL SHAPING

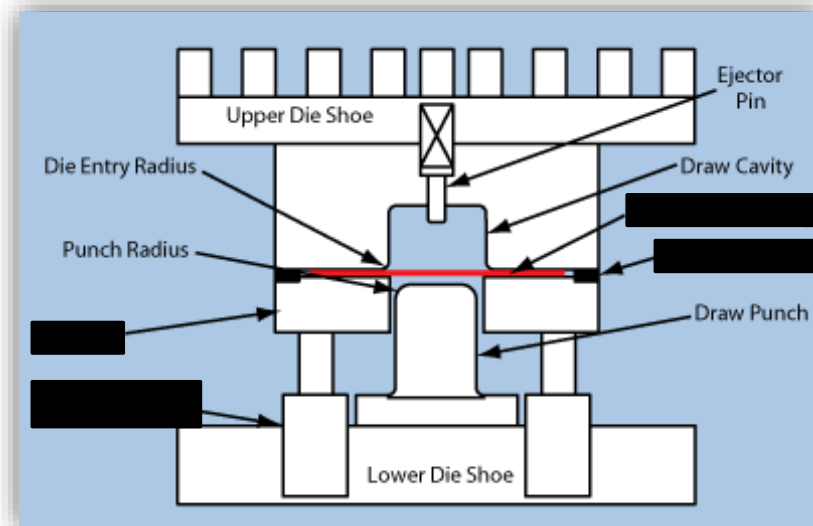
Sheet metal stamping



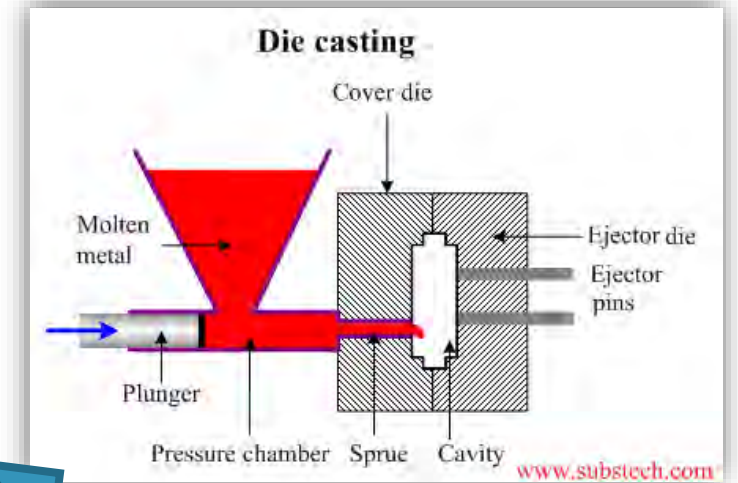
Drop forging



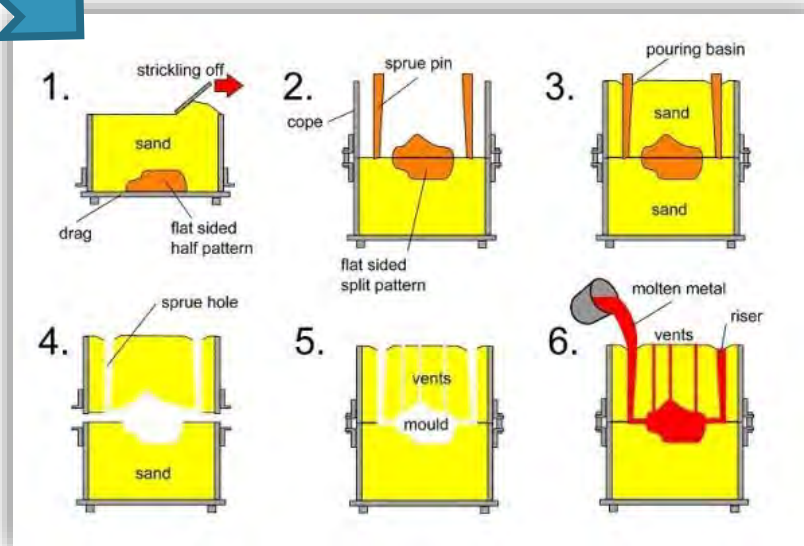
Press forging



Die casting



Sandcasting



LATHE / TURNING OPERATIONS

The lathe differs from all other machines as the work piece rotates and the tool remains relatively stationary.

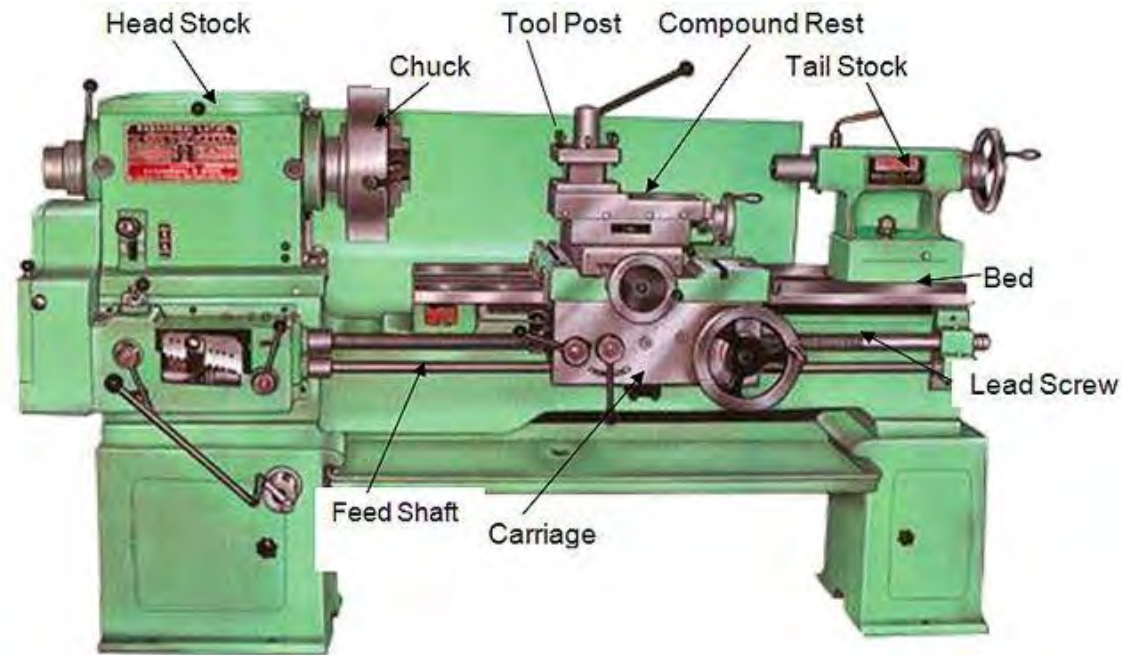
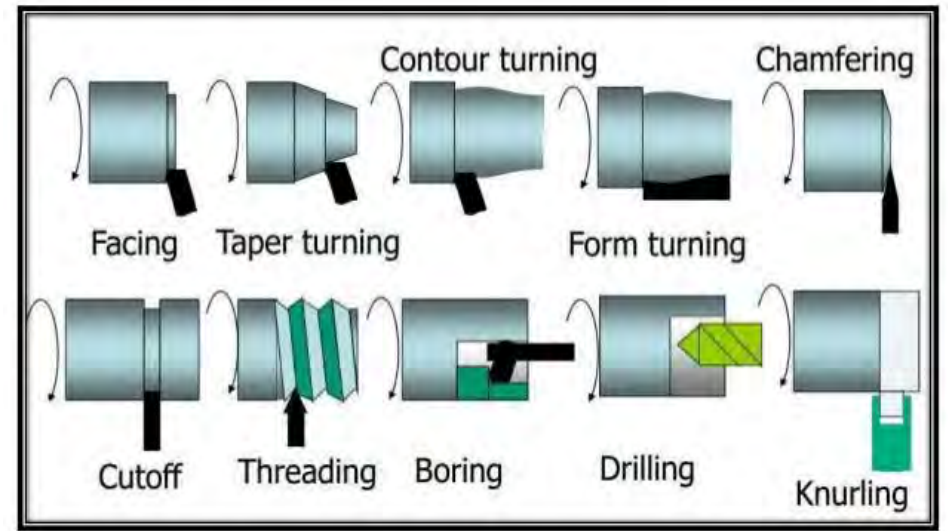
Main operations completed on the lathe

Turning down – Reducing the diameter.

Facing – Running the tool across the face of the work piece to clean it.

Centre drilling – Drilling down the centre of the work, a centre drill is used first to start the hole.

Boring – A tool mounted on the tool post that enlarges a drilled hole.

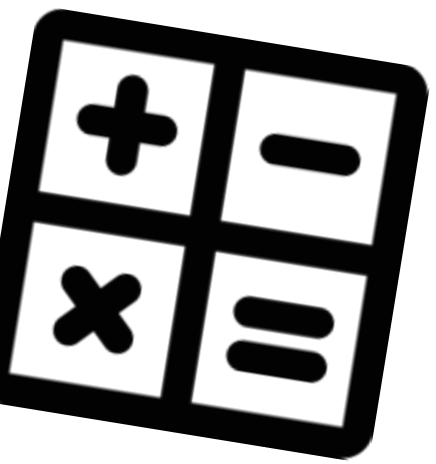


ENGINEERING PROCESSES — ADDITIONAL INFORMATION

Jigs, fixtures and templates are all used to ensure accuracy when shaping or assembling a product.

- **Jigs** — Positions or holds work without being fixed in place.
- **Fixtures** — Holds work in a specific position and is secured in place.
- **Template** — Allows shapes to be accurately copied.





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HEAT TREATMENT PROCESSES

The properties of some metals can be changed by the careful application of heat. High carbon steel in particular can be hardened and softened (tempered) with heat.

Hardening

The high carbon steel is heated until it becomes red hot. (800° - 1000°)

It is then quenched quickly in clean water or oil. This gives the metal a high hardness rating, but it does make it quite brittle.

Tempering

The hardened steel is then re-heated to a specific temperature and allowed to cool slowly. This re-introduces some of the softness lost through the hardening process. This is often done in a vacuum or inert gas environment.



Annealing

Annealing is like tempering but primarily used to remove internal stress caused by a manufacturing process.

Metal products are heated and allowed to cool very slowly in a controlled environment. This process remove stresses and toughens the part.

CHEMICAL TREATMENT PROCESSES

Cleaning and degreasing

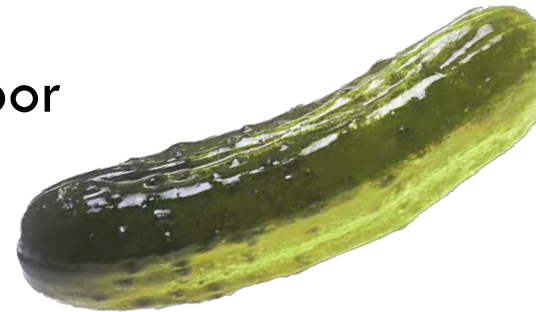
Chemical degreasing removes left over chemicals. This can be done by submerging parts in a bath of degreasing solution or spraying with a vapor degreaser.

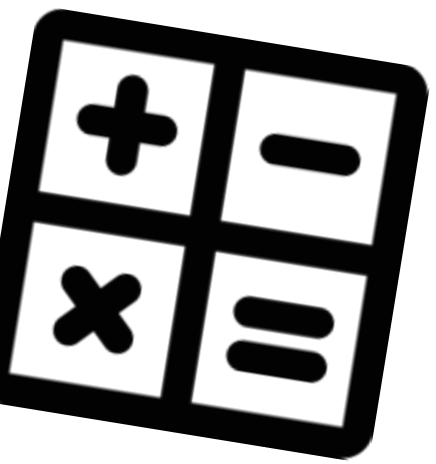
Pickling

A product is sprayed or submerging in acid, this removes a thin layer exposing fresh metal underneath. This process is often used to clean parts prior to another finish being applied, or to restore a materials surface finish after fabrication.

Passivation

This quickly rebuilds the oxide layer that would form naturally preserving the newly exposed surface.





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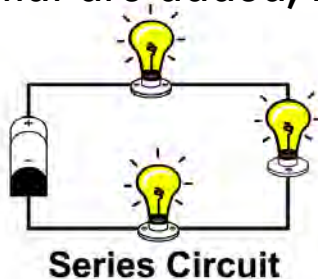
MATHS — OHMS LAW

Electric current flows around a circuit from the positive terminal of a battery to the negative. As that current flows it releases energy.

Circuits can be arranged in 2 forms, **parallel** and **series**.

Series circuit

- The circuit below shows three bulbs placed in series.
- Current flows through each of the bulbs in sequence.
- Current flows through each bulb in turn, remove 1 and the circuit is broken.
- The more bulbs that are added, the less bright they shine.



Electronics terms

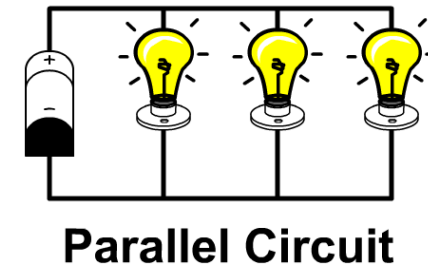
V = Voltage (Measured in Volts - V)

I = Current (Measured in Amps - A)

R = Resistance (Measured in Ohms - Ω)

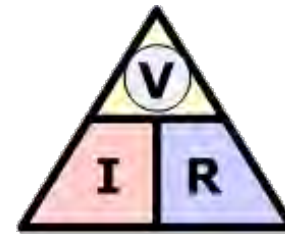
Parallel circuit

- The circuit below shows three bulbs placed in parallel.
- Current can flow through each of the bulbs without first having to flow through any others, remove one and the rest remain powered.
- More bulbs added to a parallel circuit will not cause it to get dim.

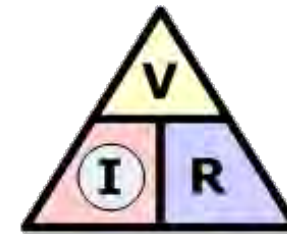


MATHS — OHMS LAW

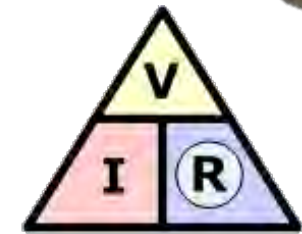
At times we need to calculate either the Voltage, Current or Resistance in a circuit. For that we need to use Ohms law, $V=IR$. This formula can be rearranged as seen to the right.



$$V = I \times R$$



$$I = \frac{V}{R}$$



$$R = \frac{V}{I}$$

Calculating the required resistor to protect an LED

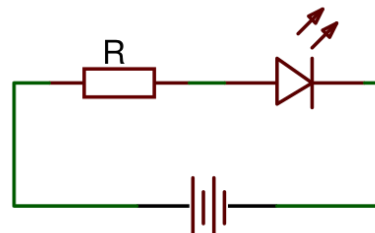
$$R = V \div I$$

$$\text{Resistance} = (\text{Source Volts} - \text{LED Volts}) / \text{Current}$$

So if we have a 12V battery powering a Blue LED (3.2V, 25mA) our formula becomes:

$(12V - 3.2V) / 0.025A = 352 \text{ ohms}$. You will have to find the resistor closest to that value.

LED Colour	Voltage	Current Draw
Red	2 V	15mA
Green	2.1 V	20mA
Blue	3.2 V	25mA
White	3.2 V	25mA



Using resistors to lower a voltage

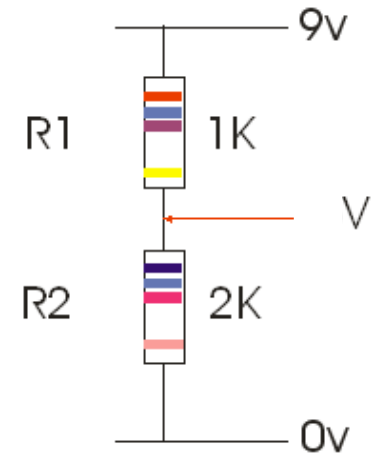
We can use resistors to lower a voltage to a desired value. This circuit is called **Potential Divider Circuit**.

Here is the formula to achieve this:

$$V = \text{Supply voltage} \times R2 / (R1 + R2)$$

$$V = 9V \times 2000 / (1000 \Omega + 2000 \Omega)$$

$$V = 6V$$



Electronics terms

V = Voltage (Measured in Volts - V)

I = Current (Measured in Amps - A)

R = Resistance (Measured in Ohms - Ω)

MATHS — EFFICIENCY

Devices that use energy can be given an efficiency rating. This rating tells us how much energy is wasted when the device is in use.

For example old lightbulbs would generate heat when they ran, that is inefficient as we only make use of the light energy. Modern lights require far less energy to light a room, partly because they don't produce nearly as much heat. LED light can be 10x as efficient as old lights.

Efficiency = Useful energy transferred

Total energy applied

To find the efficiency as a percentage do the following calculation

Percentage efficiency = Efficiency x 100



Worked example

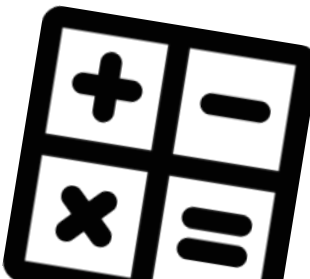
A kettle is transferred 400J of energy, 58J gets usefully transferred. How efficient is the kettle?

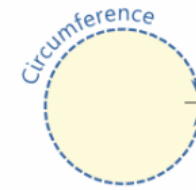
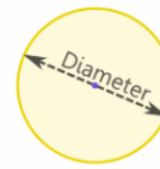
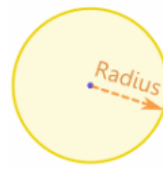
$$\text{Efficiency} = 58/400$$

$$\text{Efficiency} = 0.145$$

$$\text{Percentage efficiency} = 0.145 \times 100$$

Percentage efficiency = 14.5% efficient.





MATHS — AREAS AND VOLUMES

Essential Formula

Area of a circle = πr^2

Circumference of a circle = πD

Area of a rectangle = $L \times W$

Volume of cylinder = $A \times H$ ($\pi r^2 \times H$)

Volume of cuboid = $A \times H$ ($L \times W \times H$)

π = Pi (3.14)

r = Radius of the circle

D = Diameter of a circle

A = Area

L = Length of a rectangle

W = Width of a rectangle

H = Height of cuboid or cylinder

Units

For some calculations you will have to convert your units. If you are calculating volume for example, make sure all the measurements have the same unit before doing any calculations. The chart on the right will help you to change between units.

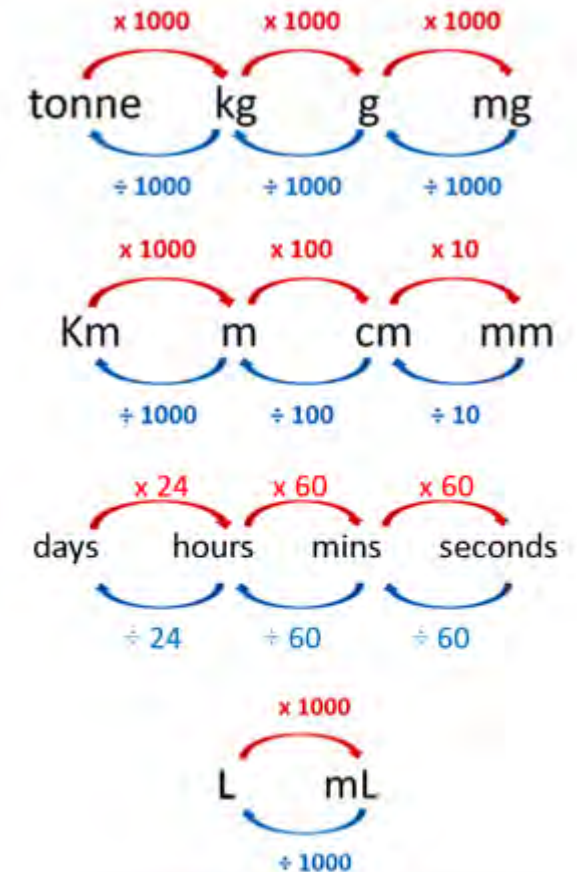
Length, width and height = mm

Area = mm^2

Volume = mm^3

Round answers to 1 decimal place.

Unit conversions



Starting units

Distance – metres (m)

Weight – grams (g)

Liquid – litres (l)

Voltage – Volts (V)

Resistance - Ohms (Ω)

Current – Amps (A)



MATHS — MEASURING AND ESTIMATION

It can be helpful when trying to solve a problem to be able to estimate the answer. Here are a few examples to help visualize distance, volume of liquid and weight.

Distances

1 mm = As wide as a pencil's lead.

1 cm = As wide as a pen.

10 cm = As long as a pen.

1 m = As tall as a stool.

1 km = A short walk.

Liquid

1 mL = A bottle cap full.

1 L = A family carton of juice.

Weights

1 g = A few grains of rice.

1 kg = A bag of sugar.

1 t = A smart car.

Base units

Distance – metres (m)

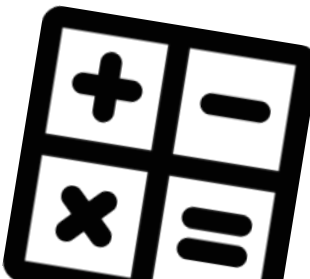
Weight – grams (g)

Liquid – litres (l)

Voltages – Volts (V)

Resistance Ohms (Ω)

Current – Amps (A)



MATHS — AVERAGES

This course requires understanding of the Mean, the others are good to know as well.

Here is a set of data containing the marks 11 students got in a test: 5,2,7,4,9,4,2,7,6,3,2

Mean : Add up all the numbers and divide by the number of scores (11).

$$5+2+7+4+9+4+2+7+6+3+2 = 51$$

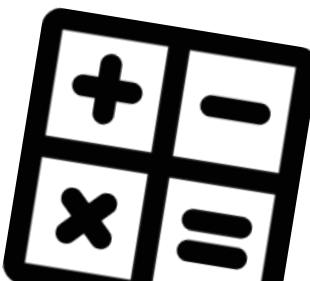
$$51/11 = 4.6$$

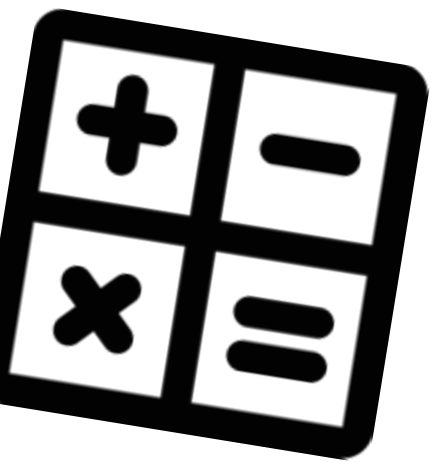
Median : Arrange the scores in order, then pick the middle. If there are 2 answers in the middle work out the mean of the 2.

2,2,2,3,4,4,5,6,7,7,9 The median value for this test is 4.

Mode : This is simply the value that came up the most often. In this example it is 2.

Range : You take away the smallest value from the largest. $9-2 = 7$.





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TECHNICAL DRAWINGS

When we produce technical drawings they must adhere to a set of international conventions called the BS8888. These conventions govern most aspects of a drawings and ensure they can be interpreted anywhere in the world.

Line styles

Geometry lines – show visible edges, these should be solid.



Hidden lines – show hidden features such as holes, these should be dashed.



Centre lines – Show the centre of circular features, these should be lines comprising long then short dashes.



Leader lines – Project from the part to show where dimensions run to and from. Also used to identify features or diameters.



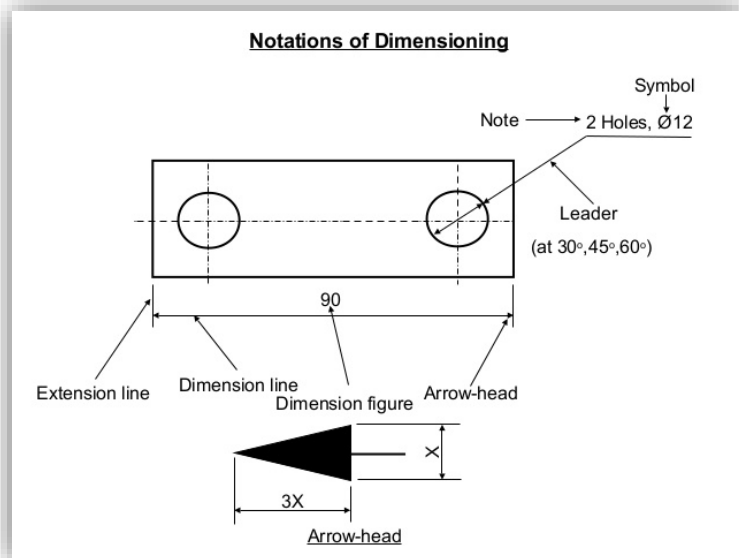
TECHNICAL DRAWINGS

Dimensions

Arrowhead – These must be solid.

Dimension lines – These must be parallel and have a small visible gap from the edge of the drawing.

Dimensions – These should be centred and above, or to the left, of the line.

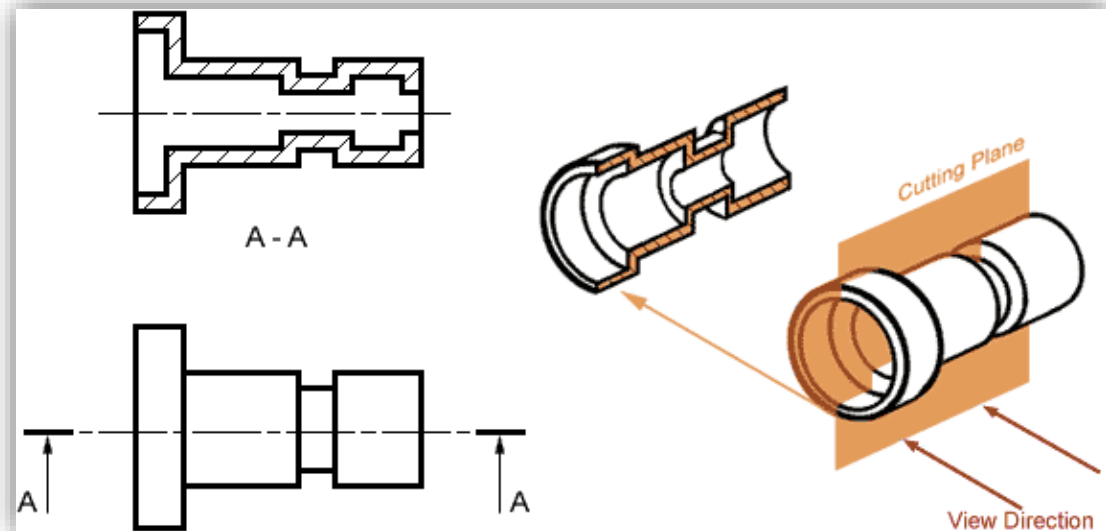


Sectional view

At times we need to see inside a component to get all the information to manufacture it.

Letters are used to link where the 'cut' would have been for that view.

The cut surface is identified by the diagonal lines.



TECHNICAL DRAWINGS

Scale

Sometimes the parts we draw are too large for the paper. To fit them on we draw them smaller, but to keep it accurate we scale our work. It may help to think of the : symbol as a /

Standard engineering scales are:

$$1:1 = 1/1$$

$$1:2 = 1/2$$

$$1:5 = 1/5^{\text{th}}$$



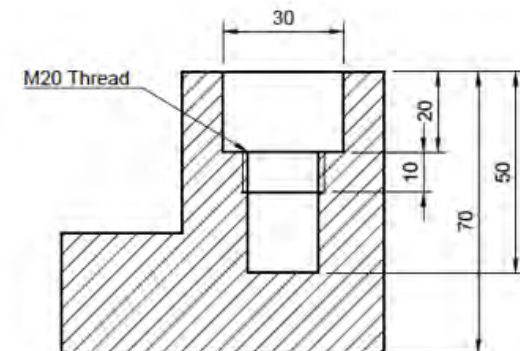
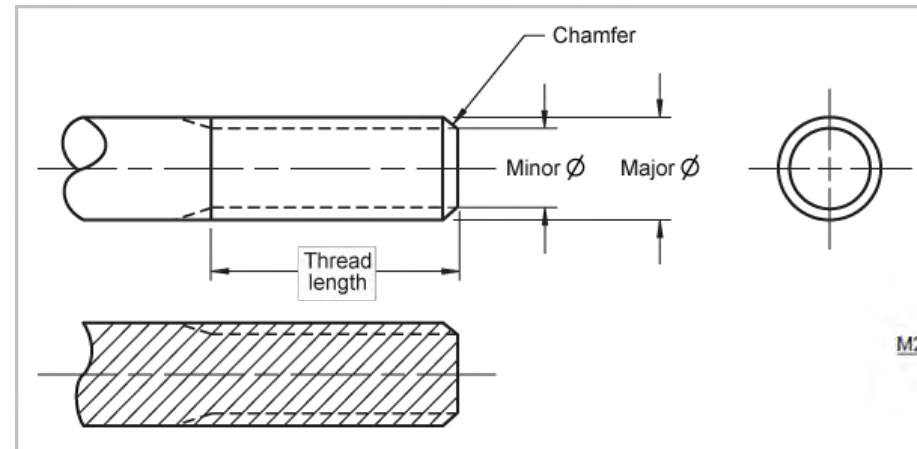
Scale of 1:1



Scale of 1:2

Screw threads

When drawing screw threads in a technical drawing we use a solid line to indicate the outer diameter (M8 would be 8mm). For the minor diameter we use a 'hidden detail' line. We do not draw the individual teeth.



A-A (1:1)



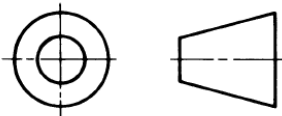
TECHNICAL DRAWINGS

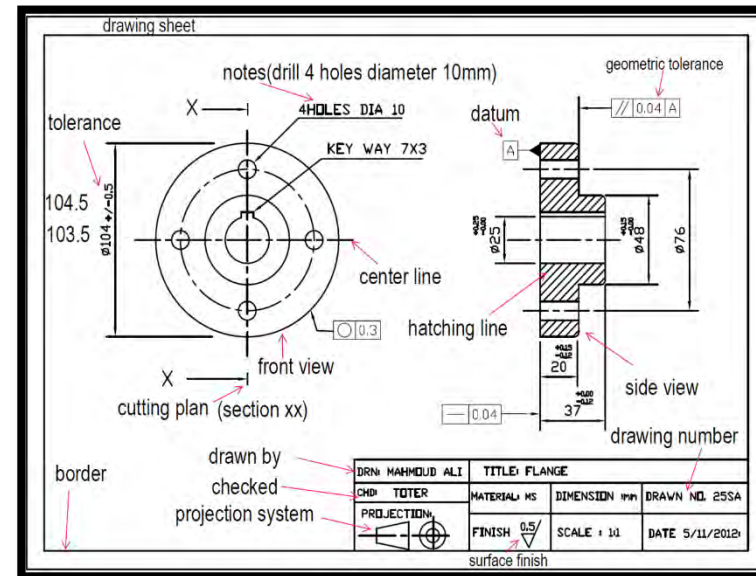
Page layout

All technical drawings must be laid out to sector specific standards. This includes a title box.

The title box must include:

- A drawing name or title.
- A drawing number.
- The scale of the drawing.
- The name and signature of the person making the drawing.
- Version number and date.
- Projection symbol.
- Tolerance.

Title		
	Scale 1:1	Drawing number : 1
	Name:	Date:
	Version: v2	Tolerance:



TECHNICAL DRAWINGS

Orthographic drawing

Orthograph drawing is a way to show 3D parts accurately in 2D. We usually draw 3 faces as if we are looking directly at them.

Orthographic drawing layout

- Front view usually goes in the bottom left.
- The Plan view (Top) goes directly above it, make sure it's inline
- The Side view goes to the right of the Front view, again make sure it's inline.
- The gap between the Front and Side and Front and Plan view must be the same.

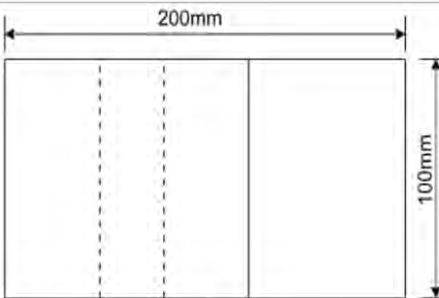
Click here for a video explaining how these drawing are laid out.



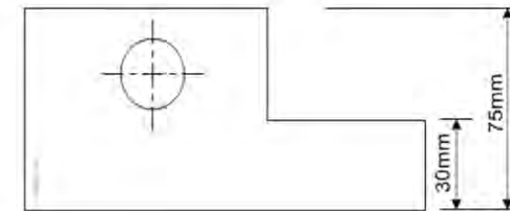
Plan View

Side View

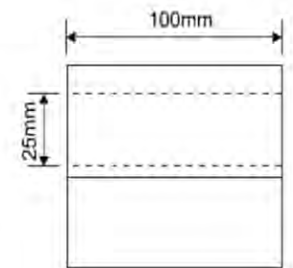
Front View



PLAN VIEW



FRONT VIEW



SIDE VIEW

TECHNICAL DRAWINGS - TOLERANCES

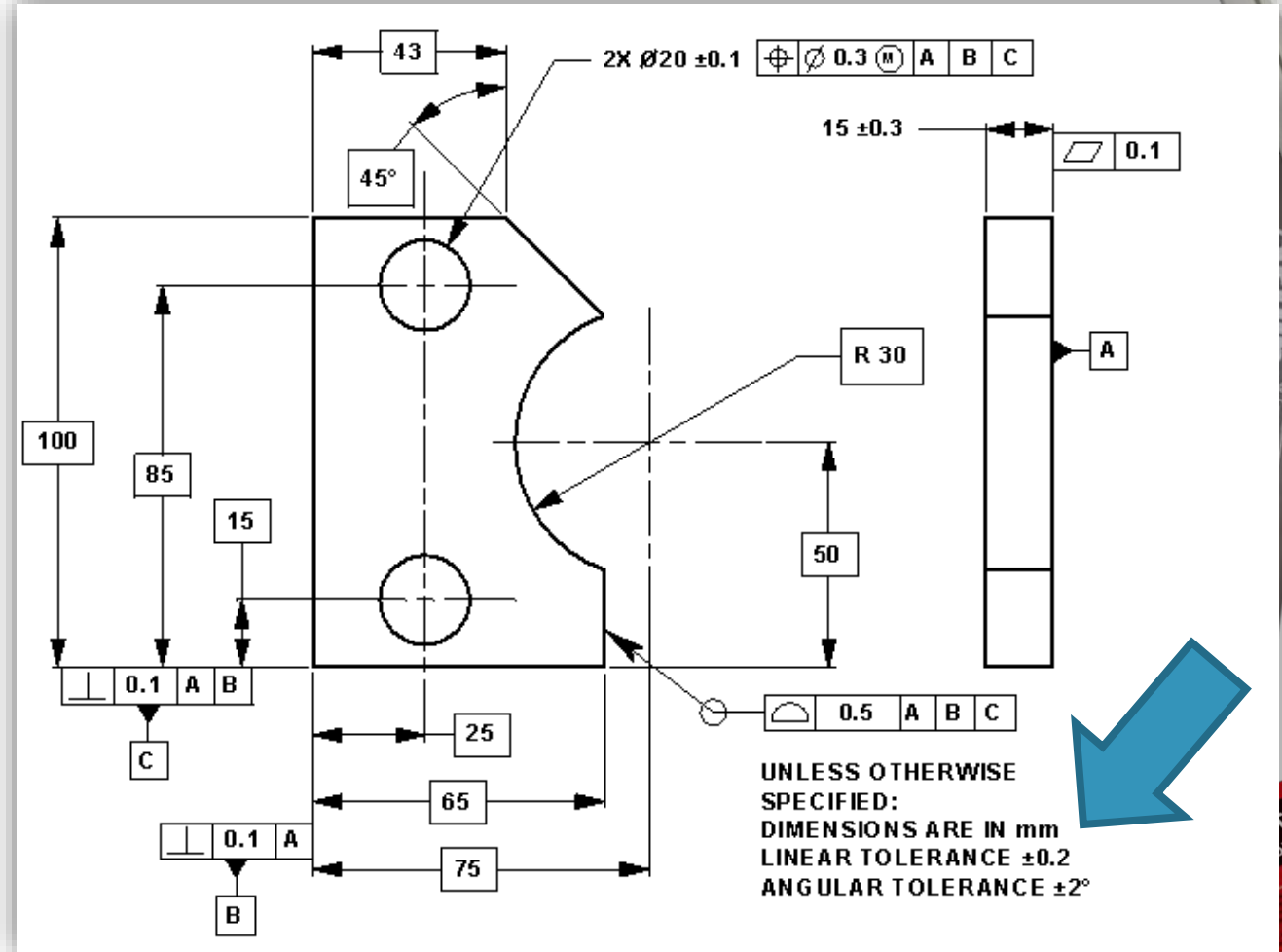
When engineers manufacture a component it will have to be made within a specific tolerance. This is usually so it can work with another component.

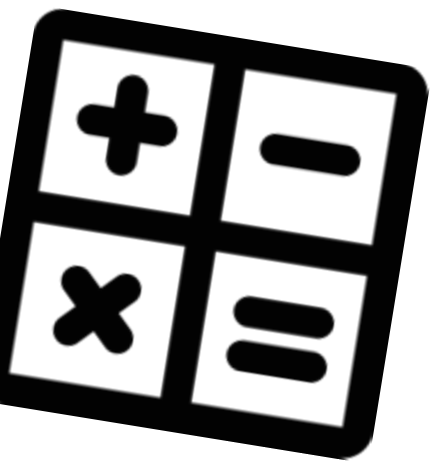
Sometimes the whole drawing has a tolerance. At times individual components, or even individual measurements within a component, can have their own tolerance.

A tolerance is often written like this :

$\pm 0.5\text{mm}$ or sometimes $+/- 0.5\text{mm}$

This means a dimension can be 0.5mm over or undersized. Sometime a tolerance only has a + symbol which means it can only be oversized.





WJEC UNIT 3 – AC 4.3 & 4.4

Mr Gra...

[Contents page](#)

CONTENT FOR AC 4.3 & 4.4

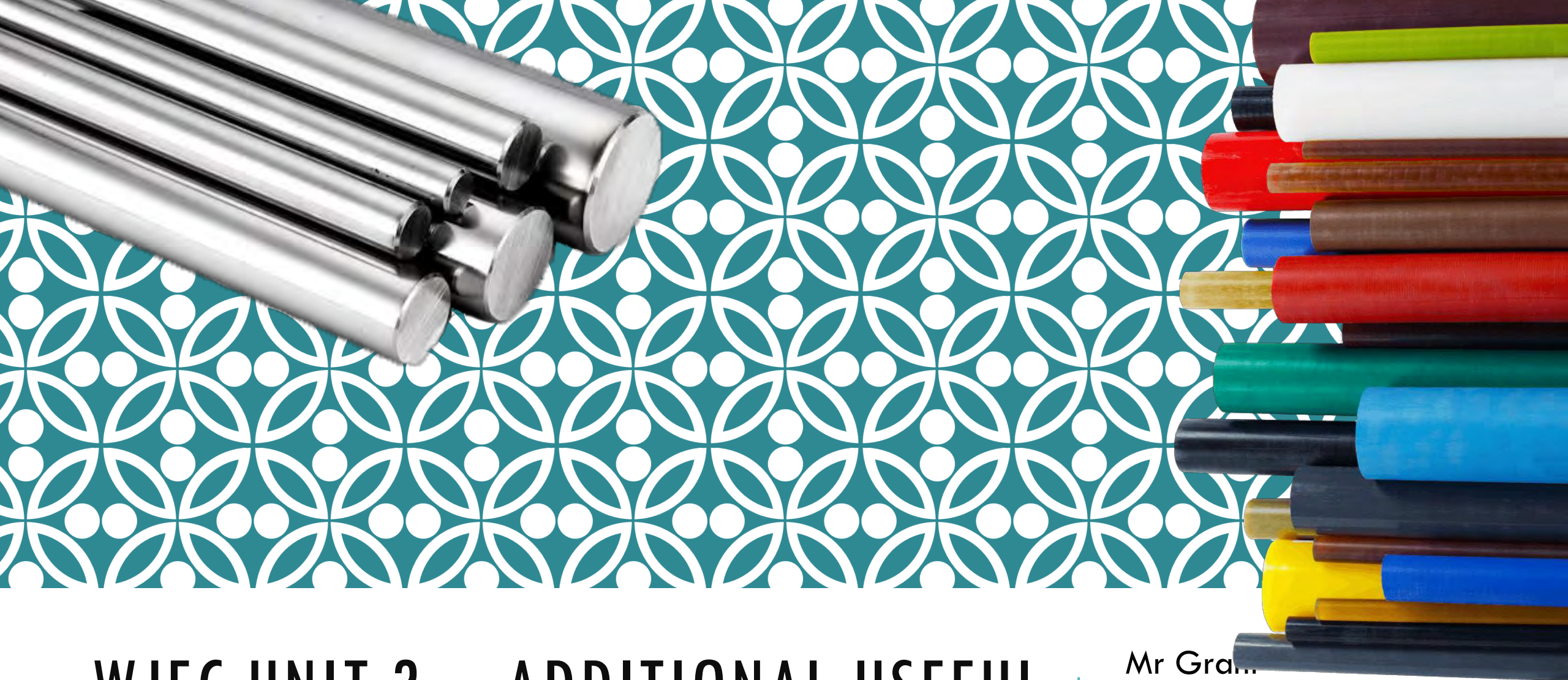
The content of these two areas is covered during the Unit 1 Design task;

AC4.3 is covered by the product analysis, brief and specification writing.

AC4.4 is covered by the sketched design ideas, CAD model and technical drawings produced.

“AC4.3 analyse situation for engineering problems by filtering through information, work out what is important and identify requirements.

AC4.4 design solutions in response to engineering problems logically and with clear communication both written and drawn.”



WJEC UNIT 3 – ADDITIONAL USEFUL INFORMATION

Mr Graham

[Contents page](#)



QUALITY ASSURANCE AND QUALITY CONTROL

Quality control (QC) is checking **after** a product has been made.

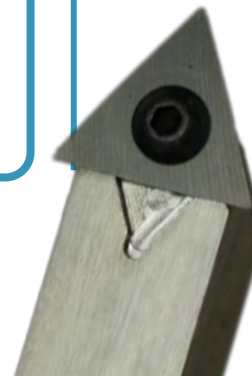
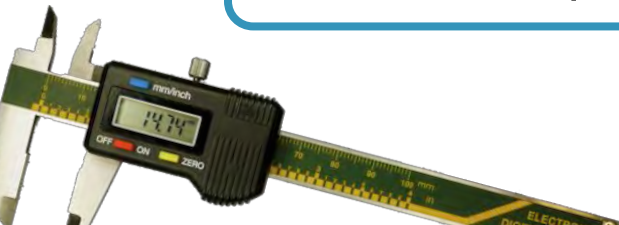
Quality assurance (QA) is making sure a product gets made **right first time**.

Advantages of quality control

- Reduced customer complaints.
- Accurate products.
- Control of costs.
- Avoids further processing of faulty part.
- Increased sales.
- Increased profit.

Go, NoGo gauges

- These are precisely ground gauges that can be used to see if holes have been made to the correct diameter.
- The Go gauge should fit through the hole, if it doesn't the part fails QC as it is too small.
- The No Go gauge should not fit through the hole, if it does the part fails QC as it is too large.

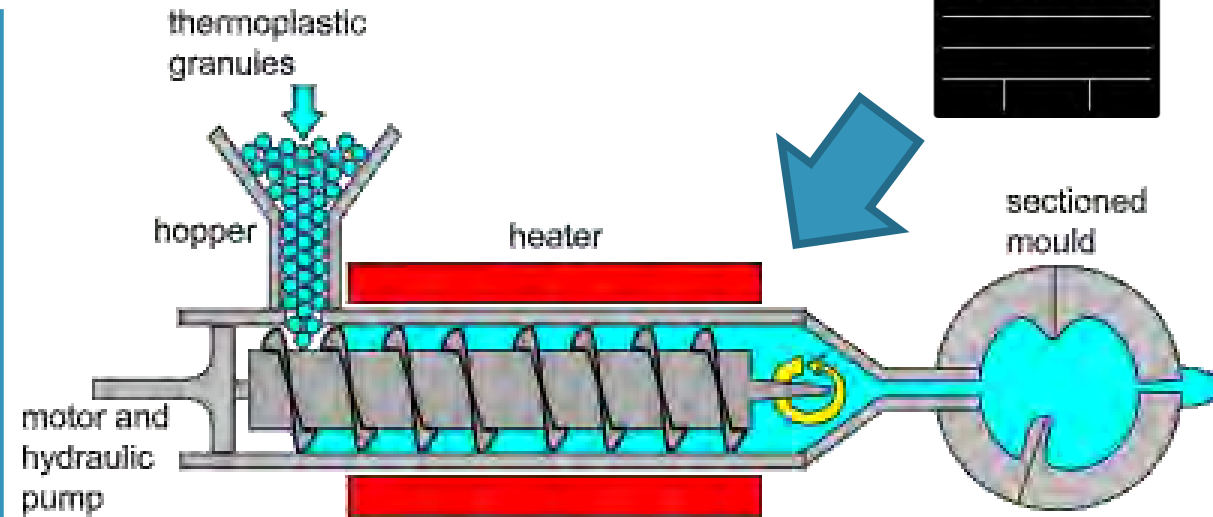




POLYMER FORMING PROCESSES – INJECTION MOULDING

Process

1. Plastic granules are fed into the hopper.
2. The screw in the chamber rotates sending the granules forward.
3. Heated jackets around the screw melts the polymer granules.
4. The hydraulic ram pulls the screw back, then pushes it forward forcing the polymer into the mould.
5. The plastic is allowed to cool and the halves of the mould release.
6. The “sprue” is machined off.



Clues to Injection Moulding:

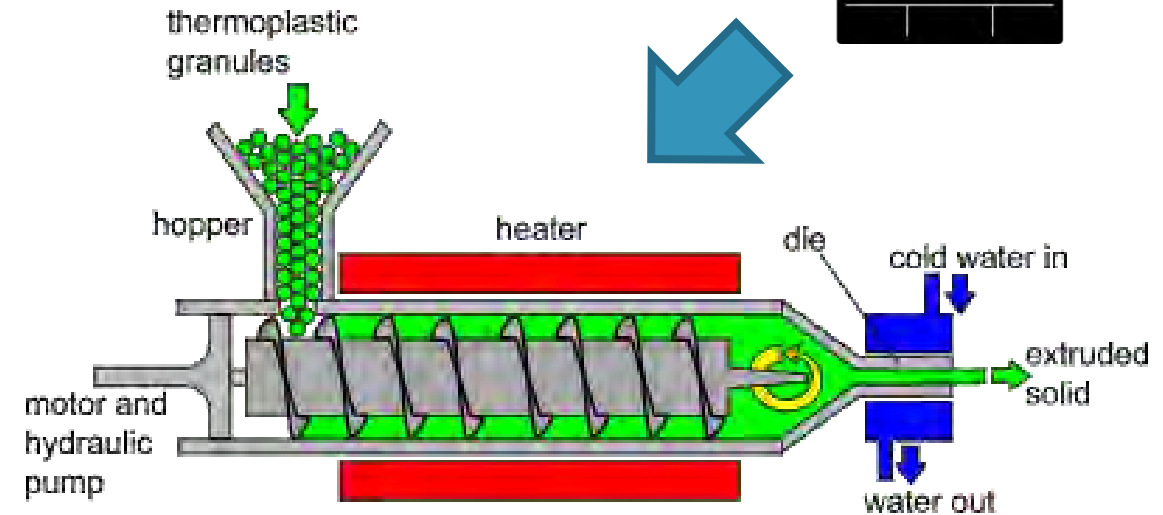
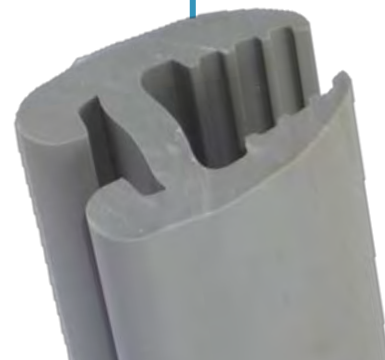
- Complex shape
- Lots of detailed features
- ‘Sprue’ around edges

POLYMER FORMING PROCESSES — EXTRUSION

Process

1. A motor turns a thread which feeds granules of plastic through a heater.
2. The granules soften and are forced through a die, forming a long 'tube like' shape.
3. The extrusion is then cooled, often in a water bath, and forms a solid shape.

The shape of the die determines the shape of the extrusion.



Clues to extrusion:

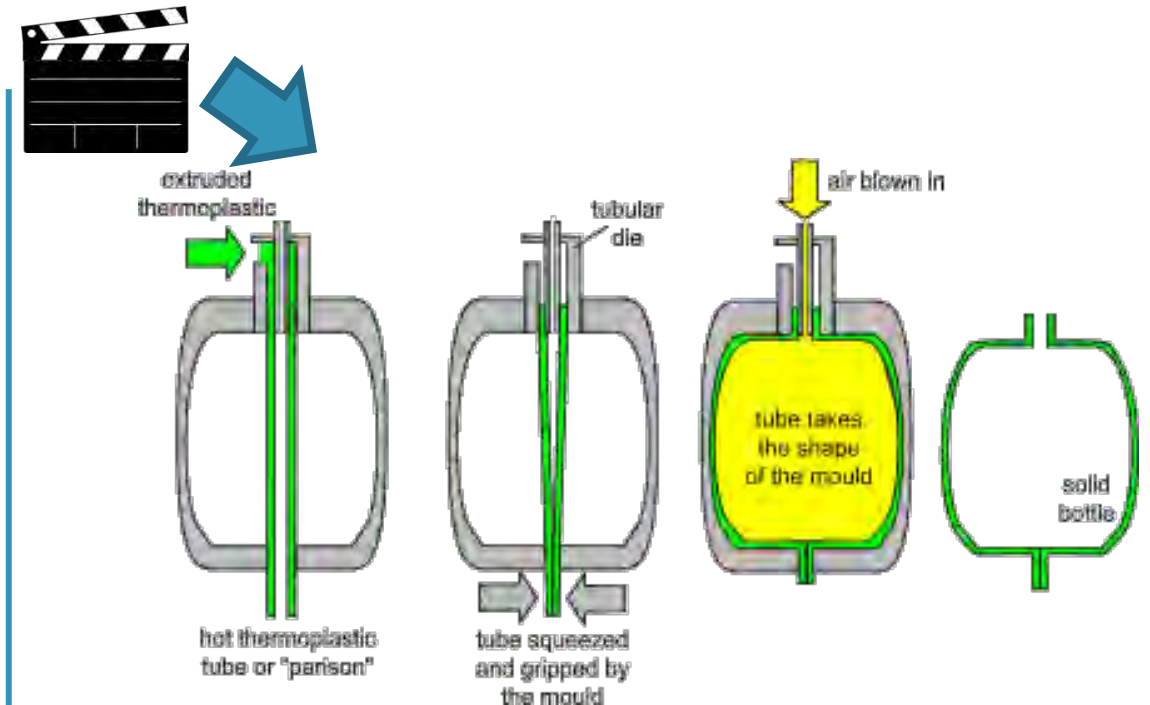
- The profile (shape) doesn't change.
- Bar and tubes are usually extruded.



POLYMER FORMING PROCESSES — BLOW MOULDING

Process

1. Mould is opened into it's two halves.
2. A hollow tube of polymer known as the parison is heated.
3. The parison is lowered into the mould.
4. Mould is clamped shut, leaving only a small hole for air to be blown into the parison.
5. Air is forced into the parison at high pressure. The plastic is forced to the mould sides and cools.



Clues to Blow Moulding:

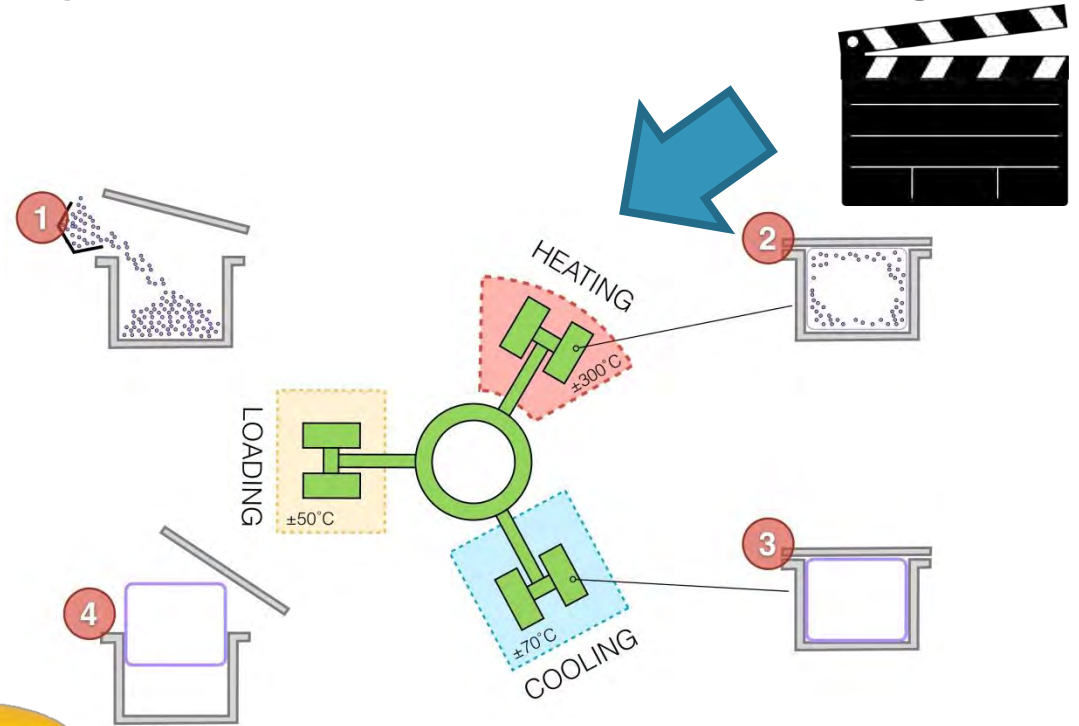
- Sprue mark
- Closed neck/hollow shape
- Ejection mark in the bottom.



POLYMER FORMING PROCESSES – ROTATIONAL MOULDING

Process

1. A measured amount of polymer granules are placed in a mould.
2. The mould is sealed and rotated on two axis within an oven.
3. The mould is removed from the oven and cools.
4. The mould is broken open and the product removed.



Clues to Rotational Moulding:

- Simple shapes
- Solid, lightweight components
- Low precision parts.

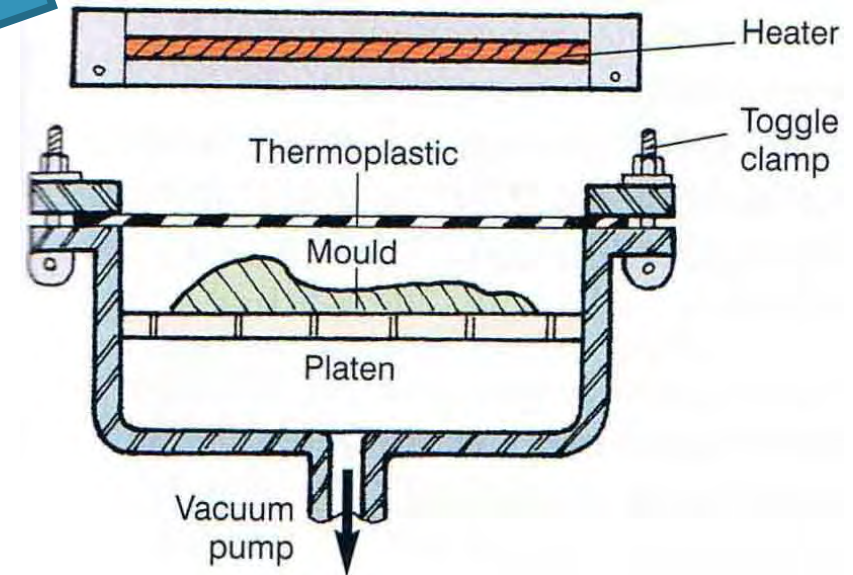




POLYMER FORMING PROCESSES – VACUUM FORMING

Process

1. The mould is placed into the former.
2. A sheet of thermoplastic, such as HIPS is clamped over the mould.
3. The polymer is slowly heated to become soft.
4. The mould is raised and the air is sucked, drawing the polymer over the mould to take on it's shape.
5. The polymer is allowed to cool and then removed from the mould.
6. The edges must then be trimmed and finished.



Clues to Vacuum forming:

- Simple, tray shape
- Sloped slides
- Thin walls

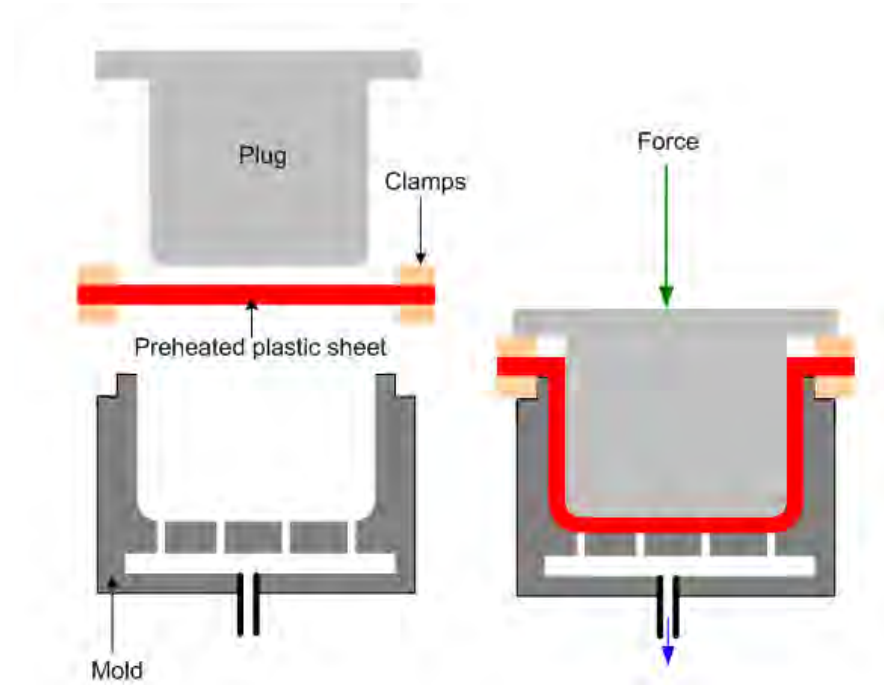


POLYMER FORMING PROCESSES — THERMO FORMING

Process

The process is very similar to vacuum forming but can provide greater levels of detail.

In addition to the vacuum a 'plug' is pressed into the polymer sheet to give the part greater definition.



Clues to Thermoforming forming:

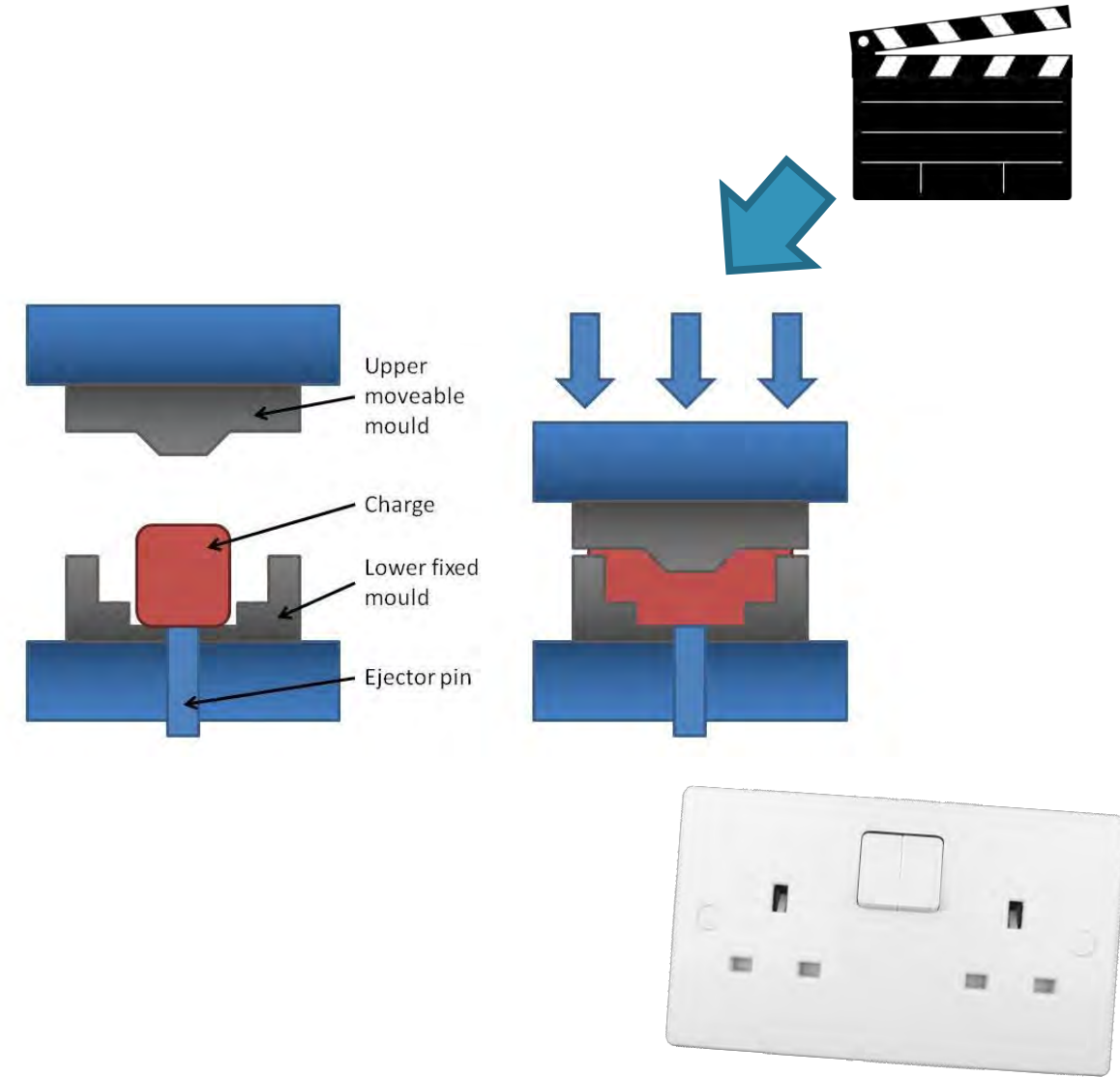
- Simple, tray shape
- Sloped slides
- Thin walls

POLYMER FORMING PROCESSES – COMPRESSION MOULDING

Compression moulding is the primary method for forming parts in thermosetting plastics. For this reason it is often used to make parts that must not deform or soften when heated, like electrical hardware.

Process

1. Preforms (charge on diagram) of compressed powder are placed in a heated mould
2. The heat allows **cross-links** to form within the polymer
3. The top half of the mould closes deforming the preform to shape
4. The mould opens and the ejector pin pushes out the part. Due to the **cross-links** the part maintains shape and doesn't have to cool first.

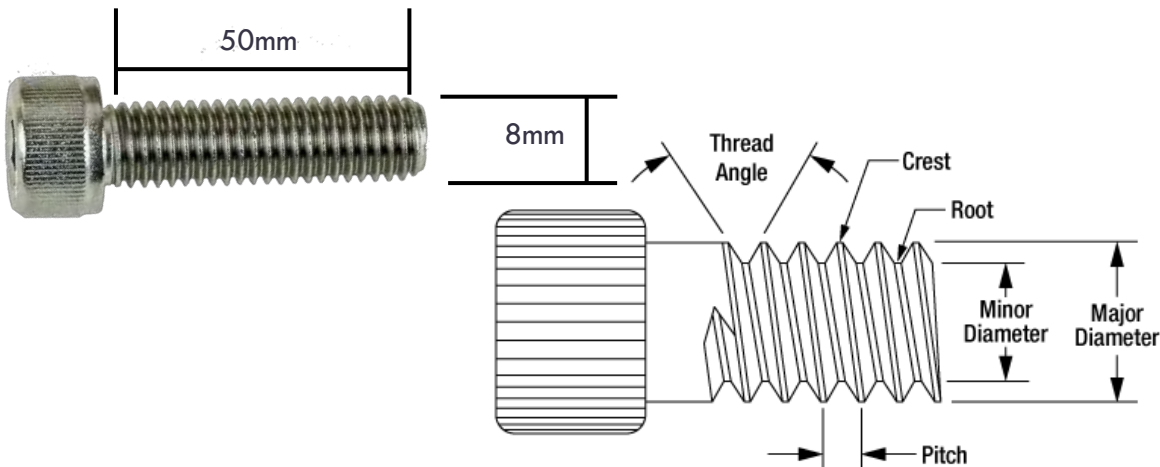


SCREW THREAD THEORY

Thread terminology

All metric bolts adhere to the same naming system. The example below is a M8 x 1.25 x 50mm bolt. Note the pitch is often missed out when describing a bolt e.g. M8 x50mm.

- M = Metric thread.
- 1.25 = The **pitch** of the thread (Distance between threads).
- 8 = 8mm outer diameter.
- x 50mm = the length of the thread.

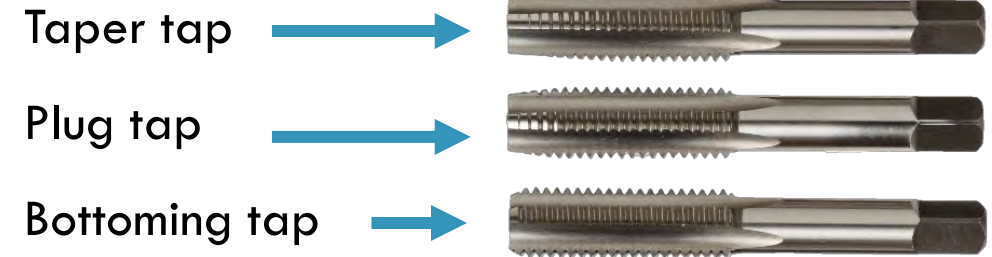


Cutting screw threads

Internal threads

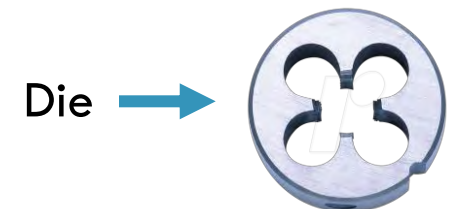
When cutting an internal thread we first drill a tapping hole, use a tap chart to find the correct drill size. We then use 2 or 3 taps to cut the thread.

First we use a **Taper tap**, then a **Plug tap**. For a 'blind hole' (One that doesn't go all the way through) we use a **Bottoming tap**.



External threads

When cutting an external thread (e.g. M8) we start with a round bar 8mm in diameter and use a M8 **Die** and **die holder**.



These are the most common thread sizes you will use.

DRILL AND TAP CHART

METRIC THREAD - Drill & Tap Chart

Course Thread Sizes

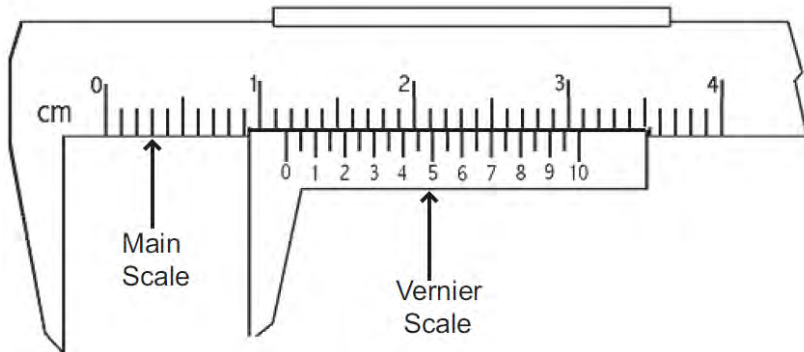
Thread Size	Tap Drill (mm)	Thread Size	Tap Drill (mm)	Thread Size	Tap Drill (mm)	Thread Size	Tap Drill (mm)
M1 x 0.25	0.75	M3.5 x 0.6	2.90	M12 x 1.75	10.20	M36 x 4	32.00
M1.1 x 0.25	0.85	M4 x 0.7	3.30	M14 x 2	12.00	M39 x 4	35.00
M1.2 x 0.25	0.95	M4.5 x 0.75	3.70	M16 x 2	14.00	M42 x 4.5	37.50
M1.4 x 0.3	1.10	M5 x 0.8	4.20	M18 x 2.5	15.50	M45 x 4.5	40.50
M1.6 x 0.35	1.25	M6 x 1	5.00	M20 x 2.5	17.50	M48 x 5	43.00
M1.8 x 0.35	1.45	M7 x 1	6.00	M22 x 2.5	19.50	M52 x 5	47.00
M2 x 0.4	1.60	M8 x 1.25	6.80	M24 x 3	21.00	M56 x 5.5	50.50
M2.2 x 0.45	1.75	M9 x 1.25	7.80	M27 x 3	24.00	M60 x 5.5	54.50
M2.5 x 0.45	2.05	M10 x 1.5	8.50	M30 x 3.5	26.50	M64 x 6	58.00
M3 x 0.5	2.50	M11 x 1.5	9.50	M33 x 3.5	29.50	M68 x 6	62.00

Thread Size	Tap Drill (mm)
M3.5 x 0.6	2.90
M4 x 0.7	3.30
M4.5 x 0.75	3.70
M5 x 0.8	4.20
M6 x 1	5.00
M7 x 1	6.00
M8 x 1.25	6.80

HOW TO READ VERNIER CALIPERS & MICROMETERS

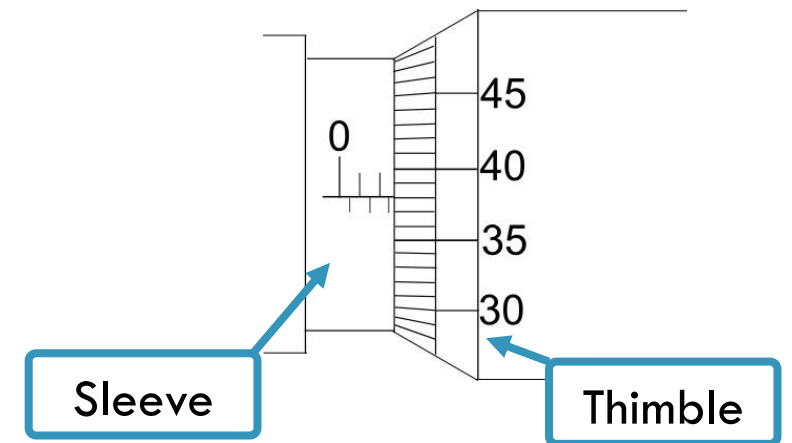
Vernier calipers

1. Look for the last whole millimetre the '0' on the Vernier Scale has passed. In this example it's 11.
2. To work out the hundredths of a mm we used the Vernier Scale. (The example below measures to 0.05mm). Find the line on the Vernier Scale that lines up exactly with the one above it, in this case 65.
3. The measurement is 11 whole mm + 65 hundredths. 11.65mm



Micrometer

1. Count how many whole and half millimetres you can see (on the sleeve of the micrometer – main body) In this example the thimble has exposed 2.5mm. This measurement will be between 2.5mm and 3mm
2. Read the hundredths on the thimble. On the example is it 38 hundredths.
3. Add the 38 hundredths to the 2.50mm to get the final measurement. 2.88mm



Understanding materials, their properties, and their selections for specific purposes

Properties and classifications of materials

Ferrous metals contain iron and are magnetic. They are also prone to rust and need a protective finish to prevent corrosion.

- **Cast iron** is brittle if thin, can be cast in a mould, has strong compressive strength, good electrical and thermal conductivity, but has poor resistance to corrosion. It is used for products such as gates, manhole covers and drains.
- **High carbon steel** is also known as tool steel. It is hard and brittle and is less malleable than mild steel. It is an effective electrical and thermal conductor. Uses include tools, screwdrivers, and chisels.
- **Low carbon steel** is also known as mild steel and is ductile and tough, easy to shape, braze and weld. It is a good conductor of heat and electricity, but also corrodes easily. Commonly used for nuts and bolts, screws, bicycle frames and car parts.

Non-ferrous metals do not contain iron and are not magnetic. They do not rust.

- **Aluminium** is lightweight, malleable and strong. It is a good conductor of heat and electricity. It is used in drinks cans, cycle frames and saucepans.
- **Copper** is very malleable and an excellent conductor of electricity and heat, which makes it perfect for plumbing and central heating applications. It is orange/brown when polished but will oxidise to a green colour.

Differences between thermoforming and thermosetting polymers

Thermosetting polymers will strengthen when heated and cannot be re-moulded or heated after the initial forming. Thermoplastic can be reheated, remoulded without causing a chemical change.

Thermoforming polymers can be heated and shaped repeatedly and are readily recyclable.

- **Acrylic** is hard with good plasticity when heated, can be bent and folded easily but scratches and can be brittle. It is a popular material in the production of car headlights, protective visors and baths.
- **High density polythene (HDPE)** is a stiff and lightweight polymer that provides excellent chemical resistance. It has good plasticity when heated; it is perfect for buckets, bottles, pipes and washing up bowls.
- **Polyvinyl chloride (PVC)** is available in a range of colours as well as transparent. It can be used for vacuum forming.
- **Thermosetting polymers** are materials that are formed once and cannot be recycled. **Melamine formaldehyde** has excellent resistance to heat, moisture, scratching and staining, making it perfect for kitchen worktops and tableware.
- **Urea formaldehyde** is a hard, stiff polymer with excellent insulation properties, making it suitable for switches, plugs and electrical fittings.

Smart and composite materials

Smart materials can display a physical change due to external stimuli.

A smart material is a category of materials that react to a change in temperature or light, for example.

- **Photochromic pigments** or film are used to change colour in ultraviolet (UV) light. This is used in spectacles that automatically darken as the sunlight gets brighter. It is useful in office blocks windows to dim sunlight.
- **Thermochromic pigments** are useful when used in baby products like spoons, bottles and bath toys. This allows the product to change colour to indicate temperature.
- **Shape memory alloys** are materials that change their shape when heated. Spectacle frames and dental braces made from Nitinol can be returned to their original shape.

Composite materials are relatively new and have specific working properties and performance characteristics.

- **Carbon fibre** has high stiffness and tensile strength, with low weight. Carbon fibre is created by bonding carbon atoms together in crystals. It is then woven into fabric and combined with other materials to form a composite.
- **Kevlar** is a heat resistant and strong synthetic fibre with the ability to stop bullets and knives from penetrating it. Kevlar is often described as being five times stronger than steel.



Understanding the physical properties of materials

Understanding that materials can be defined by a range of properties, for example:

- **tensile strength** – the ability of a material to resist stretching or breaking when pulled
- **compressive strength** – a materials ability to withstand loads without changing its shape
- **hardness** – this is a materials ability to resist changing shape when impacted by another object
- **toughness** – the ability of a material to absorb energy (impacts) before it starts to deform (change shape)
- **malleability** – the materials ability to be repeatedly hammered, pressed, bent or rolled into thin sheets
- **ductility** – the ability of a material to be drawn or plastically deformed without breaking
- **conductivity** – a measure of how well the material conducts heat or electricity
- **corrosive resistance** – how well the material can withstand damage caused by chemicals or oxidation
- **elasticity** – the ability of a material to limit distorting and return to its original shape and size
- **environmental degradation** - how the physical environment is degraded, damaged or compromised through a range of situations such as air pollution, water contamination etc.

Physical properties required for specific products (examples)

Mobile phones

- **compressive strength** to resist weight put on the phone casing
- **corrosive resistance** to limit damage to the phone casing from chemicals such as hairspray, sun cream or other daily exposures.

Security alarm

- **compressive strength** in its casing to avoid deformation from high winds
- **hardness** to avoid possible vandalism or attempts to gain access to the circuit.

Bicycles

- **ductility** to allow the tubular forms of the frame to be created (drawn)
- **toughness** to absorb impact, for example when children drop bikes on the floor or during a crash in a race
- **compressive and tensile strength** to absorb the shifting weight of the cyclist on the bike.

Children's play area

- **toughness** to absorb impact when children climb frames and obstacles
- **elasticity** when children climb ladders and ropes or walk across suspended bridges
- **compressive strength** to withstand loads of several children standing in a small area or climbing on frames
- **tensile strength** when children hang or swing on sections of the play area.

How materials are tested to determine their physical properties

Testing is undertaken in engineering to determine the physical properties of materials.

Destructive testing will test the material, part or product until it breaks or is destroyed. Non-destructive testing is used to evaluate the property of the material without causing it damage.

Tensile testing - the material or part is clamped in two locations, usually on opposite ends, and increasing pulling force is applied in opposing directions to measure stretching.

Hardness testing - this is tested by indenting the material with a known hard material such as diamond. The force used to create this is measured to determine hardness.

Toughness testing – this is undertaken by allowing a pendulum with a mass on the base to strike the side of the material or part. The extent to which the shape bends (deflects) dictates its level of toughness.

Malleability testing is done by applying a stamping action (pressing) on the material to see how much the malleable material will flatten without breaking.

Ductility testing is performed in a similar manner to tensile strength testing, where the material is drawn apart.

Conductivity testing is done by passing an electrical current through the metal material and measuring its resistance.

Elasticity is another stretching test but measures a material's ability to be stretched without permanent deformation.



Describing engineering processes

Understanding the application of engineering processes including:

- **Marking** includes applying a marking out medium such as engineer's blue to the material and using a scribe to mark lines for cutting or forming. Dividers and calipers may also be used for marking out. Common tools also used would be engineers square and a steel rule.
- **Cutting** can occur using a hand tool like a hacksaw, sheers or snips saw or fretsaw, or using machinery such as a metal bandsaw.
- **Finishing** applications can include oil bluing, lacquer applications, paint, dip coating etc.
- **Shaping** can involve the removal of materials using saws, files or grinding equipment. It is usually applied to change the form/ shape of stock material.
- **Drilling** is a process whereby a hole is required in a material. Drilling can be done using a hand drill, or drill press/pillar drill, and use a variety of different drill types.
- **Milling** uses a milling machine to cut accurate features such as; open slots, steps and enclosed slots. It can also be used to face off edges and produce holes.
- **Brazing** typically involves a brazing hearth to braze metals together to form a permanent joint. The brazing hearth can also be used to heat treat metals by annealing, normalizing, tempering or hardening a range of metals.
- **Turning** uses a machine called a lathe that can be used to turn a piece of metal to create differently shaped round pieces. It can also be used to create threads and to apply different knurled finishes, as well as to apply chamfers or rebates to material.
- **Joining** metals can be done permanently using welding, brazing, epoxy resin adhesives and soldering. Temporary methods include nuts and bolts, hinges, screws and rivets.
- **Soldering** is used to heat join softer metals such as silver in jewelry (silver solder) or to attach electronic components to printed circuit boards.
- **Forming** is a process used to change the shape of the material, for example by bending, compressing or extruding. Additional tools such as vices and clamps are often used in this process. Heat is often used to assist forming processes.
- **Preparing** materials includes cutting materials to rough sizes (slightly larger than required) from stock material (the material as purchased from the supplier). Preparation can also consider ensuring that all of the tools and equipment identified in the planning stages is available and ready to use. This can also include undertaking appropriate risk assessment measures to ensure safe working practice is undertaken.

Risk assessments and safe working practices

Risk assessments are performed prior to manufacture to ensure that operations can be undertaken safely.

They can include the following:

Identifying potential hazards

- Visual inspection of the workplace to ensure that no obstructions or hazards are present.
- Visual inspection of equipment, which includes guards and safety features.
- Checking of tools to ensure there are no defects or missing parts.

Undertaking a risk assessment

Risk assessments aim to identify potential risks based on the work which will be undertaken during manufacture. The risk assessment will classify the risk according to severity of harm. Once the areas are identified, the likelihood and the control measures are put into place to reduce and minimize the risks from becoming potential accidents to the machinist or operator.

Personal protective equipment (PPE)

The risk assessment document should also identify appropriate PPE, which should be used for key equipment and processes. For example:

- ear defenders
- safety goggles
- protective aprons
- heat resistant gloves
- face shields.

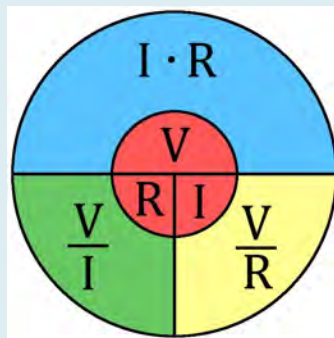


Describing engineering processes

Engineering often involves the need to understand calculations and apply mathematical techniques. These include:

Formulae

- **Ohm's Law** is used to calculate resistance, current and voltage. A typical application may be to calculate the correct value of resistor in an LED circuit.



Mechanical advantage

- When using mechanisms, you can calculate the mechanical advantage (MA) of the system using the formula:

$$(MA) = \text{Load/Effort}$$

Velocity ratio

- Calculating the velocity ratio (VR) of a mechanism requires the information of the distances moved by the load and the distances moved by the effort.

$$VR = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$$

Calculations

- Calculations for mechanisms formula above should include an understanding of application on gears, levers and pulleys.

Areas and volumes

- Calculating areas of engineered parts where subtractions or additions of materials are made by:
 - calculating volumes of cylinders
 - calculating volumes of shapes
 - working out areas of objects.

Estimating costs and materials

- Using a range of sourced costs to calculate the cost of material needed to manufacture a part or component in the engineering outcome.

Scale

- Being able to apply and understand scale factors when reading or producing an engineering drawing is a vital skill. Scales are shown as ratios, for example 2:1 or 1:5.

Units

- Using metric and imperial units for measurements and calculating costs such as:
 - **millimetres** and metres – used in giving sizes on engineering drawings and during manufacture of products
 - **pounds** and pence – used for estimating and working out costs of materials etc
 - **time** in hours, minutes and seconds – used in planning stages for manufacture.

Graphs

- A range of graphs can be applied in planning the manufacture or other relevant areas.

Technical details in engineering drawings

Engineering drawings may be made up of several different parts to the drawing. All elements of an engineering drawing must conform to a standard convention.

Orthographic views

- These are the views of a product or part, which appear on engineering drawings. Typical views are Plan View, End View and Front View.

Hidden detail

- Hidden detail lines are used to show surfaces that are not directly visible. All surfaces must be shown in all views. If an edge or surface is blocked from view by another feature, it is drawn using a hidden detail line.

Section view

- A sectional view or a section looks inside an object. Sections are used to clarify the interior construction of a part that cannot be clearly described by hidden lines in exterior views.

Isometric views

- Isometric projection is a method for visually representing three-dimensional objects in two dimensions in technical and engineering drawings.

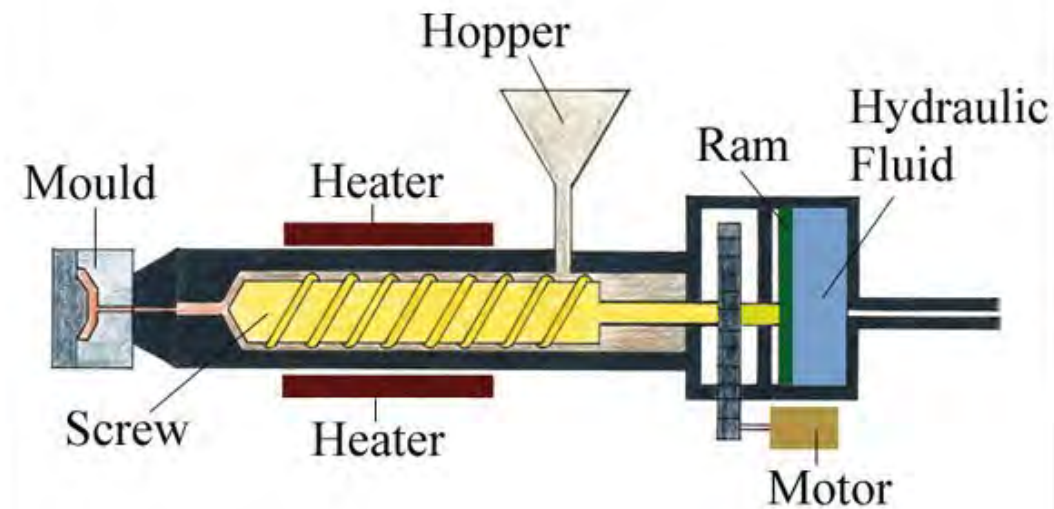
Injection Moulding

This process is normally associated with thermoplastics and used to create complex 3D Shapes.

Image



Diagram



Example Product



Step by step

- Granules of plastic powder or granules are poured or fed into a hopper.
- A motor turns a thread which pushes the granules along the heater section which melts then into a liquid. The liquid is forced into a mould where it cools into the shape.
- The mould then opens and the shape is removed.

Advantages

- Very complex 3D shapes can be produced.
- High volumes can be produced with consistent quality.
- Very fast compared to other moulding processes.
- Little labour costs.
- Little waste.
- Little to no finishing of the shapes produced.

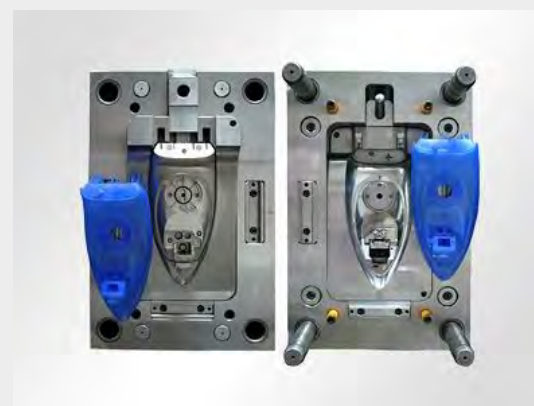
Materials used in this process

- Polystyrene
- Polythene
- Nylon
- ABS (below)
- Polypropylene (below)



Disadvantages

- High initial set-up costs.
- Moulds (pictured) are expensive.



The **Panton Chair** is an S-shaped chair first designed by the Danish designer Verner Panton in the 1960s. It is considered the world's first moulded plastic chair and to be a masterpiece of Danish design.

Today's Panton Chairs are manufactured by injection moulding out of polypropylene, which is fully recyclable. Injection moulding technology makes it possible to offer this design classic as an inexpensive version, thereby making it available to a wider market.



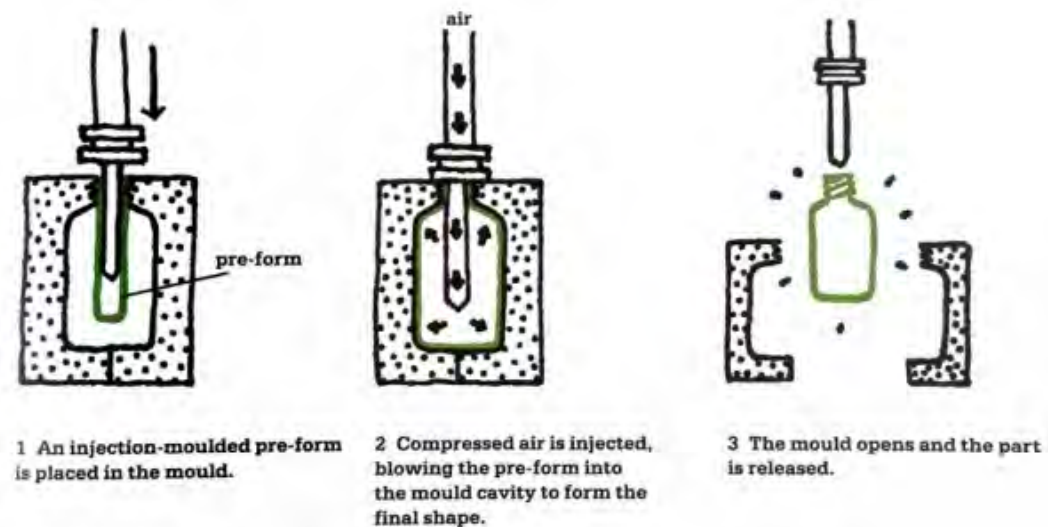
Blow Moulding

This process is used in the manufacture of bottles and other containers. Objects produced are usually hollow.

Image



Diagram



Example Products



Although originally made of concrete, today's **traffic cones** are more commonly brightly coloured thermoplastic. Recycled PVC from bottles can be used to create modern traffic cones. Blow moulding is ideal for traffic cones as they need to be mass produced, easily transported and hollow so they can be filled and weighted down with sand, water or concrete.

Step by step

- The plastic is fed in granular form into a 'hopper' that stores it.
- Heated plastic granules are injection moulded into a pre-form shape which is positioned into a mould.
- Air is forced into the mould which forces the plastic to the sides, giving the shape of the bottle.
- 5. The mould is then cooled and is removed.

Advantages

- Once set up, blow moulding is a rapid method of producing hollow objects with narrow necks.
- Well suited to low or high production scales.
- Many types of plastic can be used.
- Can be less expensive than injection moulding.

Materials used in this process

- HDPE
- LDPE
- PP
- PVC
- PET (pictured)



Disadvantages

- Limited to hollow parts.
- Moulds can be expensive.
- It is difficult to produce 're-entrant shapes' (shapes that do not allow easy extraction from the mould).
- Difficult to produce triangular shapes.



There are many different **kayaks** on the market made from different construction methods which all have their advantages and disadvantages. Blow moulding is the most inexpensive form of production, but has the poorest performance properties. It makes for great low prices but the finish and thickness of material may be thin where kayakers really need it thick, such as in the corners on the bottom of the boat. Also you will rarely find a long pointy kayak that has been blow moulded because of problems getting the plastic into the ends.

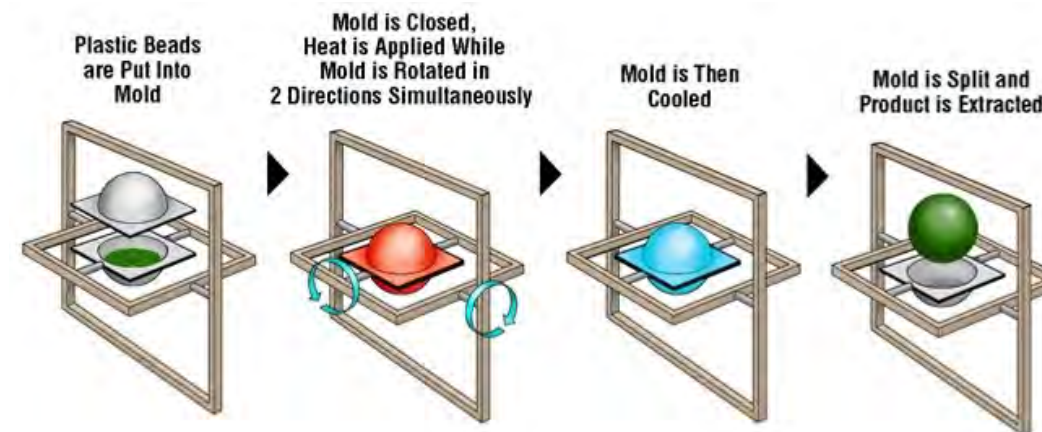
Rotational Moulding

Used in the manufacture of hollow plastic products.

Image



Diagram



Example Products



The **Q Drum** is the simple, durable, effective and user-friendly solution to trouble of fetching water invariably over long distances in disadvantaged and rural communities. The idea of the Q Drum originated in response to the needs of rural people in Southern Africa who struggle conveying adequate quantities of potable water from a reliable source.

The Q Drum is manufactured by means of rotational moulding, leaving a seamless finish. It is made from LLDPE (Linear Low Density Polyethylene) which is compatible to most dry foodstuffs or consumable liquids. The simplicity of the design ensures the ease of use - even a child can pull 50 litres of water without undue strain.

Step by step

- Moulds are loaded with a precise amount of thermoplastic powder (*pictured*). 
- The mould is clamped together.
- The mould is then rotated in a heated chamber and the thermoplastic is melted. The continuous rotation ensures the thermoplastic covers all of the inside of the mould.
- The mould is cooled and then opened.
- The product is extracted.

Advantages

- A hollow part can be made in one piece with no seam lines or joints.
- Ideal for rigid, tough and flexible shapes.
- There is no material wastage as all the material is normally consumed in making the product.
- Different types of product can be moulded together on the one machine.
- Surface textures can be applied to the finished products by applying a texture to the mould.
- Moulds tend to be cheaper than injection moulding or blow moulding.

Materials used in this process

- More than 80% of all the materials used in rotational moulding are from the polyethylene family of plastics.
- Polyethylene
 - Polypropylene
 - Polyvinyl chloride
 - Nylon
 - Polycarbonate

Disadvantages

- Only hollow shapes can be produced. More complex shapes need injection or blow moulding.
- The plastic used must be ground down into a fine powder, and in many cases there is need for special additive packages. This makes the manufacturing costs fairly high.

Polyethylene water tanks and chemical tanks are manufactured using rotation moulding. They are tough shapes, impact resistant and non-corrosive. The one piece seamless inner polyethylene construction these tanks to be used for the storage of most industrial chemicals, including a wide range of herbicides and fertilisers.

Unloading a moulded polyethylene tank from a large scale industrial rotational moulding machine.



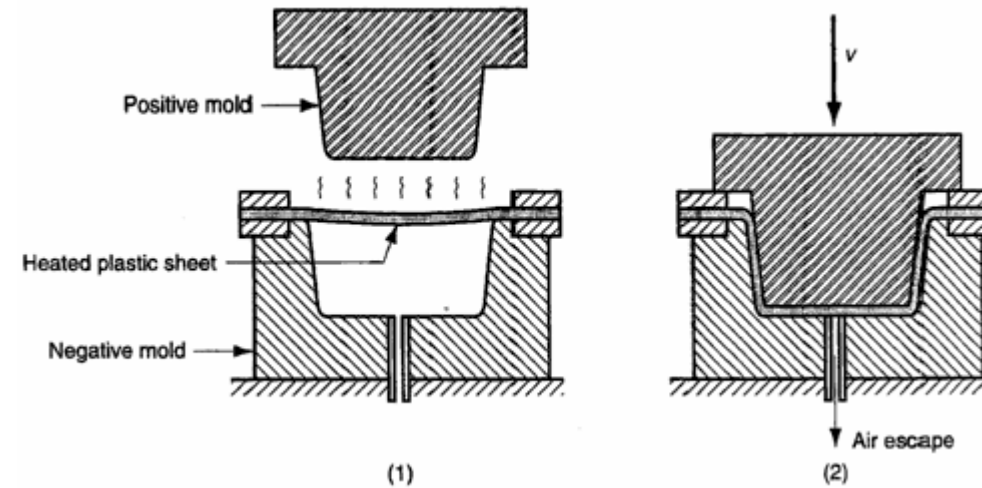
Thermoforming

This is a form of vacuum forming, where an additional female mould assists the moulding process so that greater detail can be achieved.

Image



Diagram



Example Products



Thermoforming is an important application for the manufacture of polypropylene **rigid food packaging**. The thermoforming process is used for producing mass parts of packaging products, but is also used in small production where injection moulding is not cost effective.

Step by step

- Sheet plastic is held securely between the two halves of the mould.
- The plastic is heated just above its softening point.
- The mould halves close and a vacuum is applied through the lower/negative mould.
- The upper/positive mould ensures the required amount of detail is achieved.

Advantages

- Low cost process.
- Works well when creating smooth shapes that need extra detail.

Disadvantages

- Deep moulds can result in thin and stretched of parts of the product.
- Limited to simple designs.
- Trimming is often required, creating some waste.

Materials used in this process

Most Thermoplastic sheet plastic.

- ABS
- Polystyrene
- Acrylic
- Polycarbonate



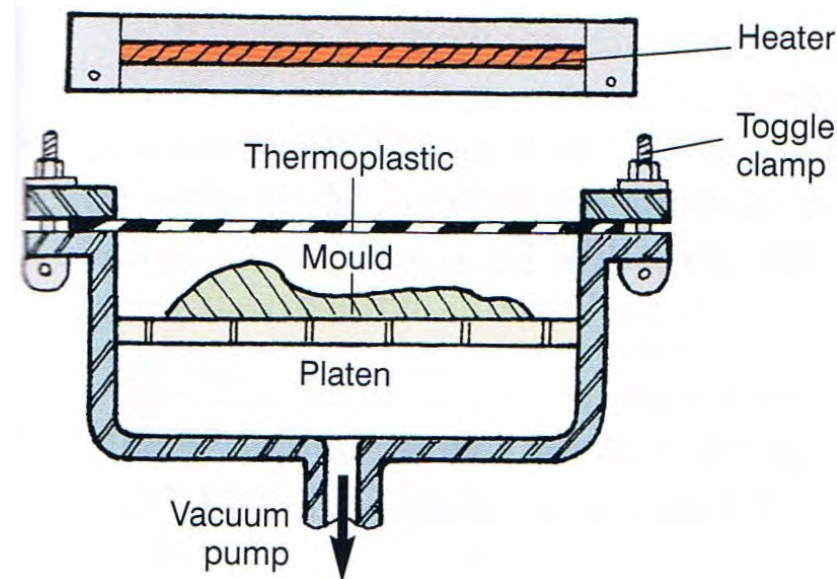
Vacuum Forming

Sheet plastic is stretched onto or into a single-surface mould, and held against the mould by applying a vacuum.

Image



Diagram



Example Products



Step by step

- A sheet of plastic is heated to a temperature suitable for forming.
- A mould is then pushed up into the plastic sheet.
- The 'vacuum' is turned on and this pumps out all the air beneath the plastic sheet.
- The sheet has the shape of the former pressed into its surface.

Advantages

- Available to schools (*pictured*), colleges and industry.
- Simple process, easy to use.
- The mould can be made from a range of materials, including inexpensive materials, because the pressures involved are low.
- Suitable for one-off and large scale production.



Materials used in this process

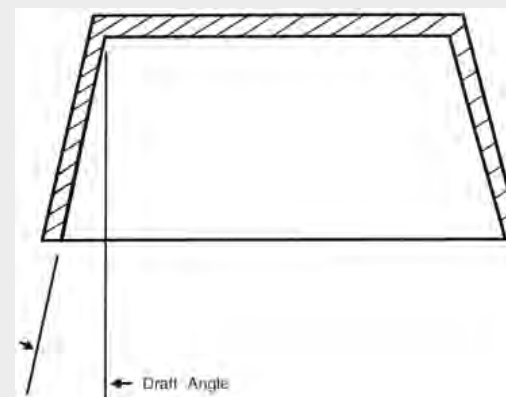
Most Thermoplastic sheet plastic.

- ABS
- Polystyrene
- Acrylic (*pictured*)
- Polycarbonate



Disadvantages

- Additional processing required is required to trim excess material which produces a lot of waste.
- Moulds must have no vertical sides—draft angles are needed (*pictured*).
- You can only have undercuts with special moulds.



Australian designer Marc Newson has designed a **carrying case to hold a single bottle for champagne** for the brand Dom Pérignon. It is called '**The Black Box**'. The packaging is vacuum formed from polycarbonate which is durable and is able to act as a good insulator. It is able to protect its precious contents from shock and temperature variations, thus preserving it and making a design statement.



Moulds used to create **garden ponds** are often vacuum formed. They can be produced quickly and on a large scale (sometimes one every five minutes) making them affordable and available across garden centres nationwide.



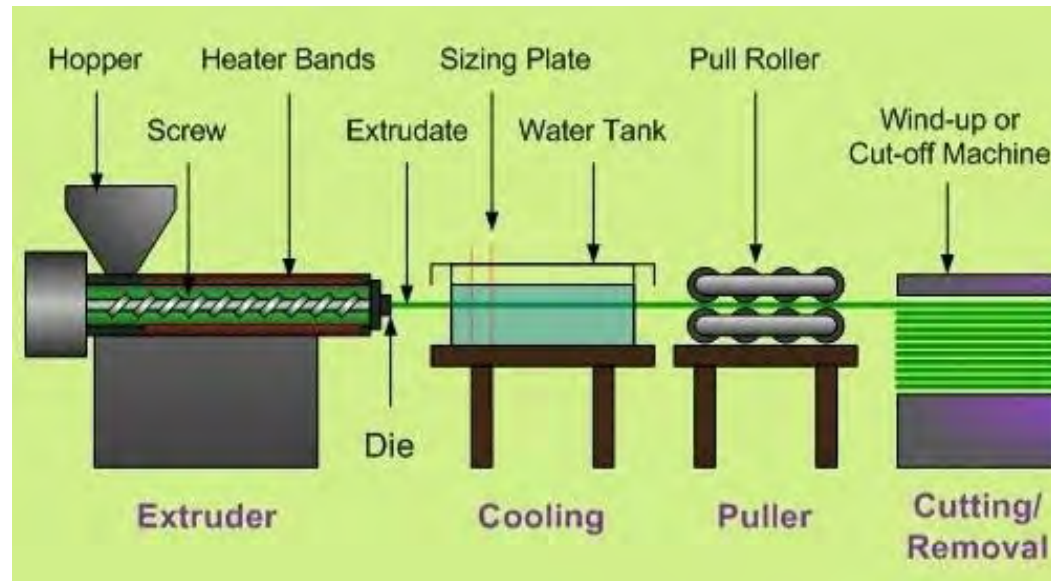
Plastic Extrusion

Plastic extrusion is the process where plastic is formed into a shape with a continuous profile.

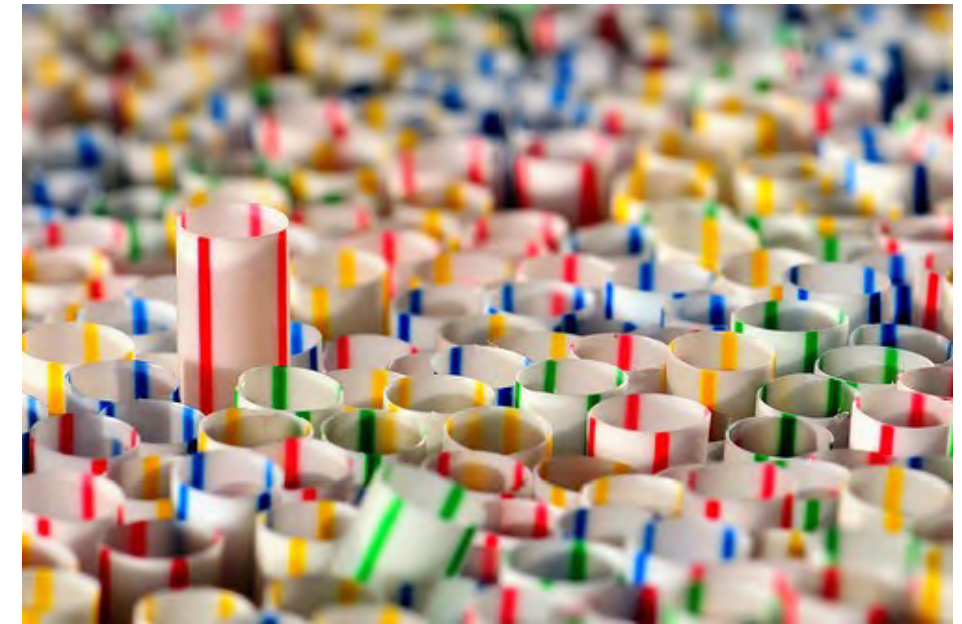
Image



Diagram



Example Products



Step by step

- Granules of plastic powder or granules are poured or fed into a hopper.
- A motor turns a thread which pushes the granules along a heater section.
- The heater softens the plastic which is then forced through a die.
- As the plastic leaves the die it is cooled.
- The extruded product is then cut to the required length.

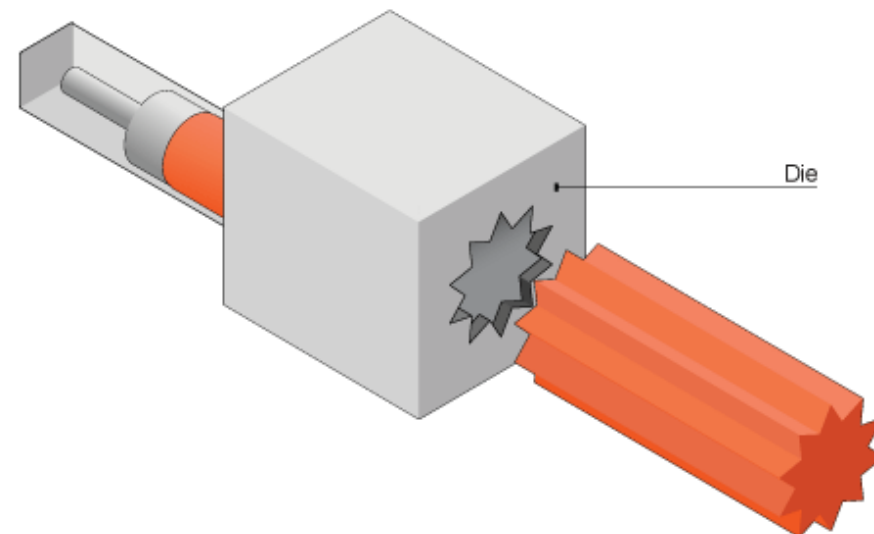
Advantages and disadvantages

- The best way to make long products with the same profile.
- Only requires simple dies (*pictured below and right*).
- Parts need to be cut to shape, assembled or drilled.
- Not suitable for one-off productions (unless your one-off is 50 meters long!).



Materials used in this process

Extrusion can be used with a range of materials. As well as plastics aluminium, wood-plastic composites and ceramics are commonly extruded.



Plastic drinking straws are made from extruded polypropylene. During the extrusion process the heated polypropylene resin exits the die in a long string in the shape of a straw. This elongated tube is directed through a cooling stage—usually a water bath. Some operations run the plastic over a chilled metal rod, called a mandrel, which freezes the internal dimension of the straw to that of the rod. It is continuously moved along by a puller which helps maintain the shape of the straw as it is moved through the manufacturing process. Ultimately, the long tubes are cut to the proper length by a knife assembly.

Polypropylene has many properties which make it suitable for use in straw manufacturing. It is light-weight, has fair abrasion resistance, good dimensional stability, and good surface hardness. It typically does not experience problems with stress cracking and it offers excellent chemical resistance at higher temperatures. Most importantly for extrusion, it has good thermoplastic properties.

Another key attribute of this plastic is that it is safe for contact with food and beverage. Polypropylene is approved for indirect contact with food.

The major waste product from straw manufacturing is the plastic resin. Resin, which is contaminated, overheated, or otherwise ruined must be discarded. However, straws, which fail for other reasons, can be reworked. This process of reusing plastic is known as regrounding and involves pulverizing the straws and re-melting them. This can be done without loss of quality because of the thermoplastic nature of polypropylene.

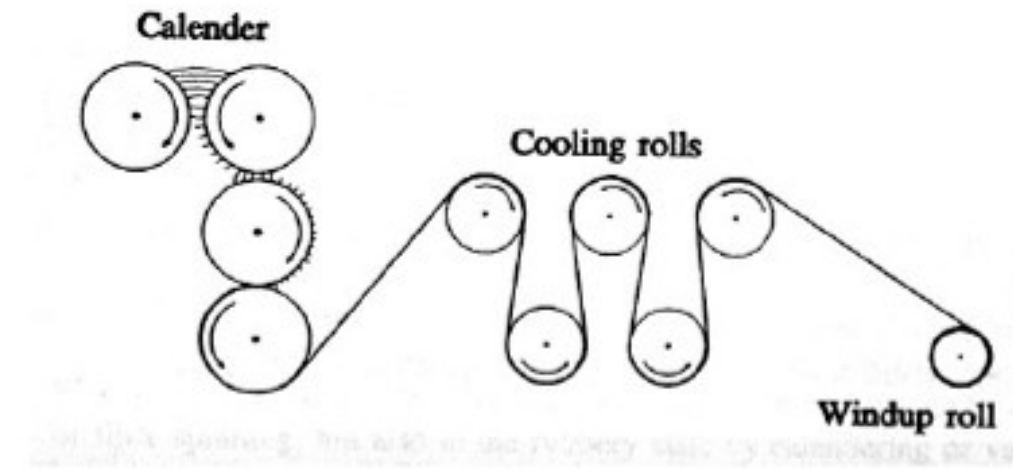
Calendaring

A process used to manufacture thermoplastic sheet, film and coating materials

Image



Diagram



Example Products



Step by step

- Pre mixed thermoplastic material is fed into rollers.
- Rollers are heated to just above the softening point of the thermoplastic.
- The plastic is forced through a gap roller to determine the thickness of the final product.
- The final roller chills the material.

Advantages

- Produces long continuous rolls without joins.
- Excellent for producing large quantities of flat sheets.
- Can be combined with printing or with laminating a layer of fabric or paper.
- Calendaring is very good at handling polymers that are heat sensitive as it causes very little thermal degradation.

Disadvantages

- Suited to large scale production only.

Materials used in this process

- PE
- PVC
- ABS
- Cellulose acetate
- MDPE



(above) PVC rolls produced by calendaring.

Products made from calendaring include:

- floor coverings (*pictured below*)
- continuous flooring
- rainwear
- shower curtains
- table covers
- pressure-sensitive tape
- automotive and furniture upholstery
- wall coverings
- luminous ceilings
- signs and displays



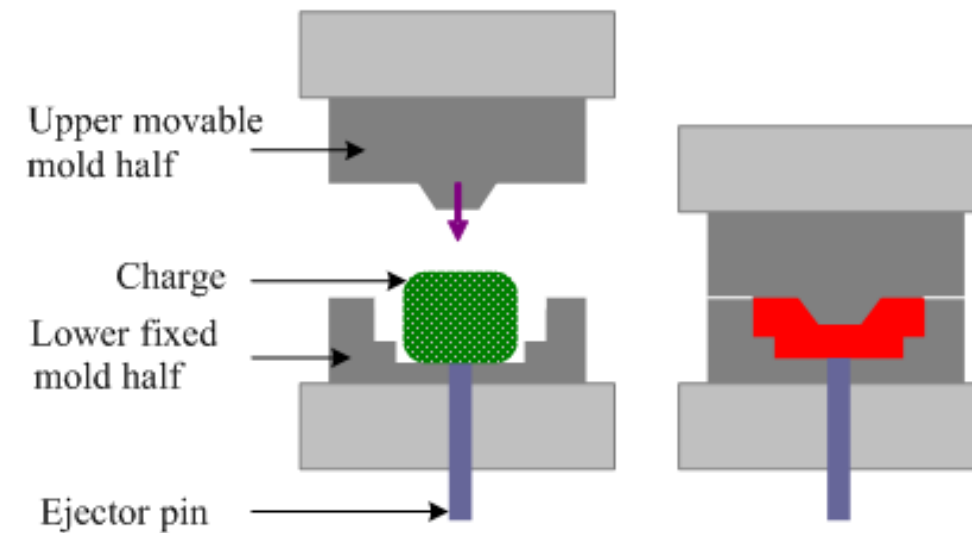
Compression Moulding

Possibly the most important process for manufacturing with thermosetting plastics.

Image



Diagram



Example Products



Step by step

- A performed charge (compressed plastic powder) is placed between the two halves of the mould.
- The mould is heated to a temperature that will allow the long chain molecules of the thermosetting plastic to fix together (this is called cross-link).
- The mould is closed and held together for a period of time that will allow all cross-links to be formed.

Advantages

- Idea for thermosetting plastics.
- Long production runs.
- Low set-up and mould costs compared with injection moulding.
- Little waste material.
- Idea for creating solid parts with thick walls.

The thermosetting plastic urea formaldehyde is stiff and a good electrical insulator making it a good choice of material for a **plug socket**. Its solid shape with thick walls makes compression moulding the only really suitable manufacturing process.

Materials used in this process

Thermoset Plastics and ceramics.

Disadvantages

- Limited complexity of shapes produced.



Melamine is combined with formaldehyde to produce melamine resin, a very durable thermosetting plastic. **Melamine kitchenware** is often made by compression moulding.

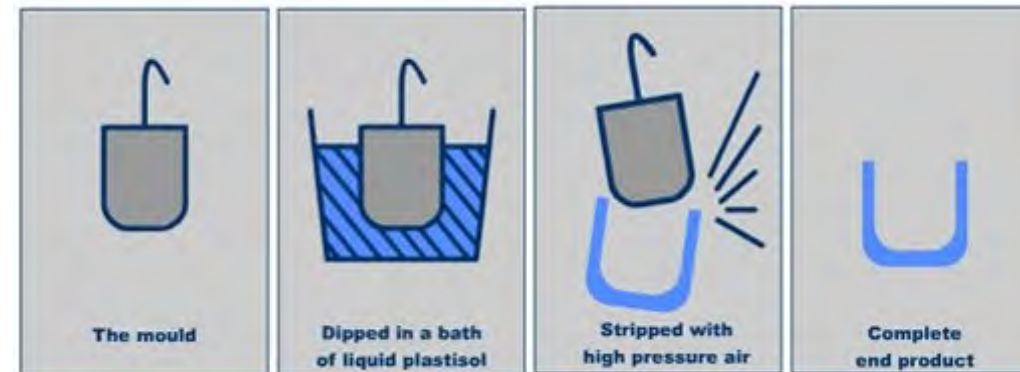
Dip Moulding

Simple and cheap method of manufacturing shapes where a shape is dipped into a melted plastic.

Image



Diagram



Example Products



Dip-moulding is usually used for cheap, industrial applications. Only the inside of the product is controlled by tooling. The exterior finish is affected by gravity, which causes the material to form little drips on the bottom of your product. Designer Liz Kinnmark challenged, herself to design a product with a form that embraces drips on the bottom. **Egg pants** (above) are what emerged. The product is a cute, flexible egg cup, which won't shatter and which is easy to clean.

Step by step

- A mould is dipped into a bath of liquid/molten plastic.
- The mould is removed from the plastic having been coated with a layer of the plastic.
- The mould is cooled.
- The end product is removed from the mould.

Advantages

- Highly cost effective for short production runs.
- Prototypes and formers can be produced very quickly.
- No split lines in final product.
- Suitable for very large production runs.

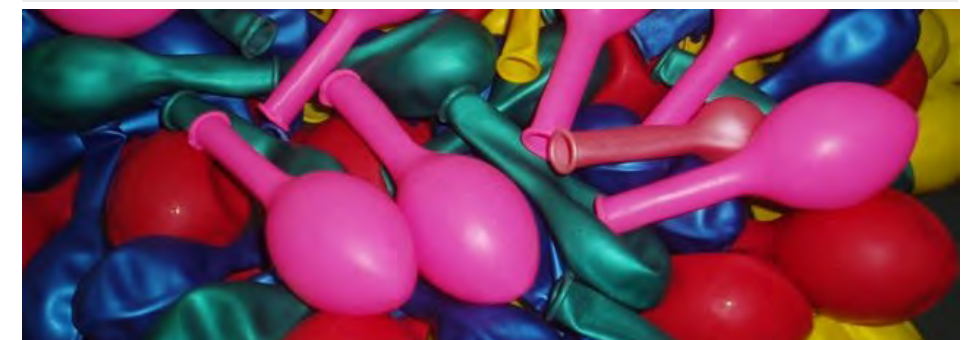
Disadvantages

- Limited to simple shapes.

Materials used in this process

Soft materials that can be stretched over the moulds including:

- PVC
- Polyurethanes
- Latex
- Elastomers
- Silicones



Balloons are mass produced using dip moulding.



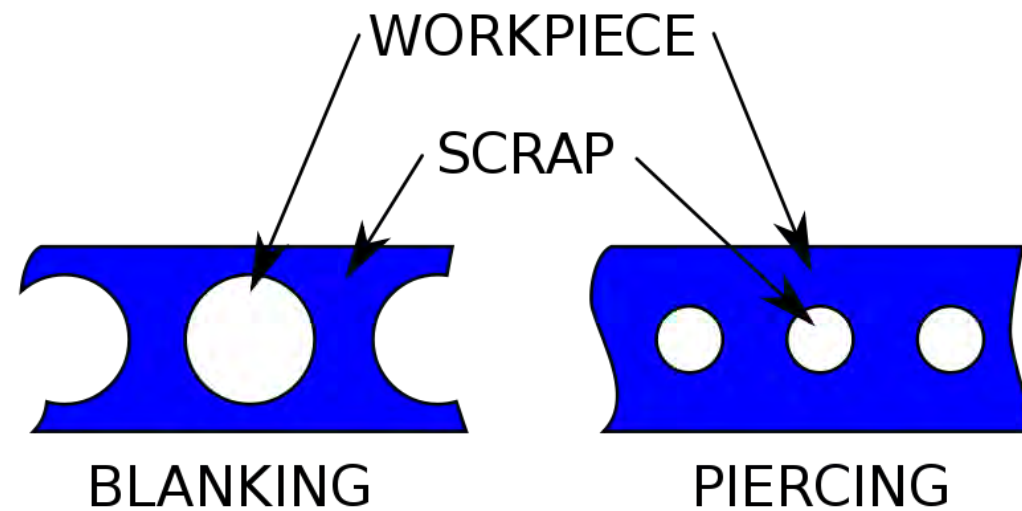
Blanking and piercing

When a sheet of metal has a hole punched through it, it has been pierced. When a part to be used is punched out of sheet metal it is called a blank.

Image



Diagram



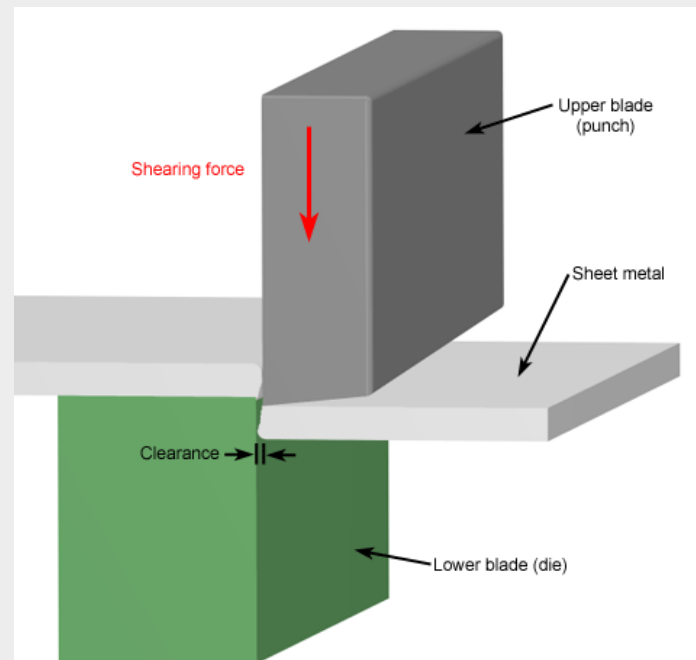
Example Products



Blanking is a way of making simple components like washers

Step by step

- Piercing and blanking sheet metal requires punches. These punches use a shearing action.



Advantages and disadvantages

- Can produce many different shapes (*pictured*).
- Can be used for any sheet metal.
- High level of accuracy.
- Limited to size of stock materials.
- If the material is not fully utilized there can be a fair amount of wastage.
- Restricted to sheet metal.



punching lots of holes into something, like the computer casing pictured above, is called perforating.

Perforated circles can be formed into bowl shapes to create a colander (*pictured*).



Materials used in this process

Sheet metal. Aluminium is common.



Products such as soft drinks cans are made by punching disc-shaped blanks from sheet aluminium. This is an everyday product that has to be cost effective, work all the time and be safe when used. The process is set-up to maximise manufacturing efficiency with as little waste as possible.

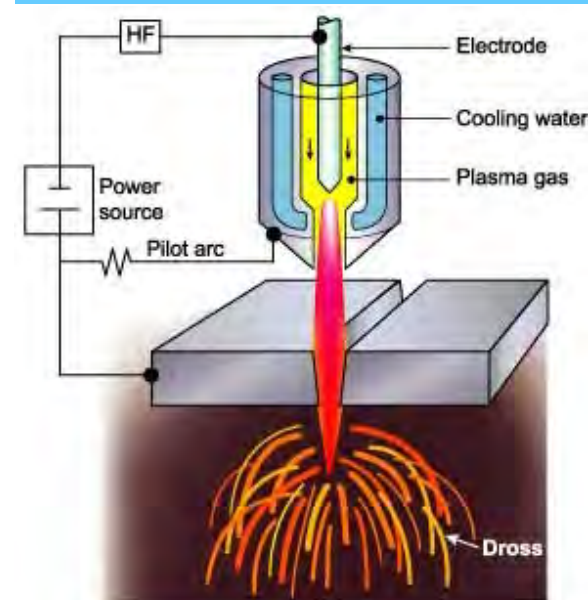
Plasma Cutting

Plasma cutting is a stream of ionised gas which becomes so hot it vaporises the metal that is being cut.

Images



Diagram



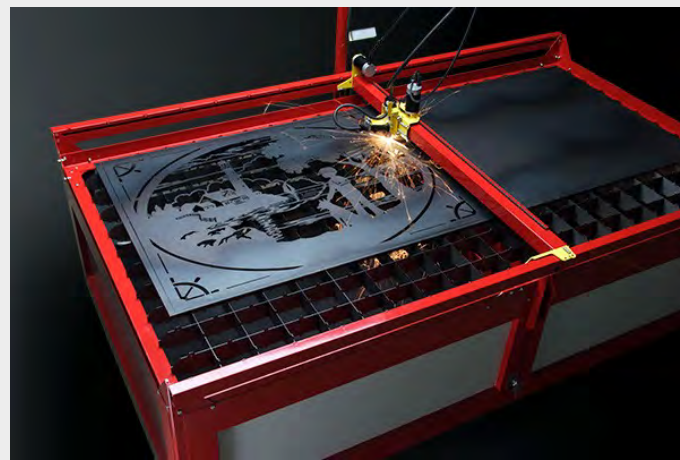
Example Products



Plasma cutting is used in heavy construction including ship building aircraft building and the manufacture of machine components. It can be also used artistically.

Step by step

- Plasma cutting can be done handheld/manual or controlled by CNC (*pictured*).



Advantages and disadvantages

- Economical process when creating small batches.
- Provides smooth, clean cuts.
- Sheet material thinner than 8mm may distort. Plasma cutting is not suitable for sheets under 2mm thick.
- Very energy intensive.
- Often a high amount of wastage, especially with handheld cutting.
- A large range of materials can be cut.

Materials used in this process

Any electrically conductive metallic material. Most commonly stainless steel and aluminium.



Laser Cutting

A highly accurate form of cutting and decorating materials using a fine beam of light controlled by a CNC machine.

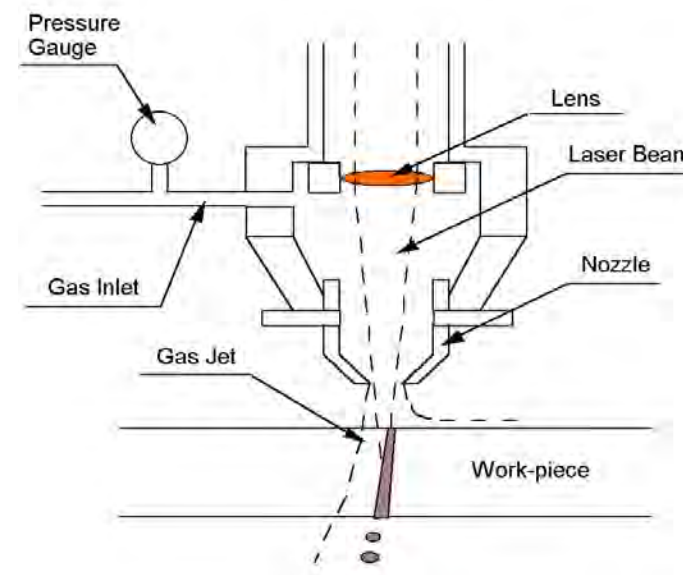
Images



Materials used in this process

• Paper	• Copper
• Card	• Stainless steel
• MDF	• Aluminium
• Plywood	• Gold
• Acrylic	• Silver

Diagram



Advantages

- Can engrave and cut materials by adjusting the power output.
- Highly complex shapes can be produced.
- Suited to batch production.
- Gives a clean edged cut on acrylic and metals.
- A much broader range of materials can be cut compared to plasma cutting.
- Low maintenance/no tool wear.

Disadvantages

- Can leave burn marks on wood and paper materials.
- Highly polished or reflective surfaces decrease the effectiveness of the laser.
- Very energy intensive.
- Slow when working with thicker materials.
- Material wastage is often high.
- Not suitable for large scale production.
- There is an optimum thickness from which materials can be cut.

Example Products



Designer Barend Massow makes interesting laser cut **lighting** pieces inspired by traditional lighting forms. These examples (above) were cut from plywood and acrylic.



The great level of accuracy that can be achieved from laser cutting plywood allows for easy, no glue, assembling **toy kits** that can be easily flat packed.

Because of the high level of accuracy and finishing quality that can be achieved laser cutting is often used in the production of intricate batch produced products such as **jewellery**. Pictured is some acrylic earrings.



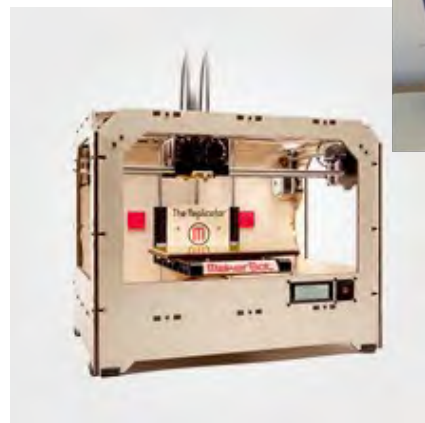
A laser cut acrylic **shop sign**.



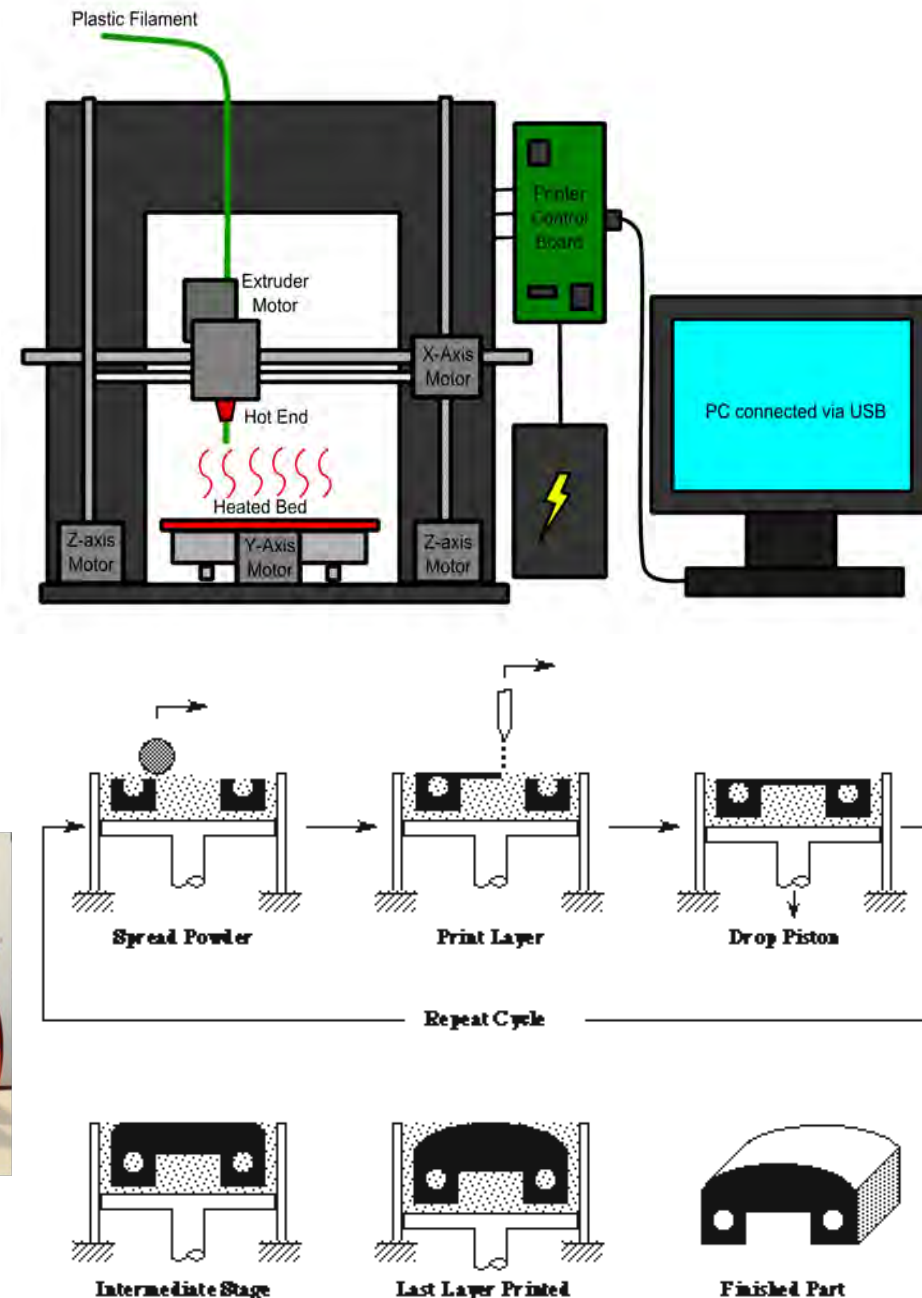
3D Printing

Additive manufacturing or 3D printing is a process of making a three-dimensional solid object of virtually any shape from a digital model.

Images



Diagram



Example Products



Architectural models were previously made by hand and the scaled-down buildings produced in foam, plastic or wood finish. But the advent of 3D printing technology now allows architects to design their work in 3D and print physical models overnight. The picture above shows two singular architectural models of football stadiums, one of Old Trafford and one of rival Manchester City's Etihad Stadium. Both of these replicas show the iconic grounds in remarkable detail.



Aerospace giant BAE Systems says his company has test flown a Tornado Fighter Jets equipped with parts made with 3D metal printing equipment. The parts included a protective cover for the radio, a landing-gear guard and air-intake door support struts. This test is a demonstration of how, maintenance crews will be able to make replacement parts quickly – and cheaply – at any air base hosting the Tornado. Predictions suggest that the 3D printing process could ultimately lead to potential cost savings to BAE of more than £1.1 million between 2014 and 2017.

Materials used in this process

- A range of thermoplastics, metal alloys and plasters.

Advantages and Disadvantages

- Any object can be easily printed. It does not matter how complex the design, 3D printing has opened the door to an infinite possibility of shapes and sizes that can also be customized to the customer's needs.
- Designers can instantly improve their prototypes, increasing efficiency and the effectiveness of an organisation. Perfection can be achieved in a matter of hours.
- Technology such as this can be misused resulting in the rise of many ethical concerns. As any desired object can be printed, an owner of a 3D printer can print objects that are protected by copyrights or could be used in fraud or even weapons.



The McDonald's IT director in Britain said in 2013 that the mega-chain is considering placing a 3D printer in each of their thousands of restaurants which would allow them to 3D print Happy Meal toys at will. Considering that McDonald's distributes more toys per year than Toys-R-Us, includes a toy in more than 20% of all its sales and spends more than £42 million a year advertising Happy Meals alone, and you might begin to understand what it would mean for the company to be able to cut costs on those meals.

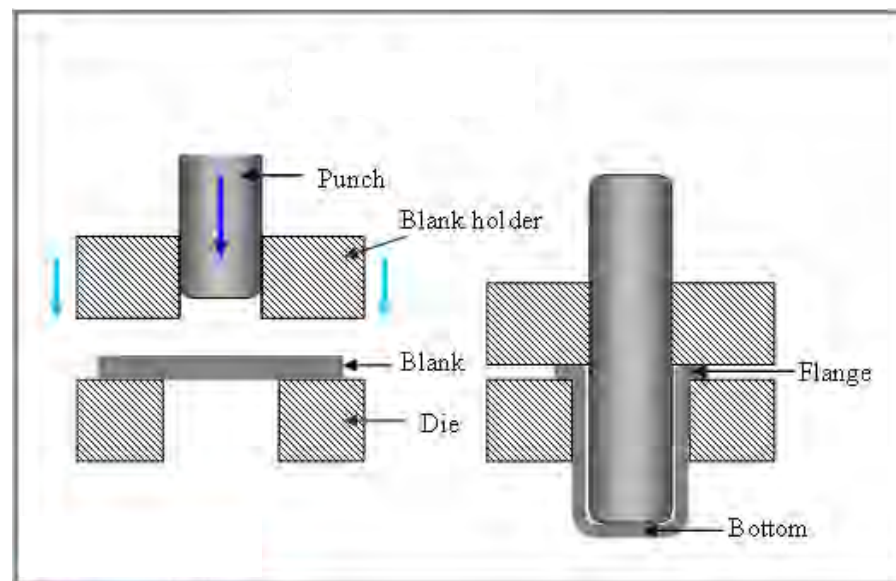
Press-forming / Deep Drawing

A process of pressing sheet metal into 3D shapes.

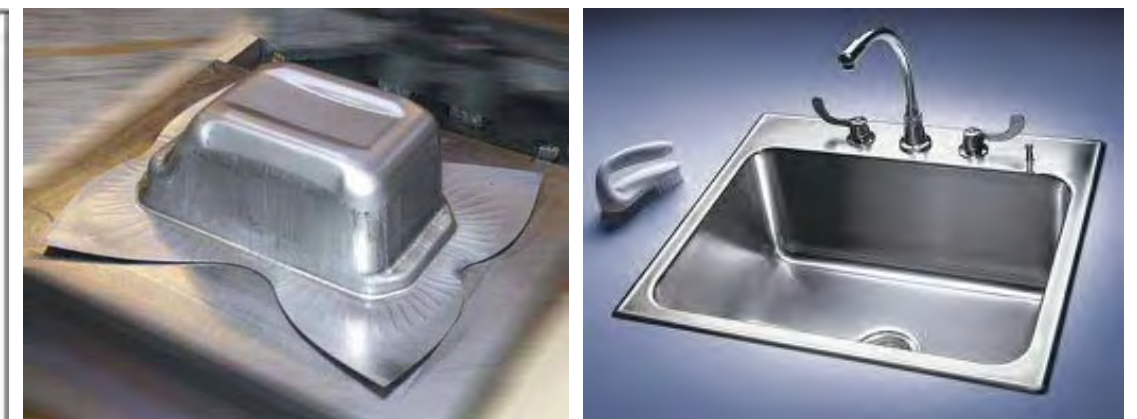
Image



Diagram



Example Products



Products of all shapes and sizes, can be economically created through this process, including items such as aluminium cans, cookware, and **kitchen sinks**.

Step by step

- Sheet metal materials/blanks are loaded into a hydraulic press and clamped into the blank holder.
- The punch forces the material through the die so it takes the shape of the punch.

Advantages

- Pressing sheet metal into more 3D shapes can increase stiffness.
- Can be carried out at room temperature.
- Suitable for medium and high volume production.
- Seamless parts created from single sheets of metal.



The picture above shows the sequence of **can** body production from circular blanks beginning with deep drawing.

Materials used in this process

Sheet metals with sufficient ductility.

They may include:

- Steel
- Copper
- Brass
- Aluminium

Disadvantages

- Very high level of stresses needed to overcome the resistance of the metal being pressed.
- High tooling costs.



The picture (left) shows formed fire extinguishers before finishing (right).



Sand Casting

A low cost method of casting metal in sand moulds. Used for one-off or low volume production.

Image



Step by step

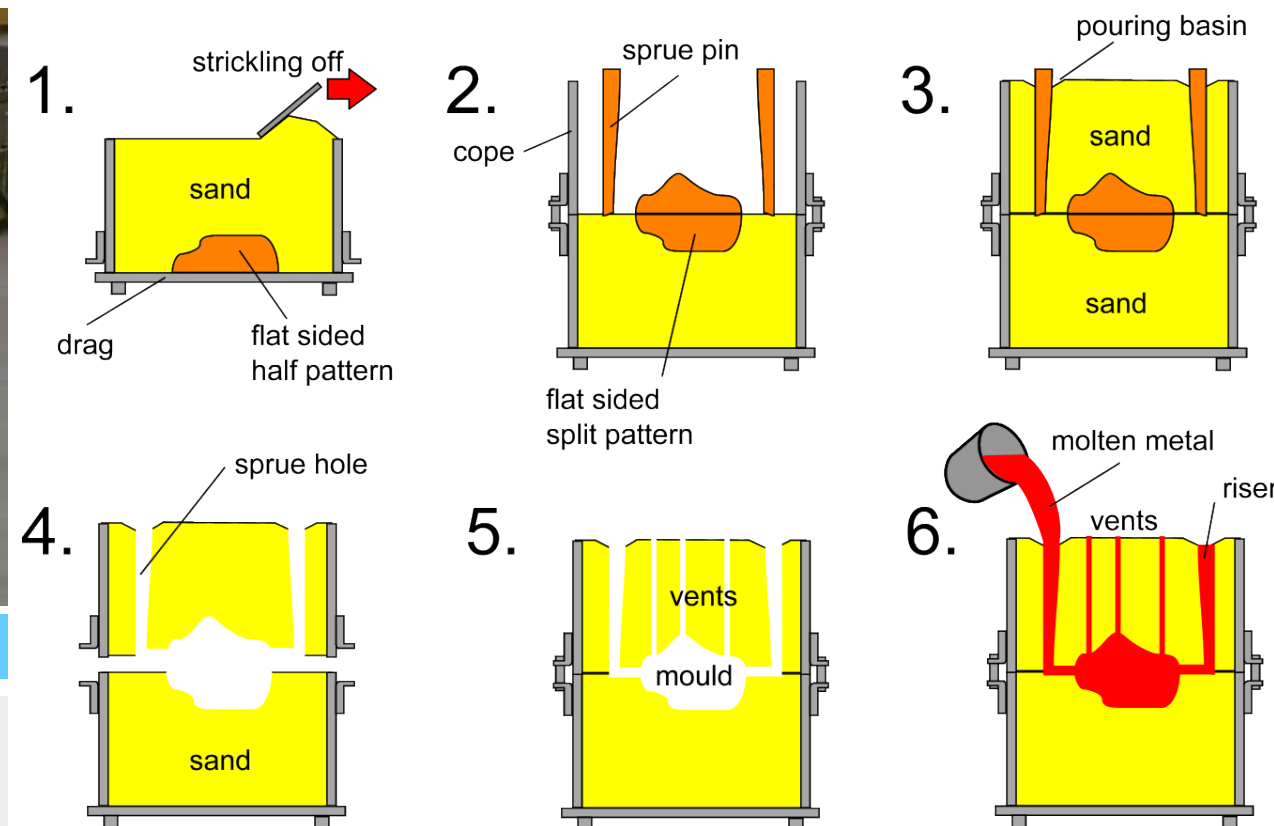
- A pattern is made.
- Each part of the pattern is placed on a base board. A mould box half is placed over it.
- Sand is packed around the pattern forcing it into contact with the pattern.
- The pattern is removed from the mould half.
- The mould halves are fitted together with locating pins ensuring correct alignment.
- Molten metal is poured into the running gate.
- Once the metal has solidified the mould is broken open.

Materials used in this process

Metals with a low melting point. These include:

- Copper alloys
- Lead
- Zinc
- Aluminium
- Tin
- Certain steels

Diagram



Advantages

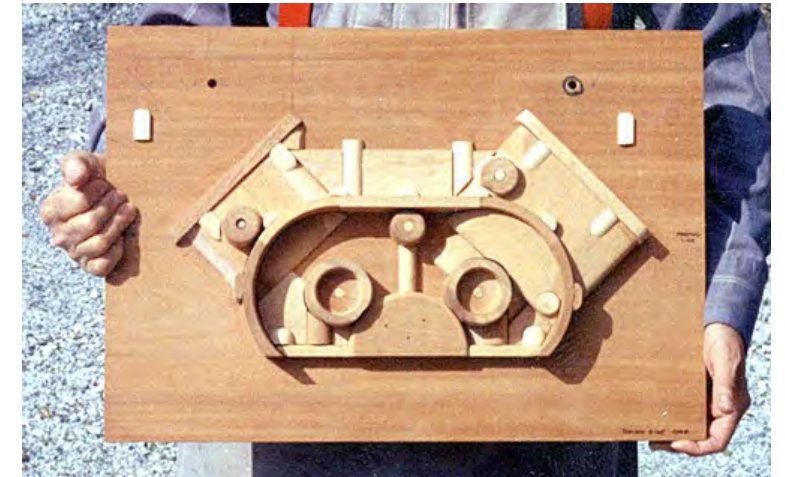
- Low cost process.
- Easy to operate.
- Advanced sand casting can produce very detailed and intricate parts.
- Flexible levels of production.

Disadvantages

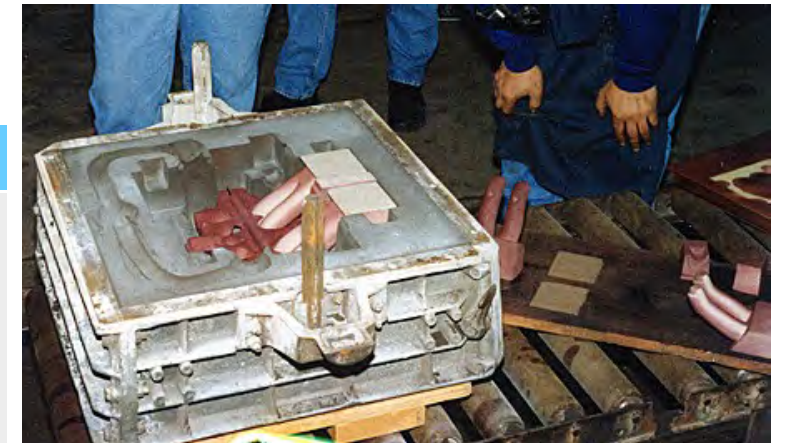
- Can be labour intensive.
- Unit costs can be high when used for one-off production.
- Parts may require a lot of finishing.



Example Products



Above is an example of a pattern produced to create a mould for an **engine part**. The images below show the mould and casting.



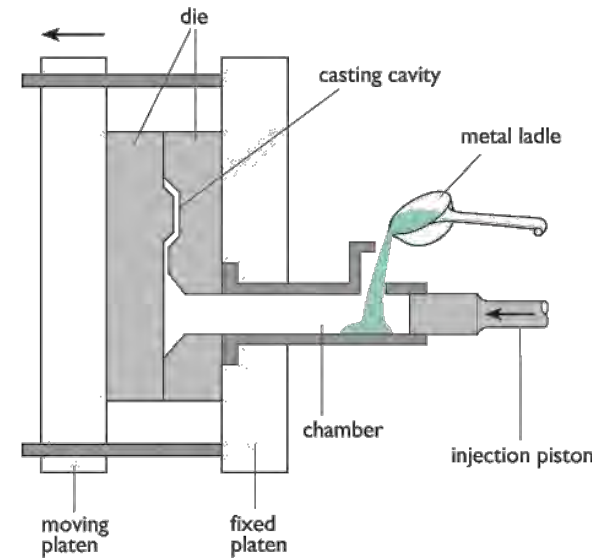
High Pressure Die Casting

High pressure die-casting is one of the most economical methods of producing metal components with complex shapes.

Image



Diagram



Example Products



Die cast metal toys have been popular for decades. Die-casting allows fine and complex details as can be clearly seen in the example pictured above.

Step by step

- Molten metal is poured into a chamber.
- An injection piston or plunger forces the molten metal under high pressure into the casting cavity.
- The pressure is maintained until the metal solidifies.
- Injector pins are used to push the components out of the die.

Advantages

- Suitable for metals with low melting points.
- Ideal for complex shapes.
- A high level of detail can be achieved.
- Excellent surface finish.
- Highly accurate.
- Can produce small and thin parts.
- Fast process.



(above) A die-cast one-piece calliper brake lever for a bicycle.

Materials used in this process

Metals with a low melting temperature such as

- Aluminium
- Zinc

Disadvantages

- Expensive, so only suitable to high volume production.
- Parts produced are not guaranteed to have high structural strength.
- Excess material requires additional trimming which adds to energy use and waste.



The Chair One designed by Konstantin Grcic is formed of polished die-cast aluminium or in die-cast aluminium treated with fluorinated titanium and painted in polyester powder. The Chair One can be stacked and there is a seat cushion also available to order if required. The black or white polyester painted version is suitable for outdoor use.

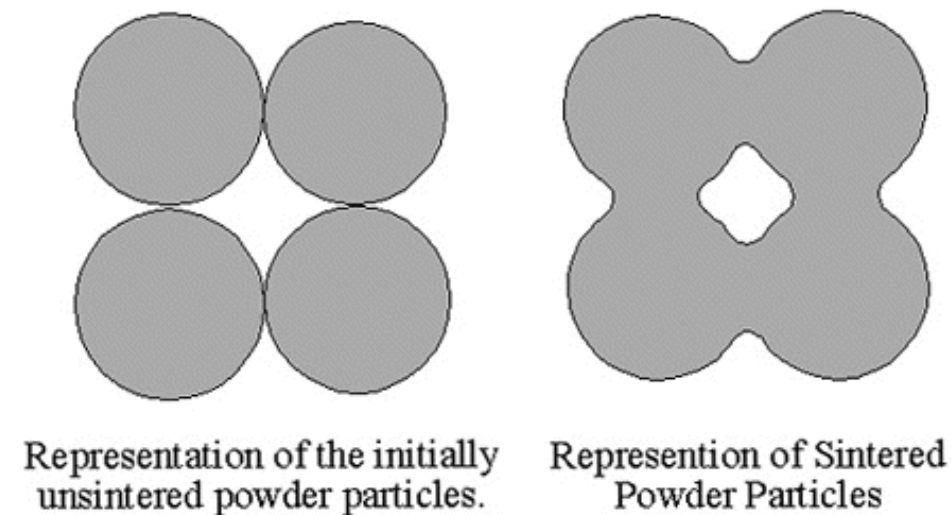
Sintering

Description

Image



Diagram



Example Products



Step by step

- Materials are crushed into a powder.
- The powder is compacted into a die, which will give the product being made its final shape.
- The compacted shape is then heated so that the powder particles bond.

Advantages

- A good process for using materials that are difficult to process in any other way.
- Good surface finish.
- No wasted material.
- Not suited for making products with thin walls.
- Can produce complex shapes.

Materials used in this process

- A variety of metals, glass, plastics and ceramics.

Disadvantages

- There can be problems with shrinkage.
- Allows use of some recovered waste materials.
- Requires a number of different stages.

There are 2 main types of bicycle disc brake pads: Sintered (or metallic), and Resin (or organic). Both types of pads have their pros and cons, and choosing the right pad depends on many things such as the rider weight, weather/trail conditions and type of riding.

Sintered pads are made up of hardened metallic ingredients, which are bound together with pressure and temperature. Their advantages are that they perform better in wet conditions and last longer, but unfortunately they are louder, take longer to break in and do not have as much initial bite

These pads will be better for heavier riders and are recommended for riding in wet, muddy, or dusty conditions. Riders notice increased performance at the end of their rides. This happens because the heat is put back through the brake calliper, rather than the disc where you would get brake fade. Since these pads are made of a harder compound they will last longer than resin pads.

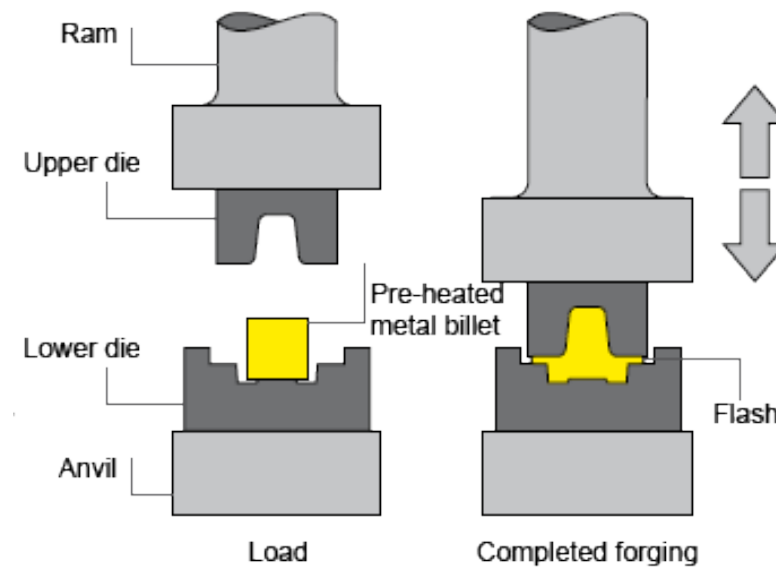
Drop Forging

Used as a refining process when large numbers of similarly shaped objects are required.

Image



Diagram



Example Products



The words "drop forged" are often stamped on **drop forged tools**. Why do manufacturers want you to know that a tool is drop forged? The reason is because this tells you something about the strength and durability of the tool. The other two ways to make a tool would be casting it from molten metal or machining it (cutting material away) from a larger block of metal. The advantage of drop forging is that it improves the strength of the metal by aligning and stretching the grain structure. A forged part will normally be stronger than a casting or a machined piece.

Step by step

- Very large forces are exerted onto a pre-heated metal billet between the die halves.

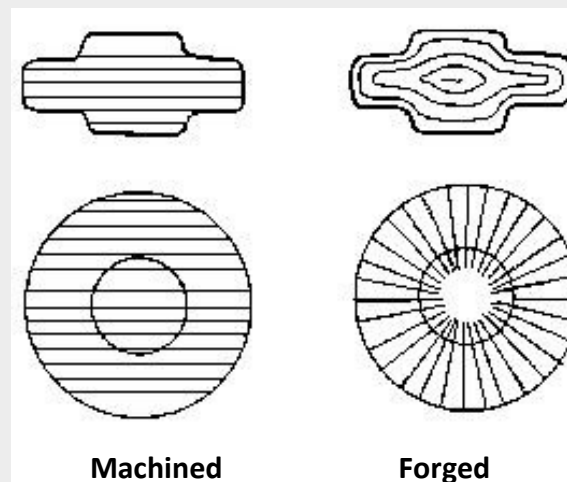
Materials used in this process

- Most ferrous metals, including stainless steel and alloys.
- Non ferrous metals including titanium, copper and aluminium are suitable.



Advantages and disadvantages

- Forging can produce a piece that is stronger than an equivalent cast or machined part. As the metal is shaped during the forging process, its internal grain deforms to follow the general shape of the part. As a result, the grain is continuous throughout the part, giving rise to a piece with improved strength characteristics (*see diagram below*).
- Some metals may be forged cold, but iron and steel are almost always hot forged. Hot forging prevents the work hardening that would result from cold forging, which would increase the difficulty of performing secondary machining operations on the piece.
- It can be very expensive.
- There are significant dangers working with the hot metal.



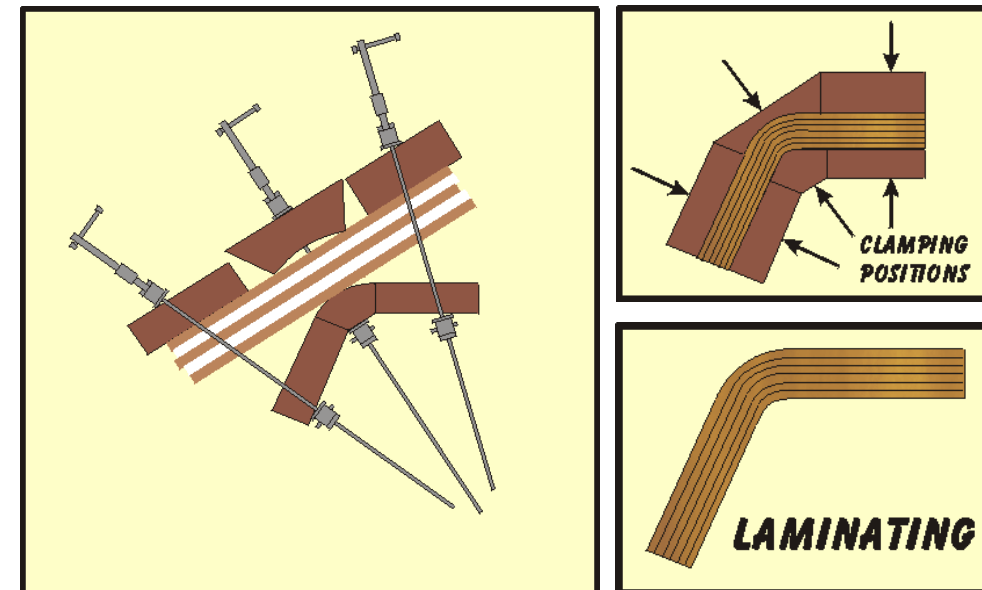
Wood Laminating

Multiple sheets of wood veneer are formed using moulds and bonded together using strong adhesives, to produce rigid, light weight structures.

Image



Diagram

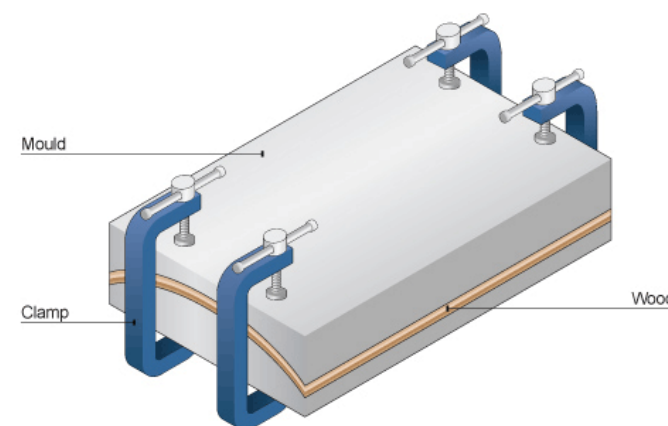


Example Products



Step by step

- Adhesive is applied to the face of each veneer.
- Each veneer is stacked on top of the other (lay-up).
- The veneers are clamped into position in a die (pictured below and above).
- The adhesive dries and the shape is formed.



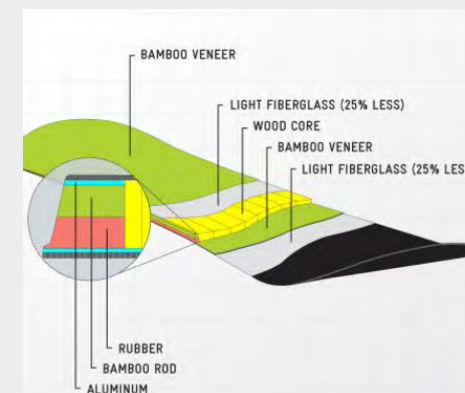
Materials used in this process

Wood veneers.

- Birch is used in majority of mass produced furniture.

Advantages

- Suitable for one-off, batch and mass production.
- Can accommodate a range of thicknesses.
- Creates strong and lightweight products and components.
- Can be combined with other materials to enhance properties such as in snowboards (pictured).



Disadvantages

- Involves many steps.
- Restricted to bends in a single direction.



Supplies of birch veneers (above)

The **Eames Lounge Chair and ottoman**, was released in 1956 after years of development by designers Charles and Ray Eames. It was designed for a high-end market. It is made of laminated plywood and leather. Examples of this design are part of the permanent collection of New York's Museum of Modern Art.

The chair has become iconic with Modern style design. The chair is composed of three curved plywood shells. In modern production the shells are made up of seven thin layers of wood veneer glued together and shaped under heat and pressure. The design is considered to be one of the first to make use of moulded plywood, which was devised during WWII for leg and arm splints. The original (vintage) chairs made use of luxurious materials such as rosewood faced plywood, cast aluminium and leather to create organic shaped seating shells.



This elegant **stackable stool** designed by Shin Azumi is formed from a single sheet of plywood. The seat and the body of the stool merge seamlessly. The wide spread of the base helps to disperse pressure.

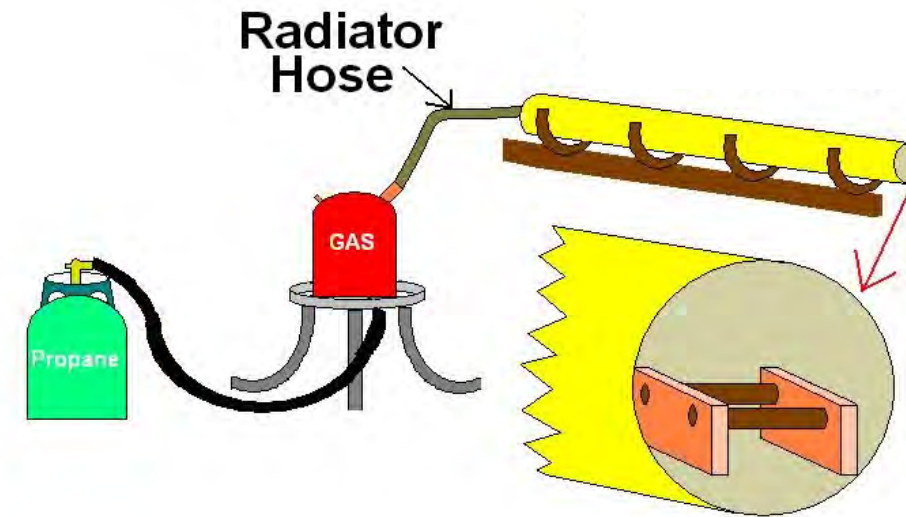
Steam Bending

The moistening of certain woods to a point where it becomes more pliable.

Image



Diagram



Example Products



Step by step

- Tools used for the steaming process include: a steam box, a steam or heat generator, a thermometer and a hose.
- Steam boxes may be constructed from PVC pipe and must completely encase the wood so that the steam may saturate the entire length of the material.
- The wood is steamed and softened.
- Once the wood becomes flexible it can be manipulated.

Materials used in this process

- Hardwoods are more suitable than softwoods and some hardwoods are more pliable than others.
- Beech and oak are common in furniture making.
- Oak is common in construction.
- Elm, ash and willow are traditionally used in boat building.
- Maple is suitable for musical instruments.

Advantages

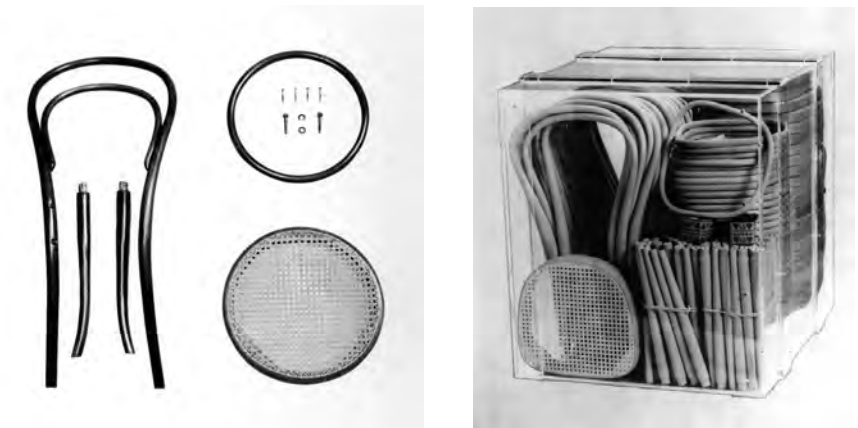
- Has good aesthetic appeal.
- The most effective technique for bending solid wood.
- Can be done with simple equipment.
- Parts with strong weight to strength ratio can be produced.
- Steam bent wood parts can be individually shaped and joined to produce almost any shape (pictured).



Disadvantages

- Only high quality hard wood timbers should be used.
- Not suitable for applications that require precision.
- The bend radius is dependant on the type of wood used.

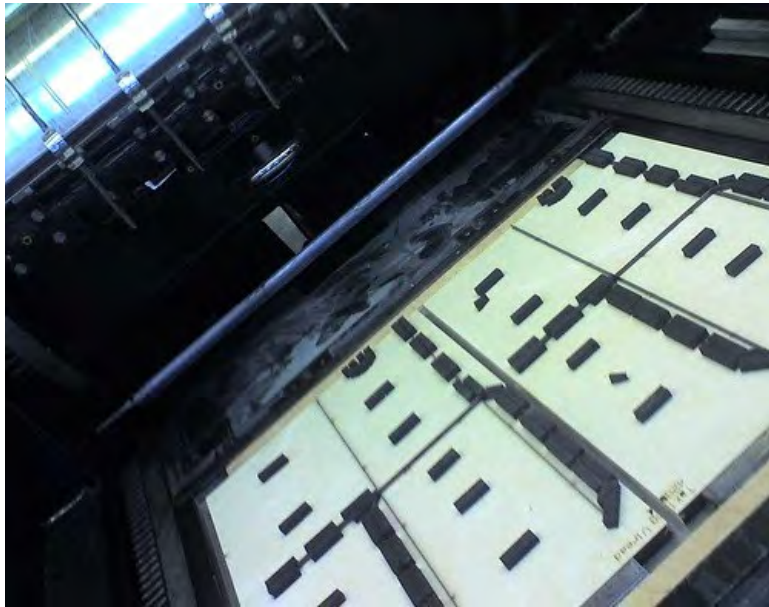
The **No. 14 chair** is the most famous chair made by the Thonet chair company. Also known as the bistro chair, it was designed by Michael Thonet and introduced in 1859. It is made using steam bending technology. With its affordable price and simple design, it became one of the best-selling chairs ever made. Some 50 million No. 14s were sold between 1859 and 1930, and millions more have been sold since. Thonet's No. 14 was made of six pieces of steam-bent wood, ten screws, and two nuts. The wooden parts were made by steam heating beechwood slats to 100 degrees Celsius, pressing them into curved cast-iron molds, and then drying them at around 70 degrees Celsius for 20 hours. The chairs could be mass-produced by unskilled workers and disassembled to save space during transportation. The design was a response to a requirement for cafe-style chairs. The seat was often made of woven cane or palm, because the holes in the seat would let spilt liquid drain off the chair. Chair No 14, today known as 214, is still produced by Thonet. While CNC machining and wood laminating can be used to produce similar shapes, steam bending is specified for applications that require the aesthetic appeal and structural benefits of solid wood.



Die Cutting

A process for cutting, perforating and creasing thin sheet materials.

Image

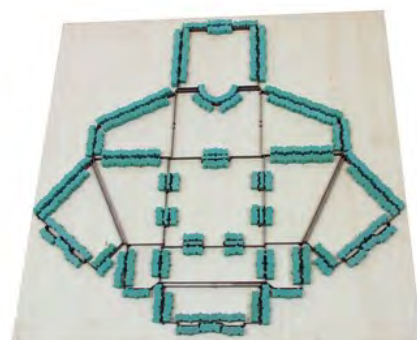


Step by step

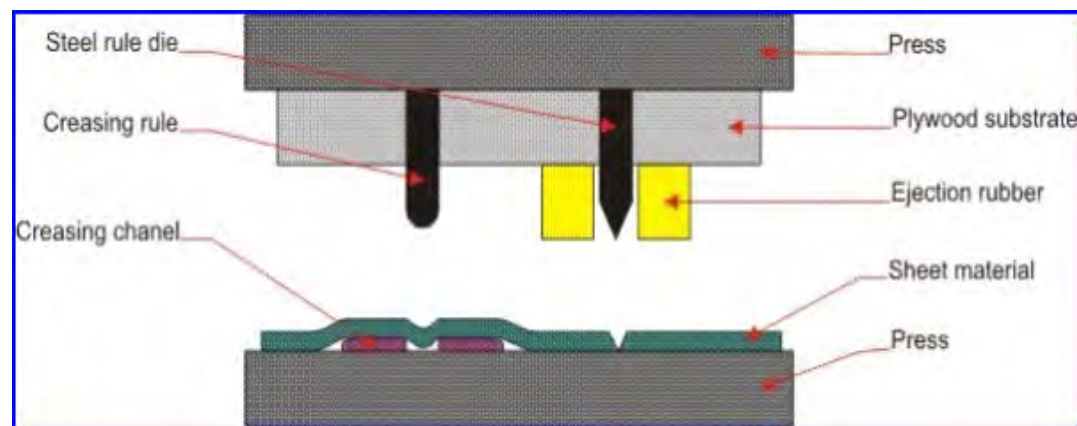
- The sharp edges of the cutting die are brought down onto a thin sheet material.
- The material can be cut, creased and perforated all on one single step.

Materials used in this process

- Paper
- All sorts of card
- PVC
- PET
- Polypropylene (pictured)



Diagram



Advantages

- Low set up costs.
- Cost effective for batches.
- Can easily be combined with printing.
- Many shapes can be cut in a single cutting action.
- Large batches can be produced very quickly.

Disadvantages

- 3D products need to be assembled by hand.



Example Products



Die Cut **Alphabet Book**. All Pages are die cut to show the interest of alphabet shapes.



Stickers are often either kiss cut or die cut. Kiss Cuts are cuts that go only through the vinyl and not the backing material. Die Cuts are cuts that go through both the vinyl and sticker backing paper. In the photo above you'll notice that the left image is a kiss cut sticker which still has the rectangle backing behind it. However, once the sticker is removed from the backing it appears as if it were die cut. The image on the right shows a die cut that is around the image so there isn't excess material. The price of the sticker will go up with the complexity of the shape around it.



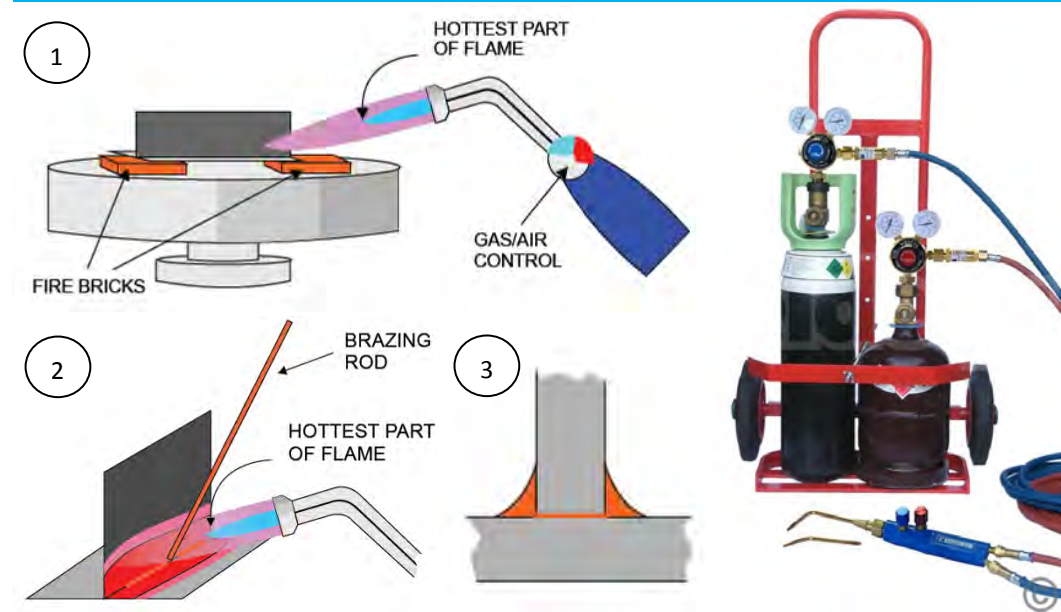
Brazing

A way of forming permanent joints in metal by melting a brazing rod at 880°C between two parts.

Image



Diagram



Example Products



Step by step

- The metal to be joined must first be cleaned so that grease and dirt is removed.
- Flux is brushed along the joint to prevent oxidation taking place on the metal surfaces.
- Pressurised gas and air is fed through a nozzle and ignited.
- The joint is heated with the flame until eventually it becomes so hot that it becomes red in colour.
- A brazing rod (copper-zinc alloy) is then pushed gently against the joint and if the temperature is right the end of the rod will melt and begin to run along the joint. The rod is fed into the joint until a brazed joint is complete.

Advantages

- Low costs.
- Does not affect the properties of the materials being brazed.
- Suitable for one-off through to mass production.
- Depending on size of joint and technique this process takes little time.
- The bond is very strong—close to the strength of the parent material.
- Can produce a clean joint without the need for secondary finishing
- Complex and intricate joints can be achieved.
- Very few rejects as faulty joints can be dismantled and re-joined.

Materials used in this process

- Copper
- Steel (particularly mild steel).

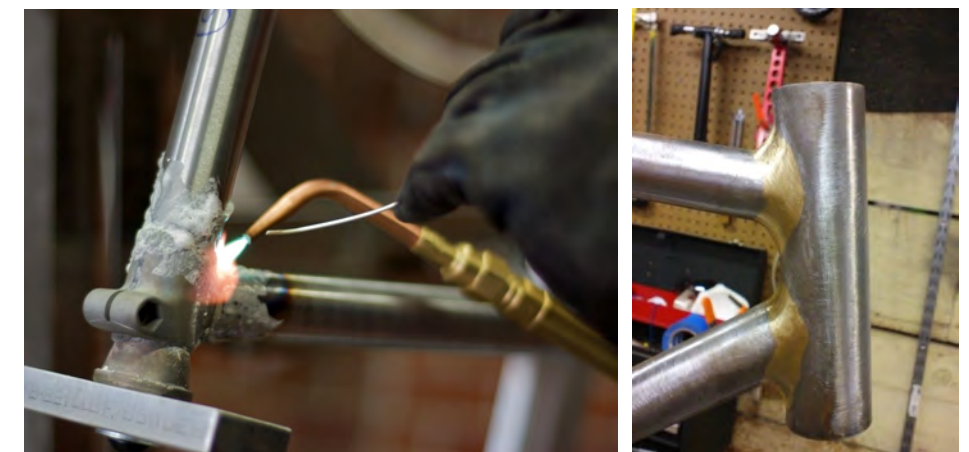
Disadvantages

- Requires a high degree of cleanliness.
- The joint colour is often different from that of the base metal, creating an aesthetic disadvantage. Although this can be changed or the materials painted.
- Not as strong as a welded joint.

The stainless steel **Alessi Bombe Milk Jug** was designed by Carlo Alessi in 1945 and is still in production today. Brazing is used to join the spout and handle. Brazing is used to maintain the integrity of the original design.

An overlap has been created between the spout and body to maximize the surface area being joined.

The wok is done in a jig and the whole process lasts about 30 seconds. Very little finishing is required, the brazed part is removed from the jig and lightly polished.



Brazed bicycle parts.

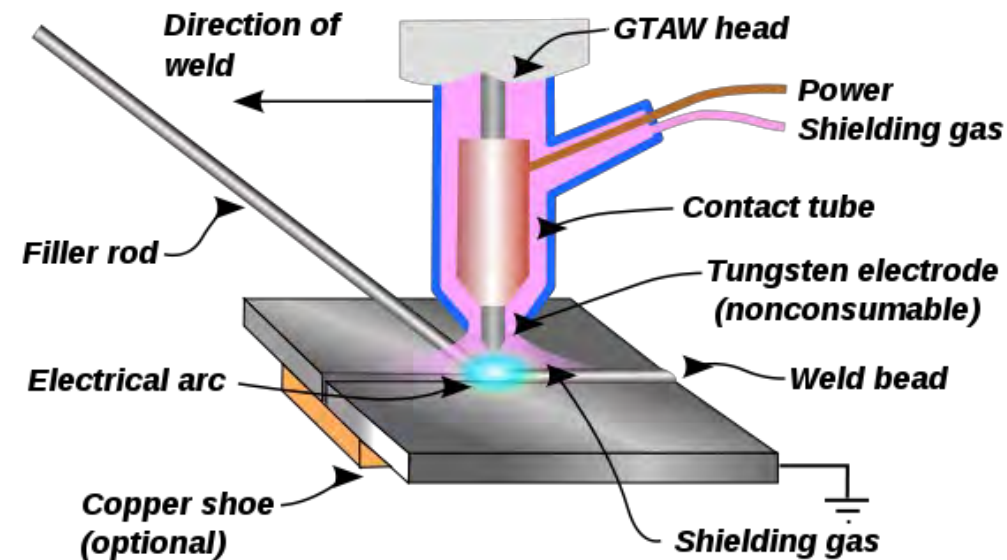
TIG (Tungsten Inert Gas) Welding

A precise and high quality form of electric arc welding that uses a non-consumable tungsten electrode.

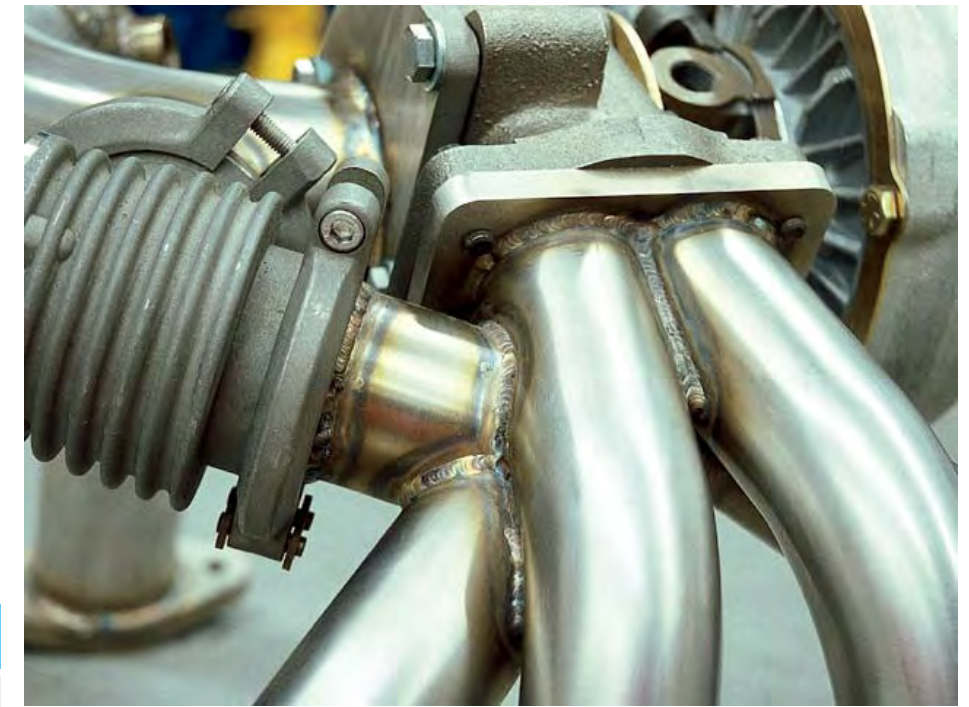
Image



Diagram



Example Products



Step by step

- TIG generates heat via an arc of electricity jumping from a (tungsten metal) electrode to the metal surfaces you intend to weld .
- The heat is sufficient to melt the joint edges.
- The electrode is coated in flux which when melted, prevents the joint becoming oxidised.

Advantages

- Using Tungsten to provide its electrical current, TIG welding decreases the amount of sparks, smoke and fumes produced.
- TIG welding has less contamination in its weld, providing more precise and higher quality welds.
- No tooling costs.

Disadvantages

- TIG welding requires more setup time than MIG welding and is not as user-friendly.
- TIG welds tend to be more expensive and take longer than MIG welding, especially in thicker metals.
- TIG welding is more complex and requires more skill than the MIG welding process.

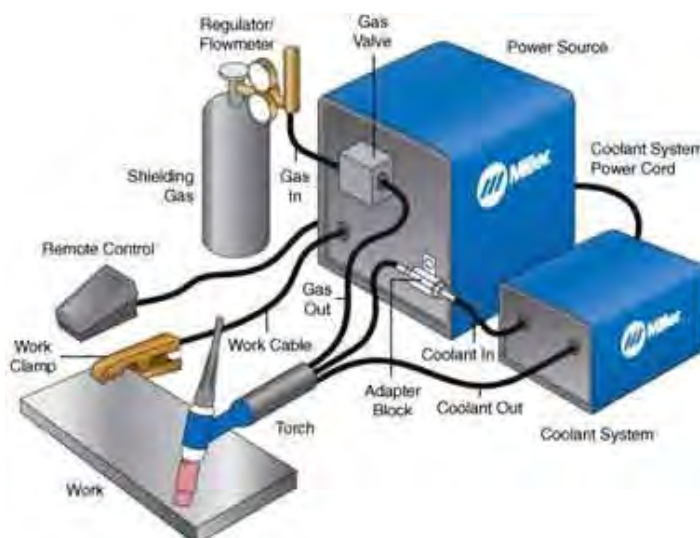
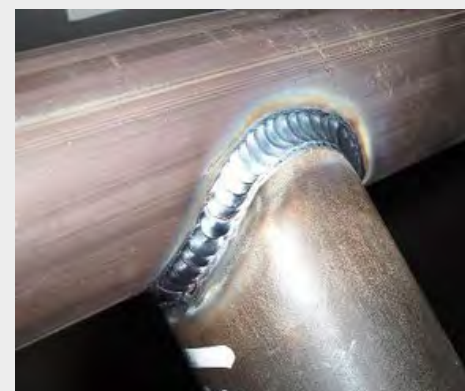
Materials used in this process

TIG is widely used on:

- Carbon Steel
- Stainless Steel
- Aluminum.

It is the main process for joining

- Titanium.





WJEC Level 1/2 Vocational award in Engineering

- Unit 3: Solving Engineering Problems (80 Marks - 40% of grade)

Unit 3: Solving Engineering Problems

Vocational context

Understanding engineering materials and processes is key to understanding the core principle of Engineering, and fundamental to an engineer's role is finding functional solutions to problems and demands. However, many areas in Engineering are fast evolving, and developments in materials, processes and technologies are constantly re-shaping the sector. This unit considers both the steadfast central tenets of modern Engineering, whilst exploring the impact of engineering developments and achievements in the home and in society in general.

Overview of unit

This unit introduces learners to how engineering design is impacted by a range of external considerations such as the properties of materials, both traditional and smart developing materials, as well as methods of manufacturing in both the traditional and new and emerging technologies. The unit also gives the learner the opportunity to explore how engineering achievements have had an impact on modern day life at home, work and in society in general. Finally, the unit allows learners to develop understanding and skills to assist them in the solving of engineering problems.

3.1 Understanding the effects of engineering achievements

Knowledge
needed

In this section learners will gain knowledge and understanding of engineering developments relevant to:

3.1.1 describing engineering developments

3.1.2 explaining the effects of engineering achievements

3.1.3 explaining how environmental issues affect engineering applications.

- Students should understand how the design has developed in response to varied ergonomic needs.
- Students should understand how electronic/ technological developments have advanced engineering capabilities/ functionalities.
- Students should understand engineering effects on the environment and how these can be controlled.

3.1.1 Describing engineering developments

Learners should know and understand how engineering developments have an impact on the design of products and structures. These include developments in:

- structural design, focusing on the development of bicycles
- mechanical design, focusing on the development of theme park rides
- electronic design, focusing on the development of mobile phone/smart technology.

- Students should be aware of what initiated the developments, how the developments happened and what improved capabilities have resulted.
- Students should understand how the developments have affected the user and how the functionalities have changed.
- Students should understand the power sources and advancements in this to affect the user experience.

a) structural design, focusing on the development of bicycles

Background information



Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life

b) mechanical design, focusing on the development of theme park rides

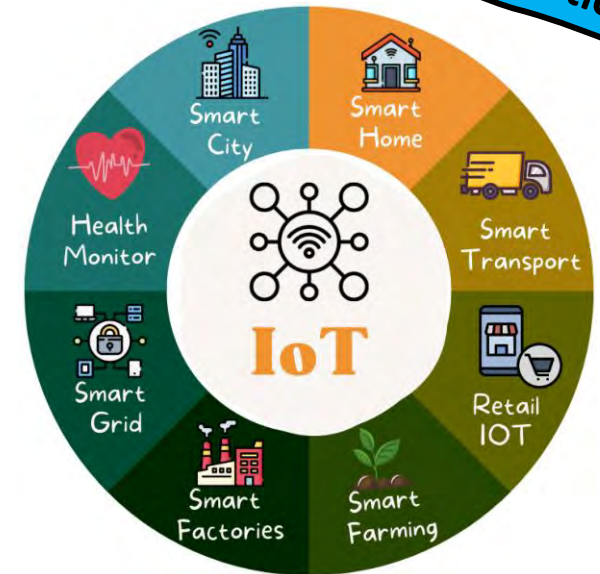
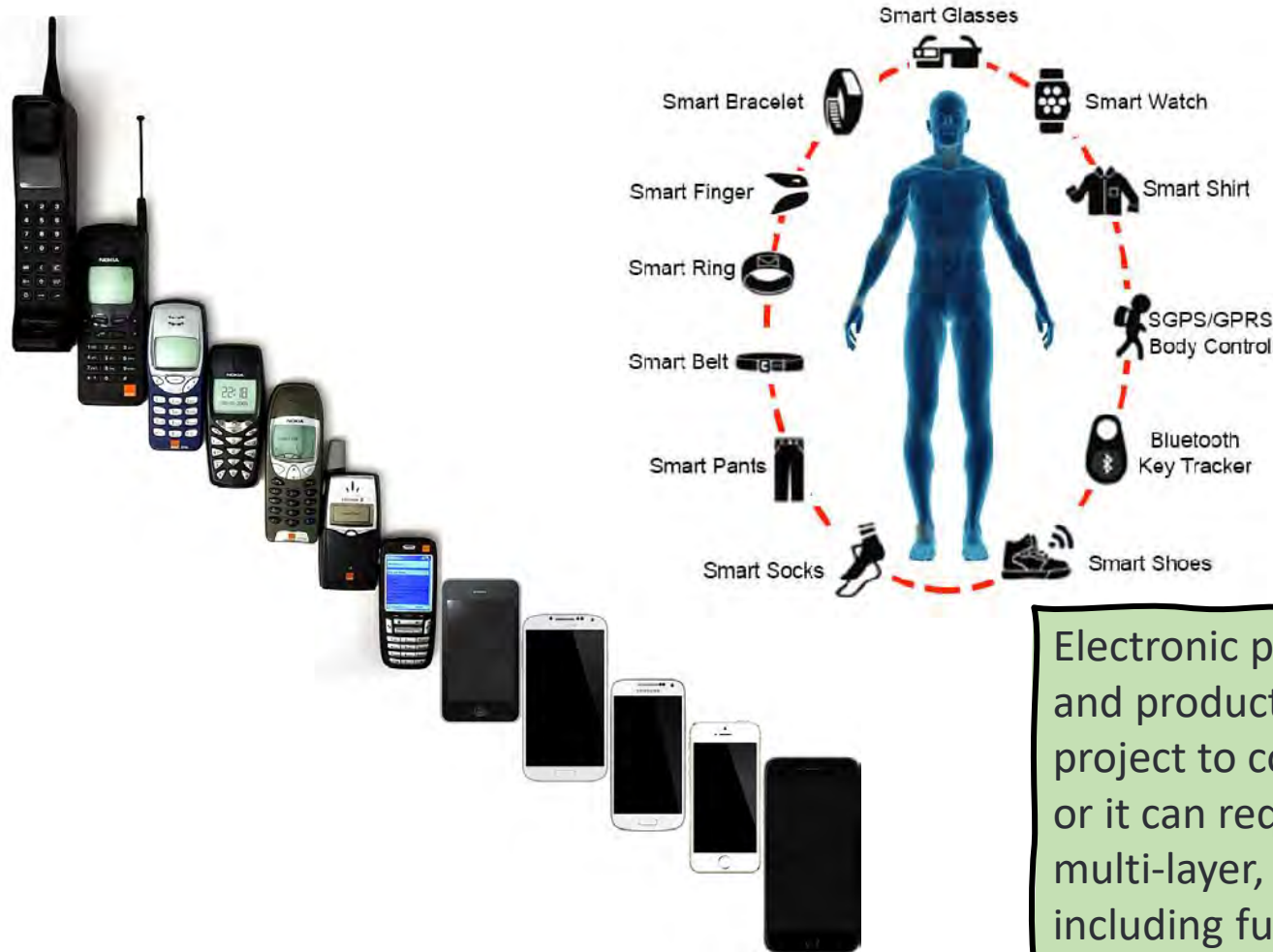
Background information



Mechanical design is the process of designing components, parts, products, and systems that are inherently mechanical in nature. Any type of **machinery** or any product that has complex parts requires some form of mechanical design. Mechanical design techniques are used to produce objects such as **gears**, clutches, shafts, and fasteners.

c) electronic design, focusing on the development of mobile phone/smart technology.

Background information



Electronic product design involves the design, development and production of the electronic hardware that allows your project to come to life. It can involve just basic control circuitry or it can require the management and delivery of complete multi-layer, multi-board projects from beginning to end, including fully assembled and tested production quantities.

3.1.1 Describing engineering developments

Learning Intent

- To understand the engineering developments and reasons for these.

Success Criteria

- **Level 2 Distinction:** Analyse engineering developments with understanding of the impacts on the user.
- **Level 2 Merit:** Describe engineering developments with understanding of the impacts on the user.
- **Level 2 Pass:** Identify engineering developments with understanding of the impacts on the user.

Lesson tasks:

Do it now task: What did you use your first mobile phone for? What else could this do?

Task 1: What is structural engineering? Describe how the development of gears affected the structure of a bike? Explain how the materials used in bike manufacture affect the structural capabilities. Analyse how the bike structure changes based on its use.

Task 2: What is mechanical engineering? Describe how the materials used for theme park rides affect the mechanical engineering. Explain how gears, pulleys and levers are used in rollercoaster rides. Analyse how rollercoaster design has developed in response to user demand.

Task 3: What is electrical engineering? Describe the electronic components of a mobile phone and how these affect the functions? Explain how the mobile phone design has changed due to developments of electronic components. Analyse how the functionality of mobile phones has changed due to developments of electronic components.

Stretch and challenge: How can modern technologies/ smart materials be used in the products discussed? What effect will this have on the manufacture process and the outcomes demonstrated?

3.1.1 Describing engineering developments

Task 1: What is structural engineering?

Describe how the development of gears affected the structure of a bike?

Explain how the materials used in bike manufacture affect the structural capabilities.

Analyse how the bike structure changes based on its use.

Task 2: What is mechanical engineering?

Describe how the materials used for theme park rides affect the mechanical engineering.

Explain how gears, pulleys and levers are used in rollercoaster rides.

Analyse how rollercoaster design has developed in response to user demand.

Task 3: What is electrical engineering?

Describe the electronic components of a mobile phone and how these affect the functions?

Explain how the mobile phone design has changed due to developments of electronic components.

Analyse how the functionality of mobile phones has changed due to developments of electronic components.

Support area:

Task 1: Consider the circumference of the wheel, the rotations of the wheel vs the rotation of the gear. What are the properties of materials used in bike manufacture? Consider limitations and costs for steel, aluminium, wood and carbon fibre. Consider aerodynamics for the final question.

Task 2: What are the functional limitations of wood vs steel. How can a rollercoaster pull against gravity. Consider hydraulics, gears, pulleys and levers and the effects on movements. Variations have happened from rotational movement, vertical movement and inversion (turning upside down)

Task 3: How have the electronic components changed due to battery size/ capabilities/ screen materials/ charging source etc. How has the development of GPS or mobile data allowing internet connection affected the functions. What apps are produced and how do these link to the changes in use of the mobile phone.

Stretch & Challenge: How can modern technologies/ smart materials be used in the products discussed? What effect will this have on the manufacture process and the outcomes demonstrated?

3.1.2 Explaining the effects of engineering achievements

Knowledge
needed

Learners should know and understand how the development of engineering products are impacted by changes in:

- Materials
- smart technologies, including:
 - voice activated
 - Bluetooth
 - Wi-Fi
- electronic and micro-electronic components and have affected modern life, including:
 - in the home
 - in society.

Materials for engineered products are chosen due to their physical and functional properties. This can include strength, electrical or thermal conductivity, hardness, transparency, elasticity or brittleness.

Smart technologies have developed in response to engineering developments. This has included engineered products such as phones and google/ Amazon Alexa devices which are voice activated and rely on Bluetooth/ Wi-Fi capabilities.

Devices such as hive energy which can control plug sockets and heating through mobile apps has changed functionalities in our home. In society there is increased demand for Wi-Fi connectivity and the use of resistors/ smaller components allows greater range of functionality.

3.1.2 Explaining the effects of engineering achievements

Lesson Tasks

Learning Intent

- To understand the effects of engineering achievements.

Success Criteria

- **Level 2 Distinction:** Analyse the effects of engineering achievements.
- **Level 2 Merit:** Describe the effects of engineering achievements.
- **Level 2 Pass:** Identify the effects of engineering achievements.

Lesson tasks:

- **Do it now task**

List the different electronic components you can think of.

- **Task 1**

Identify different smart materials used in engineering and their uses.

- **Task 2**

Describe how engineering achievements have affected society and interaction of people in communities.

- **Task 3**

Analyse how electronic components have affected the development of engineered products.

Stretch and challenge:

Explain how changes in engineering has affected how houses are designed. Consider materials, energy efficiency, population and climate change.

3.1.2 Explaining the effects of engineering achievements

Background information

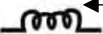
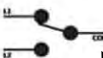
A transistor is a semiconductor device used to amplify or switch electrical signals and power. It is composed of semiconductor material, usually with at least three terminals for connection to an electronic circuit.

a semiconductor device with two terminals, typically allowing the flow of current in one direction only.

a light-emitting diode (a semiconductor diode which glows when a voltage is applied)

An amplifier is an electronic device that can increase the magnitude of a signal

A battery is a source of electric power consisting of one or more electrochemical cells with external connections for powering electrical devices. When a battery is supplying power, its positive terminal is the cathode and its negative terminal is the anode.

ACTIVE			PASSIVE		
Transistor			Resistor		
Diode			LDR		
LED			Thermistor		
Photodiode			Capacitor		
Integrated Circuit		-	Inductor		
Operational Amplifier			Switch		
Seven Segment Display			Variable Resistor		
Battery			Transformer		

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines

A capacitor is an electronic device that stores electrical energy in an electric field by accumulating electric charges on two closely spaced surfaces that are insulated from each other. It is a passive electronic component with two terminals.

An inductor, also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it. An inductor typically consists of an insulated wire wound into a coil.

In electrical engineering, a switch is an electrical component that can disconnect or connect the conducting path in an electrical circuit, interrupting the electric current or diverting it from one conductor to another

3.1.2 Explaining the effects of engineering achievements

Lesson
Worksheet

Task 1: Identify different smart materials used in engineering and their uses.

Task 2: Describe how engineering achievements have affected society and interaction of people in communities.

Task 3: Analyse how electronic components have affected the development of engineered products.

Stretch & Challenge: Explain how changes in engineering has affected how houses are designed. Consider materials, energy efficiency, population and climate change.

3.1.3 Explaining how environmental issues affect engineering applications

Knowledge
needed

Learners should know and understand how the manufacture and use of engineered products have an environmental impact in terms of:

- materials development
- costs
- transportation
- their use
- their disposal
- recycling
- sustainability.

Learners should know and understand how environmental issues affect:

- engineering processes
- engineering products.

- Engineers will need to be aware of environmental issues as part of their sustainability policies, to develop a positive brand image and to ensure continuous demand in their products. The environmental issues could be in terms of the energy usage or generation or the product disposal.
- Engineers may also need to be aware of environmental issues in the cost of manufacture and the source of materials including transportation costs to the product manufacture.
- Engineers need to consider how component parts can be disposed of and the essential properties of these parts to ensure that the 6R's can be applied appropriately.

3.1.3 Explaining how environmental issues affect engineering applications

Lesson Tasks

Learning Intent

To understand the environmental issues affect engineering applications

Success Criteria

- **Level 2 Distinction:** Analyse environmental issues affect engineering applications.
- **Level 2 Merit:** Describe environmental issues affect engineering applications.
- **Level 2 Pass:** Identify environmental issues affect engineering applications.

Lesson tasks:

- **Do it now task**

How can engineers be aware of environmental issues?

- **Task 1**

Identify different types of environmentally sustainable power source

- **Task 2**

Describe how each of these types of power generate energy

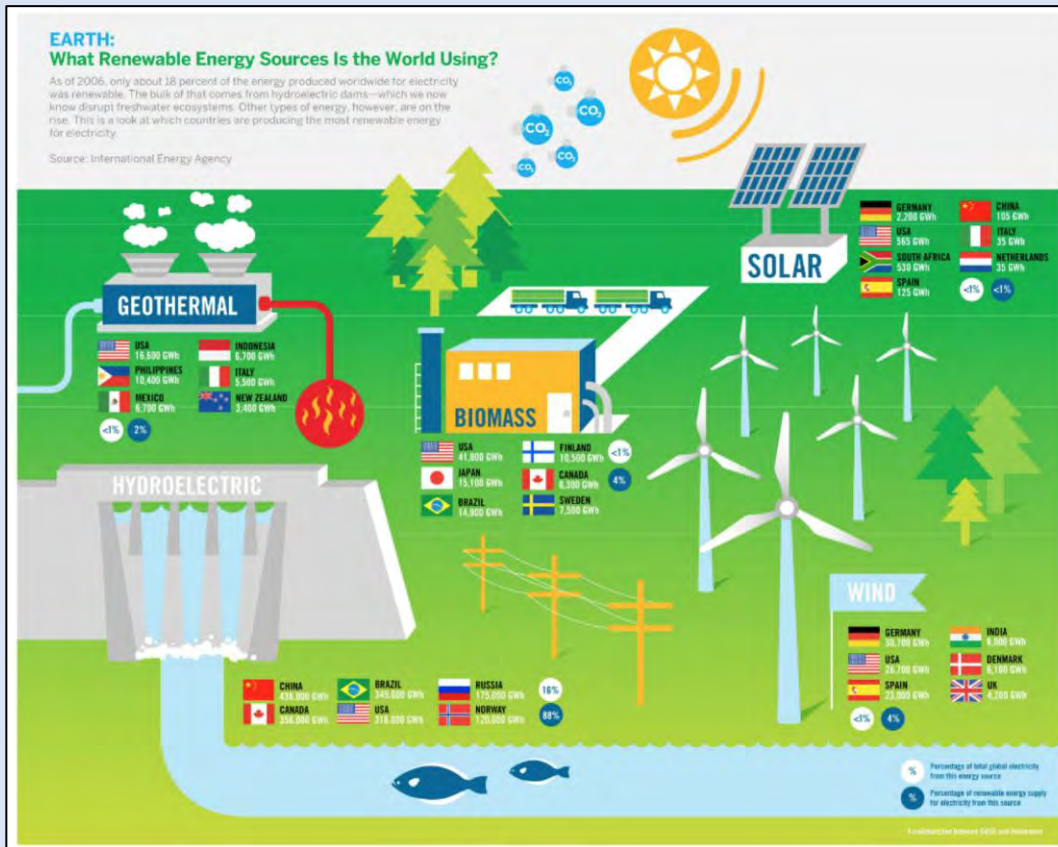
- **Task 3**

Explain advantages and disadvantages of each type of energy generation.

Stretch and challenge:

Analyse the 6R's in Engineering and how this affects manufacturers and users.

3.1.3 Explaining how environmental issues affect engineering applications

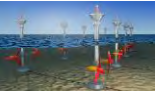
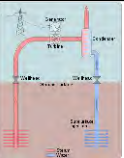


Background information



3.1.3 Explaining how environmental issues affect engineering applications

Lesson Worksheet

	Identify the different types of power	Describe how energy is created.	Explain the effect (positives and negatives)
TIDAL POWER			
SOLAR POWER			
NUCLEAR POWER			
WIND POWER			
GEO THERMAL POWER			
HYDROELECTRIC POWER			
FOSSIL FUEL POWER STATION			

Tidal power is where the waves in the sea turn turbines. The energy will be generated by these turbines turning and stored in batteries.

Tidal power is a renewable energy which does not damage the environment through producing damaging carbon monoxide. It is however very expensive to set up and can only be in parts of the world where there is a strong tidal current. It is also limited in the amount of energy that can be stored in these batteries.

Task 1: Identify different types of environmentally sustainable power source.

Task 2: Describe how each of these types of power generate energy

Task 3: Explain advantages and disadvantages of each type of energy generation.

Stretch & Challenge: Analyse the 6R's in Engineering and how this affects manufacturers and users.

3.2 Understanding properties of engineering materials

Knowledge
needed

In this section, learners will develop knowledge and understanding of the properties of materials and how they react in different situations:

3.2.1 understanding materials, their properties, and their selections for specific purposes

3.2.2 describing properties required of materials for engineering products

3.2.3 explaining how materials are tested for properties

- Students should be aware of a range of properties of materials including definitions and examples of where this is shown.
- Properties should be identified as chemical, physical or electrical with reference to the engineering examples.
- Properties of components need to be linked to the primary and secondary functions of engineered products.

3.2.1 Understanding materials, their properties, and their selection for specific purposes

Knowledge
needed

Learners should know and understand the following materials and their properties, and when they should be used for a specific purpose.

- Ferrous, e.g. mild steel, stainless steel, tool steel
- non-ferrous, e.g. brass, copper, aluminium
- thermoplastics, e.g. acrylic, nylon, HIPS
- thermosetting plastics, e.g. urea formaldehyde, silicon
- smart, e.g. thermochromic pigments/inks, shape memory alloy, nitinol wire
- composite, e.g. carbon fibre, Kevlar.

Ferrous metal – a metal which contains iron (it will therefore rust and be magnetic)

Non-ferrous metal – a metal which does not contain iron (it will therefore not rust and be non-magnetic)

Thermoplastics – these soften on heating and harden on cooling

Thermosetting plastics – these remain rigid (do not soften) on heating.

Smart materials – responsive materials which are designed to be significantly changed on an action.

Composite materials – a material made from two or more materials with different properties to create a material with specified properties e.g. become stronger.

3.2.1 Understanding materials, their properties, and their selection for specific purposes

Lesson Tasks

Learning Intent

- To understand the range of properties of engineered materials.

Success Criteria

- **Level 2 Distinction:** Analyse the range of properties of engineered materials.
- **Level 2 Merit:** Describe the range of properties of engineered materials.
- **Level 2 Pass:** Identify the range of properties of engineered materials.

Lesson tasks:

- **Do it now task**

What are the properties of the desk you are sat at? How do the properties link to the function?

- **Task 1**

Identify different properties of engineered materials

- **Task 2**

Describe how these properties relate to the functions of engineered products.

- **Task 3**

Explain how the properties link to the functions of engineered materials.

Stretch and challenge:

Analyse how smart materials have developed in the past 10 years in relation to engineering achievements and the functional properties.

3.2.1 Understanding materials, their properties, and their selection for specific purposes

Background information

IET Education The Institution of Engineering and Technology | Faraday

Materials and their properties

Camping holidays can be really fun... as long as you keep warm and dry!

The materials used to make each part of a tent are carefully chosen so the tent does its job properly.



Tent Poles

Poles hold the tent up - they need to be:

- Flexible, so they can bend without snapping.
- Light - for making carrying the tent easier.

Carbon fibre composite is a good material choice.

Guy Ropes

The ropes keep the tent upright so it doesn't collapse - they need to be:

- Strong.
- Not prone to shrinking or stretching.

Canvas

The material has to be:

- Waterproof but breathable, so air can get in but rain can't.
- Opaque, so people outside can't see in.

A polymer, such as nylon or polyester would be a good choice of material.

Pegs

The pegs will be pushed into the ground - they need to be:

- Hard.
- Rust-proof.

Suitable materials would be metals like stainless steel or aluminium.



3.2.1 Understanding materials, their properties, and their selection for specific purposes

Lesson
Worksheet

Task 1: Identify different properties of engineered materials

Task 2: Describe how these properties relate to the functions of engineered products.

Task 3: Explain how the properties link to the functions of engineered materials.

Stretch & Challenge: Analyse how smart materials have developed in the past 10 years in relation to engineering achievements and the functional properties.

3.2.2 Describe properties required of materials for engineering products

Knowledge
needed

Learners should know and understand the physical properties of materials, including their:

- tensile strength
- compressive strength
- hardness
- toughness
- malleability
- ductility
- conductivity
- corrosive resistance
- environmental degradation
- Elasticity
- ... and how they can be applied in an engineering context.

Learners should know and understand the properties needed for the following engineering products:

- mobile phones
- security alarm found in the home
- Bicycles
- children's play areas.

- **Tensile strength** - Tensile strength is the maximum stress that a material can withstand while being stretched or pulled before breaking.
- **Compressive strength** - Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size
- **Hardness** - a measure of the resistance to localized deformation, such as an indentation (over an area) or a scratch (linear), induced mechanically either by pressing or abrasion
- **Toughness** - the ability of a material to absorb energy and plastically deform without fracturing
- **Malleability** – . the property of a material to deform under compression and take on a new shape without breaking or cracking.
- **Ductility** - a mechanical property that describes how readily a material can be drawn into a wire and sustain plastic deformation without failure
- **Conductivity** – relates to the transfer of energy throughout a material and is measured in different ways, such as electrolytic conductivity, thermal conductivity, and electrical conductivity
- **Corrosive resistance** - the ability of a material to withstand corrosion damage caused by either oxidation or other chemical reactions
- **Environmental degradation** - any change or disturbance to the environment perceived to be deleterious or undesirable.
- **Elasticity** - the ability of a material to return to its original shape and size after being deformed by an external force

3.2.2 Describe properties required of materials for engineering products

Lesson Tasks

Learning Intent

- To understand the engineering properties of a range of products.

Success Criteria

- **Level 2 Distinction:** Analyse the engineering properties and functions of a range of engineered products.
- **Level 2 Merit:** Describe the engineering properties and functions of a range of engineered products.
- **Level 2 Pass:** Identify the engineering properties and functions of a range of engineered products.

Lesson tasks:

- **Do it now task**

What are the properties of the desk in front of you and how does this relate to the functions?

- **Task 1**

Identify the properties of a range of engineered products

- **Task 2**

Describe how the properties link to the functions of a range of engineered products.

- **Task 3**

Explain how the properties are linked to user requirements.

Stretch and challenge: What further properties are there of the given engineered products?

3.2.2 Describe properties required of materials for engineering products – Mobile phone

Background information

Task: Can you explain the materials used and the properties required for the component parts of mobile phones?

Rigidity of case



Why does the case need to be rigid?
What are the range of properties?

Transparency of screen



Why is this important? How does this link to the other component parts?

Conductivity of electronic parts



What are the different component parts and their functions?

Charging of battery



How has this developed? What are the different materials used and why?

Rigidity of printed circuit board (PCB)



Why is a PCB used? What effect does solder have on the properties?

Stretch and challenge: Can you think of any further component parts and property requirements?

3.2.2 Describe properties required of materials for engineering products – home security alarm

Background information

Task: Can you explain the materials used and the properties required for the component parts of a home security alarm?

Water resistant



Why does the case need to be water resistant?

Tough



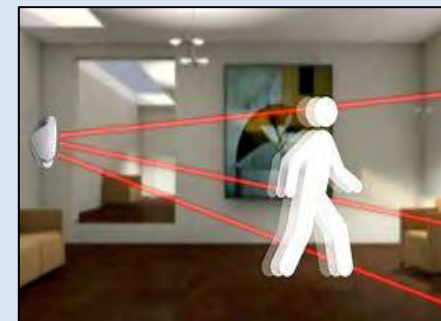
Why is this important? How does this link to the other component parts?

Conductivity of electronic parts



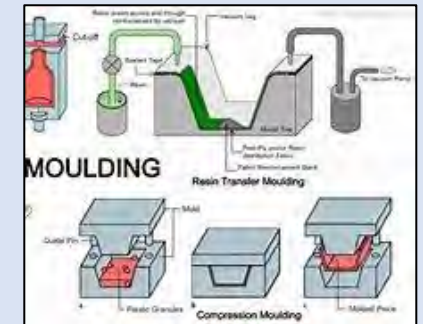
What are the different component parts and their functions?

Transmitter microwave energy



Why are the sensors required to transmit microwave energy? What other energy could be used?

Mouldable



Why are the different component parts needed to be mouldable?

Stretch and challenge: Can you think of any further component parts and property requirements?

3.2.2 Describe properties required of materials for engineering products - bicycles

Background information

Task: Can you explain the materials used and the properties required for the component parts of bicycles?

Compression of
tyres



How does the wheel
component parts
adapt to the surface?

Rigidity on frame



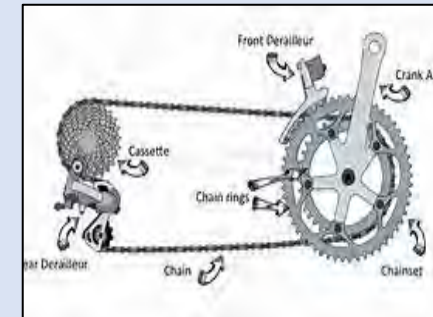
What pressures are
on the different
component parts of
the bike?

Weather resistance
on whole bike



How are the
component parts
affected by water?
What finishing is
applied to effect this?

Gearing
mechanisms



What are constraints/
maintenance
requirements due to
component part
properties?

Tensile strength
of brake cable



Why is this
property important
for the lifecycle of
this equipment?

Stretch and challenge: Can you think of any component parts and property requirements?

3.2.2 Describe properties required of materials for engineering products – children's play areas

Background
information

Task: Can you explain the materials used and the properties required for the component parts of playground equipment?

Flooring to play equipment



Why rubber matting made from recycled car tyres?

Structure to climbing frames



Why are finishes/treatments applied to the wood before installation?

Hinge movement on swings



What joining methods are used? How do these affect functions?

Rotational movement on roundabouts



What are constraints/maintenance requirements due to component part properties?

Tensile strength of ziplines



Why is this property important for the lifecycle of this equipment?

Stretch and challenge: Can you think of any further equipment/ property requirements?

3.2.3 Explaining how materials are tested for properties

Knowledge
needed

Learners should know and understand how destructive testing (DT) and non-destructive testing (NDT) is undertaken to determine physical properties of engineering materials, including:

- Tensile strength
- Hardness
- Toughness
- Malleability
- Ductility
- Conductivity
- Elasticity.

- Destructive testing is where the product is tested beyond its limits and a change is made which makes the product unusable e.g. vehicle crash testing, measuring the weight limits on a shelf/ bridge.
- Non-destructive testing is where the capabilities of a product are measured without affecting the future function of the product e.g. monitoring the functionality of a hinge, the temperature of a fridge, the decibel output of a speaker etc.

3.2.3 Explaining how materials are tested for properties

Lesson Tasks

Learning Intent

- To understand the properties of materials and how these are tested.

Success Criteria

- **Level 2 Distinction:** Analyse properties of materials and how these are tested.
- **Level 2 Merit:** Describe properties of materials and how these are tested.
- **Level 2 Pass:** Identify properties of materials and how these are tested.

Lesson tasks:

- **Do it now task**

What are different properties of materials used in engineering?

- **Task 1**

Identify definitions of different properties of engineered materials.

- **Task 2**

Describe the difference between destructive (DT) and non-destructive testing (NDT) in engineering with examples.

- **Task 3**

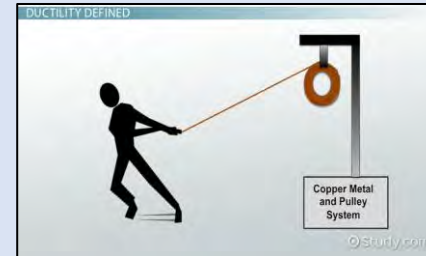
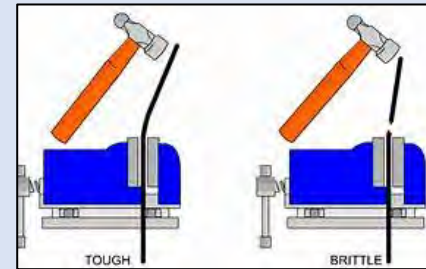
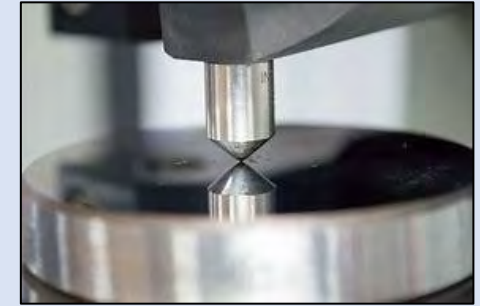
Explain examples of different DT and NDT to analyse specific properties of engineered materials.

Stretch and challenge: Analyse the importance of destructive and non-destructive testing from the viewpoints of the consumer and the manufacturer.

3.2.3 Explaining how materials are tested for properties

Background
information

- Tensile strength - the resistance of a material to breaking under tension
- Hardness – the ability to withstand surface indentation or scratching
- Toughness - the state of being strong enough to withstand adverse conditions or rough handling
- Malleability - able to be hammered or pressed into shape without breaking or cracking
- Ductility – ability to be drawn into a thin wire without losing toughness
- Conductivity – the rate at which heat/ electricity passes through a specified material
- Elasticity - the ability of an object or material to resume its normal shape after being stretched or compressed



3.2.3 Explaining how materials are tested for properties

Lesson
Worksheet

Task 1: Identify definitions of different properties of engineered materials.

Task 2: Describe the difference between destructive (DT) and non-destructive testing (NDT) in engineering with examples.

Task 3: Explain examples of different DT and NDT to analyse specific properties of engineered materials.

Stretch and challenge: Analyse the importance of destructive and non-destructive testing from the viewpoints of the consumer and the manufacturer.

3.3 Understanding methods of preparation, forming, joining and finishing of engineering materials

Knowledge
needed

In this section, learners will gain knowledge, understanding and skills in preparing, using and finishing materials. Learners will also gain knowledge and understanding in engineering processes and machining, in relation to:

3.3.1 describing engineering processes

3.3.2 describing applications of engineering processes

3.3.3 safe working practices.

- Students should be aware of how different machinery is used within the engineering workshop and the process which is completed on each.
- Students should be aware of where these processes are shown in the manufacture of engineered products and the advantages/ disadvantages of the use of each.
- Students should be aware of how machinery is used safely with appropriate PPE guidelines.

3.3.1 Describing engineering processes

Learners should understand processes, including relevant tools and equipment, used to produce engineering products including:

- Marking out
- Cutting
- Finishing
- Preparing
- Shaping
- Drilling
- Turning
- Brazing
- Joining – permanent and temporary fixings
- Filing
- Soldering.

- Marking out – engineers blue is painted onto an object, an engineers rule is used to measure and a scribe is used to mark. Measurements are checked with callipers.
- Cutting – material is sheared (cut) using a range of tools such as coping saw (cutting curves in wood/plastics), Tennon saw (straight lines in wood), hacksaw (cutting metals) scroll saw (cutting curves in wood mechanically) or band saw.
- Finishing – smoothed using various grades of abrasive paper, polished with cloths, matte finish where left as is.
- Preparing – getting material ready for use, such as cutting to manageable size or selection of appropriate tools
- Shaping – where material is shaped which could be with hammer and anvil (for metal) or with vacuum former for thermoplastics.
- Drilling – hand, power or pillar drill used with appropriate size drill bit used and depth of hole measured using calliper.
- Turning – such as on lathe where the material spins and cutting tool/ knurling tool is used to face off/ bevel edge or create indentations.
- Brazing – metal is heated and used as a filler (flux) to join two materials permanently when it cools and solidifies.
- Joining – permanent (where the join cannot be broken e.g. glue/ welding) and temporary (where the join can be removed e.g. screws) fixings
- Filing – where material to be filed is placed in a vice and then filed with an appropriate file (flat/ triangle/ round/ square etc) depending upon the desired outcome.
- Soldering – where solder is heated and creates a complete conductive circuit for electrical power of an object.

3.3.1 Describing engineering processes

Lesson Tasks

Learning Intent

- To understand the applications of a range of processes in engineering.

Success Criteria

- **Level 2 Distinction:** Analyse different processes used in engineering.
- **Level 2 Merit:** Describe different processes used in engineering.
- **Level 2 Pass:** Identify different processes used in engineering.

Lesson tasks:

- **Do it now task**

What are different processes used in engineering?

- **Task 1**

What are different processes used to shape a range of materials in engineering?

- **Task 2**

Describe different ways of joining materials and explain examples of where each may be used.

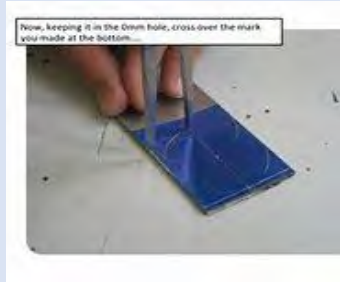
- **Task 3**

Analyse the engineering process of turning and how this is completed successfully to produce a high-quality outcome.

Stretch and challenge: Explain health and safety considerations in the completion of engineering processes.

3.3.1 Describing engineering processes

Background information



Marking out



Cutting



Polishing



Shaping



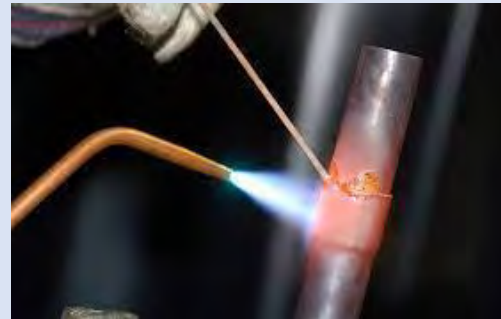
Drilling



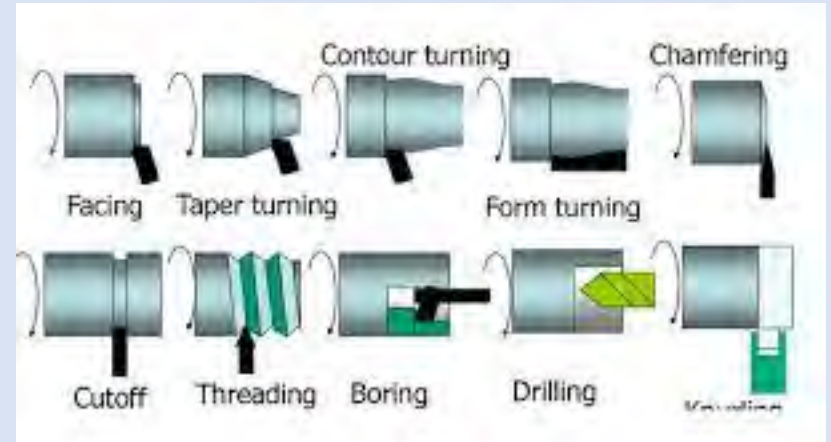
Soldering



Filing



Brazing



Turning

Health and safety – for processes using a machine then Personal Protective Equipment (PPE) should be worn including safety glasses, apron, hair tied back, material being clamped and safety guards used.

3.3.1 Describing engineering processes

Lesson
Worksheet

Task 1: What are different processes used to shape a range of materials in engineering?

Task 2: Describe different ways of joining materials and explain examples of where each may be used.

Task 3: Analyse the engineering process of turning and how this is completed successfully to produce a high-quality outcome.

Stretch & Challenge: Explain health and safety considerations in the completion of engineering processes.

3.3.2 Describing applications of engineering processes

Knowledge
needed

Learners should understand how engineering processes can be used for:

- material removal
- shaping and manipulation
- joining and assembly
- heat and chemical treatment.

- Students should understand how accurate amounts of material can be removed and produce a successful outcome.
- Students should understand how to shape metals and plastics depending upon their properties.
- Students should understand different methods of joining materials and their appropriate applications.
- Students should understand heat and chemical treatment processes and the reasons for these.

3.3.2 Describing applications of engineering processes

Lesson Tasks

Learning Intent

- To understand the applications of engineering processes.

Success Criteria

- **Level 2 Distinction:** Analyse the applications of engineering processes.
- **Level 2 Merit:** Describe the applications of engineering processes.
- **Level 2 Pass:** Identify the applications of engineering processes.

Lesson tasks:

- **Do it now task**

How can material be removed in engineering?

- **Task 1**

Discuss different methods of joining materials and there engineering applications.

- **Task 2**

Describe different methods for shaping metals and plastics in engineering.

- **Task 3**

Analyse heat treatments used for metals within engineering and evaluate why these are completed.

Stretch and challenge: Explain how material can be removed from a round aluminium bar and explain how quality assurance is checked.

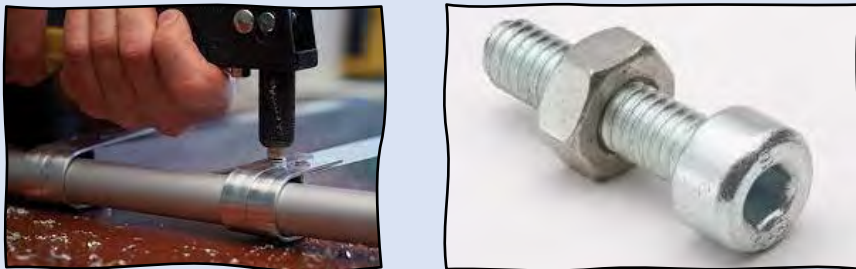
3.3.2 Describing applications of engineering processes

Background
information

Removing material – filing, grinding, sanding, turning



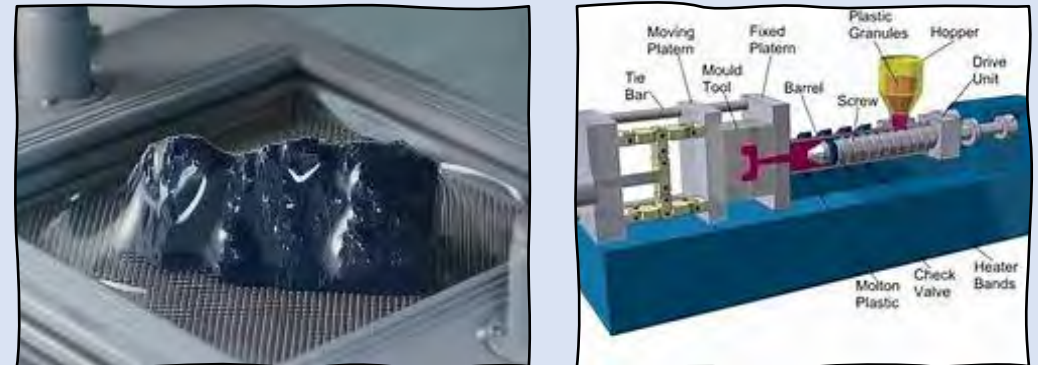
Permanent vs temporary joining methods



Heat treatment – annealing vs quenching



Shaping materials – vacuum forming vs injection moulding



3.3.2 Describing applications of engineering processes

Lesson
Worksheet

Task 1: Discuss different methods of joining materials and there engineering applications.

Task 2: Describe different methods for shaping metals and plastics in engineering.

Task 3: Analyse heat treatments used for metals within engineering and evaluate why these are completed.

Stretch & Challenge: Explain how material can be removed from a round aluminium bar and explain how quality assurance is checked.

3.3.3 Safe working practices

Learners should know and understand how to work safely when working in an engineering environment such as a school/college workshop when preparing, using and finishing materials, including by:

- carrying out a risk assessment
- identifying risks
- identifying appropriate control measures.

• Students should be able to identify

- Hazards – objects/ activities which have the potential to cause harm.
- Risk – the chance of the hazard causing injury
- Control measure – how the risk is lowered to minimise the chance of the hazard causing injury
- Risk assessment – analysis of hazards and evaluating the potential of these causing harm.

3.3.3 Safe working practices

Lesson Tasks

Learning Intent

- To understand safe working practices in the engineering workshop.

Success Criteria

- **Level 2 Distinction:** Analyse safe working practices in the engineering workshop.
- **Level 2 Merit:** Describe safe working practices in the engineering workshop.
- **Level 2 Pass:** Identify safe working practices in the engineering workshop.

Lesson tasks:

- **Do it now task**

List different health and safety issues in the workshop.

- **Task 1**

What is the difference between hazards, risks and control measures.

- **Task 2**

Describe personal protective equipment used in the engineering workshop.

- **Task 3**

Analyse risk of completing an engineering activity by completing a risk assessment.

Stretch and challenge: Discuss why engineers need to follow health and safety guidelines when completing activities in the workshop.

3.3.3 Safe working practices

Background
information

Activities which have a high likelihood of causing injury should be limited. The likelihood of injury should be minimised as much as possible. Control measures should be used whenever available.

It is an employers responsibility to provide training on the appropriate use of tools & machinery in a workshop which should be reviewed regularly. An employer should also provide personal protective equipment to minimise the risk in the workshop. The employer needs to complete a risk assessment for all activities in the workshop and these should be regularly reviewed also.

Should an accident occur, the employer should review this accident, employees should record any injury in an accident book. These may be reviewed by the **health and safety executive** should a serious accident/ injury occur.

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Critical
Almost Certain	Medium	Medium	High	Extreme	Extreme
Very Likely	Low	Medium	High	High	Extreme
Possible	Low	Medium	High	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Low	Medium

Consequence	Description of Consequence	Likelihood	Description of Likelihood
Insignificant	No treatment required	1. Rare	Will only occur in exceptional circumstances
Minor	Minor injury requiring First Aid treatment (e.g. minor cuts, bruises, bumps)	2. Unlikely	Not likely to occur within the foreseeable future, or within the project lifecycle
Moderate	Injury requiring medical treatment or lost time	3. Possible	May occur within the foreseeable future within the project lifecycle
Major	Serious injury (injuries) requiring specialist medical treatment or hospitalisation	4. Likely	Likely to occur within the foreseeable future or within the project lifecycle
Critical	Loss of life, permanent disability or multiple serious injuries	5. Almost Certain	Almost certain to occur within the foreseeable future or within the project lifecycle

Assessed Risk Level	Description of Risk Level	Actions
Low	If an incident were to occur, there would be little likelihood that an injury would result.	Undertake the activity with the existing controls in place.
Medium	If an incident were to occur, there would be some chance that an injury requiring First Aid would result.	Additional controls may be needed.
High	If an incident were to occur, it would be likely that an injury requiring medical treatment would result.	Controls will need to be in place before activity is undertaken.
Extreme	If an incident were to occur, it would be likely that a permanent, debilitating injury or death would result.	Consider alternatives to doing the activity. Significant control measures will need to be implemented to ensure safety.

3.3.3 Safe working practices

Lesson
Worksheet

Task 1: What is the difference between hazards, risks and control measures.

Task 2: Describe personal protective equipment used in the engineering workshop.

Task 3: Analyse risk of completing an engineering activity by completing a risk assessment.

Stretch & Challenge: Discuss why engineers need to follow health and safety guidelines when completing activities in the workshop.

3.4 Solving engineering problems

In this section, learners will develop knowledge and understanding of:

3.4.1 using mathematical techniques for solving engineering problems

3.4.2 understanding and producing engineering drawings.

- Students should apply knowledge of measurements, area/ volume calculations, cost per unit used, scaling and estimations to apply these principles to engineered products.
- Students should use appropriate units to record accurate information on engineered outcomes.
- Students should produce and analyse information shown from engineering drawings.

3.4.1 Using mathematical techniques for solving engineering problems

Knowledge
needed

Learners should know and understand and be able to use calculations and mathematical techniques that are required to solve engineering problems, including:

- use of formulae
- Ohms law
- mechanical advantage
- velocity ratio
- areas and volumes
- measuring using datums
- estimation (of cost/materials)
- Average
- scale (enlargement and reduction)
- units of measurement including:
 - metric (e.g. metres, millimetres)
 - imperial (e.g. feet, inches)
 - time conversion (hours, minutes & seconds)
 - graphs – histogram, bar charts, line graph, pie charts.

- Students should apply mathematical formulae to calculate information necessary for successful accurate manufacture of engineered products.
- Appropriate estimations and reasonings should be shown throughout calculations.
- Relevant units of scale should be shown throughout engineering calculations to ensure accuracy in interpretation.
- Conversions should be shown which allows the identification of different perspectives of engineered outcomes.
- A range of given formulae should be interpreted and applied to give accurate solutions to engineering problems.
- Shapes should be analysed to produce accurate area/ volume data from known formulae.

$$\text{Velocity Ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}} = \frac{Y}{X}$$

3.4.1 Using mathematical techniques for solving engineering problems

Lesson Tasks

Learning Intent

- To understand the mathematical techniques used to solve engineering problems.

Success Criteria

- **Level 2 Distinction:** Analyse mathematical techniques used to solve engineering problems.
- **Level 2 Merit:** Describe mathematical techniques used to solve engineering problems.
- **Level 2 Pass:** Identify mathematical techniques used to solve engineering problems.

Lesson tasks:

- **Do it now task**

What different calculations will engineers need to perform.

- **Task 1**

Calculate the area of different objects within the engineering workshop.

- **Task 2**

Calculate the volume of different objects within the engineering workshop.

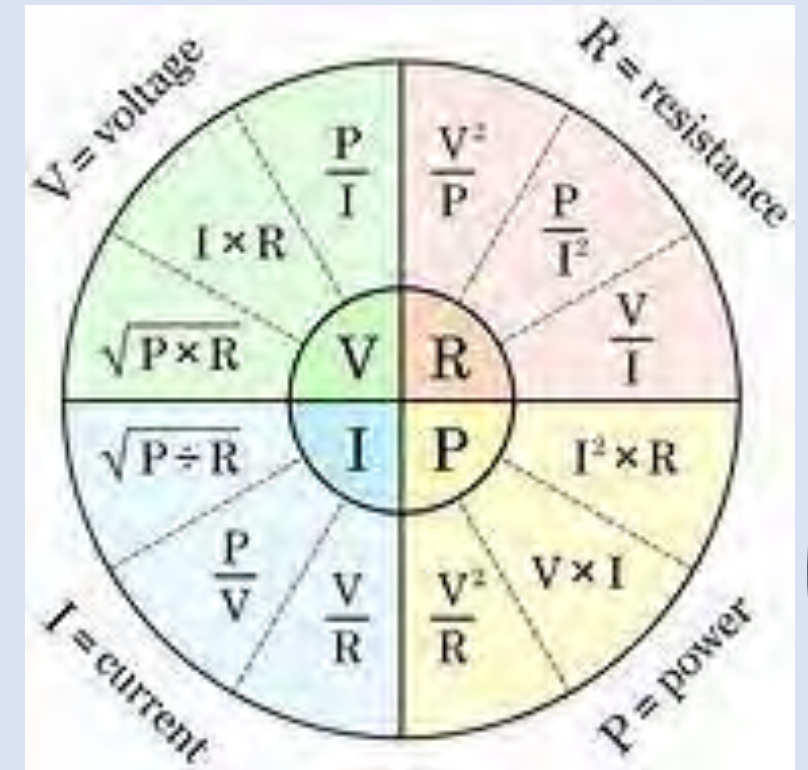
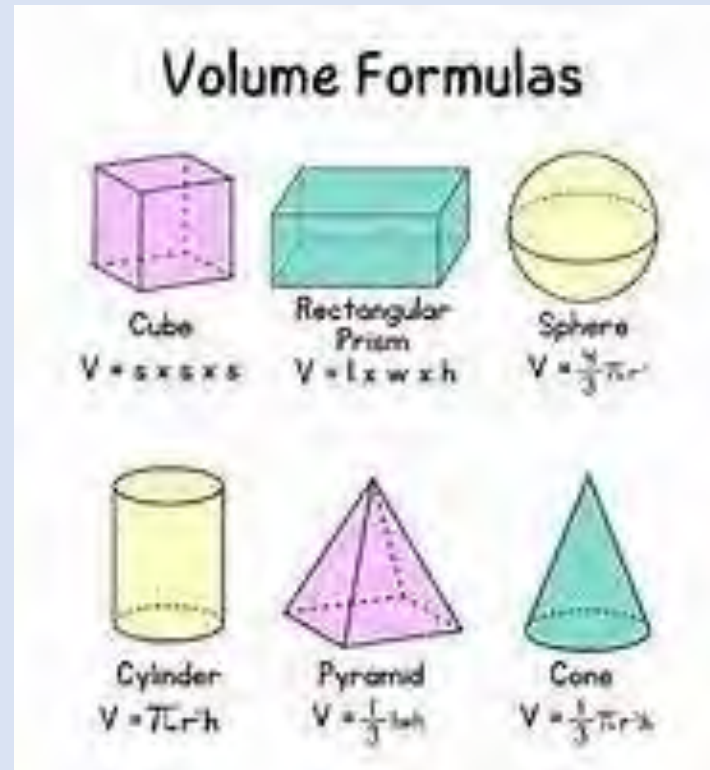
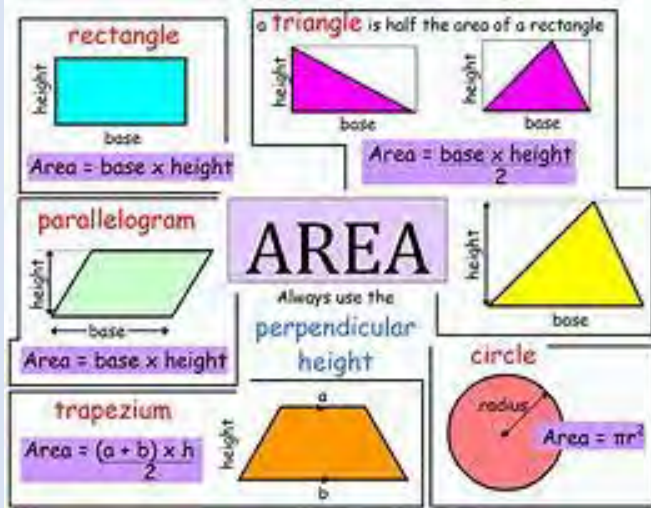
- **Task 3**

Calculate the cost of manufacture of an engineered outcome.

Stretch and challenge: Estimate how long it would take to produce an outcome in an engineering workshop and justify your response.

3.4.1 Using mathematical techniques for solving engineering problems

Background information



Time Clock Conversion Chart			
Minutes	Decimal Hours	Minutes	Decimal Hours
1	.02	10	.17
2	.03	15	.25
3	.05	20	.33
4	.07	25	.42
5	.08	30	.50

Unit Cost

$$\text{Unit Cost} = \frac{\text{Variable Cost} + \text{Fixed Cost}}{\text{Total Units Produced}}$$

Average Formula

$$\text{Average Formula} = \frac{\text{Total Sum of All Numbers}}{\text{Number of Item in the Set}}$$

3.4.1 Using mathematical techniques for solving engineering problems

Lesson
Worksheet

Task 1: Calculate the area of different objects within the engineering workshop.

Task 2: Calculate the volume of different objects within the engineering workshop.

Task 3: Calculate the cost of manufacture of an engineered outcome.

Stretch and challenge: Estimate how long it would take to produce an outcome in an engineering workshop and justify your response.

3.4.2 Understanding and producing engineering drawings

Knowledge
needed

Learners should understand the following technical details in an engineering drawing:

- section views
- construction lines
- centre lines
- hidden details
- standard conventions
- datums.

Learners should be able to interpret and produce a range of engineering drawings including:

- third-angle orthographic projections
- isometric views
- sectional views that include technical details such as:
 - dimension lines
 - sectional lines.

- Students should be able to produce an accurate outcome from engineering drawings provided.
- Students should be able to produce the drawings of objects and complete these from different viewpoints following appropriate engineering conventions.
- Students should understand how engineering drawings can be inputted as Computer Aided Designs (CAD) to produce outcomes using appropriate machinery through Computer Aided Manufacture (CAM)
- Appropriate lines should be marked following conventions to clearly demonstrate the relationship between viewpoints on engineering drawings.

3.4.2 Understanding and producing engineering drawings

Lesson Tasks

Learning Intent

- To understand the information shown on engineering drawings.

Success Criteria

- **Level 2 Distinction:** Analyse the information shown on engineering drawings.
- **Level 2 Merit:** Describe the information shown on engineering drawings.
- **Level 2 Pass:** Identify the information shown on engineering drawings.

Lesson tasks:

- **Do it now task**

What information do you need to produce an engineered product?

- **Task 1**

What information is shown on orthographic drawings?

- **Task 2**

Why would an engineer need a sectional drawing?

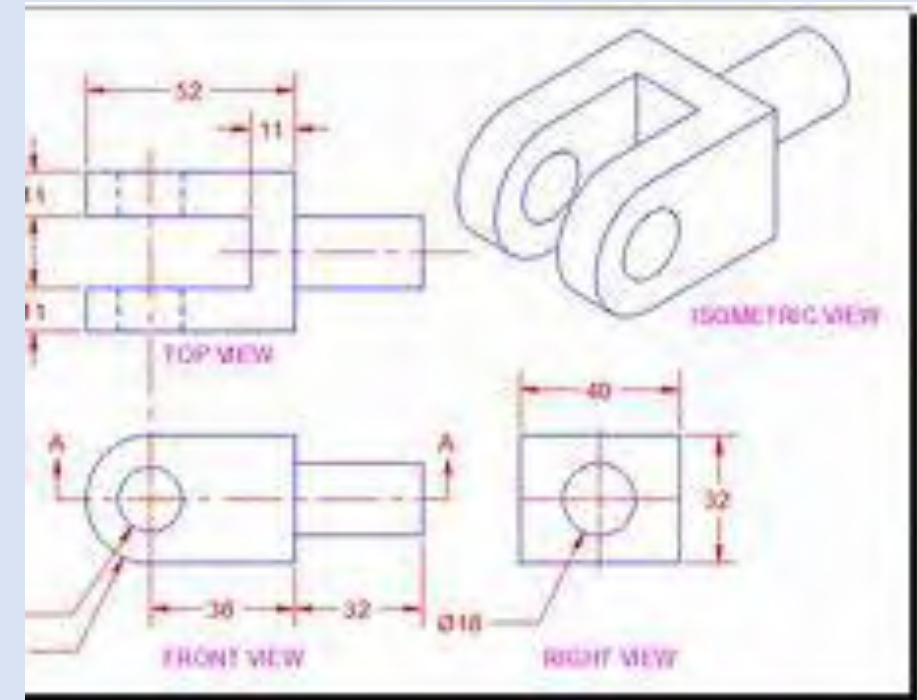
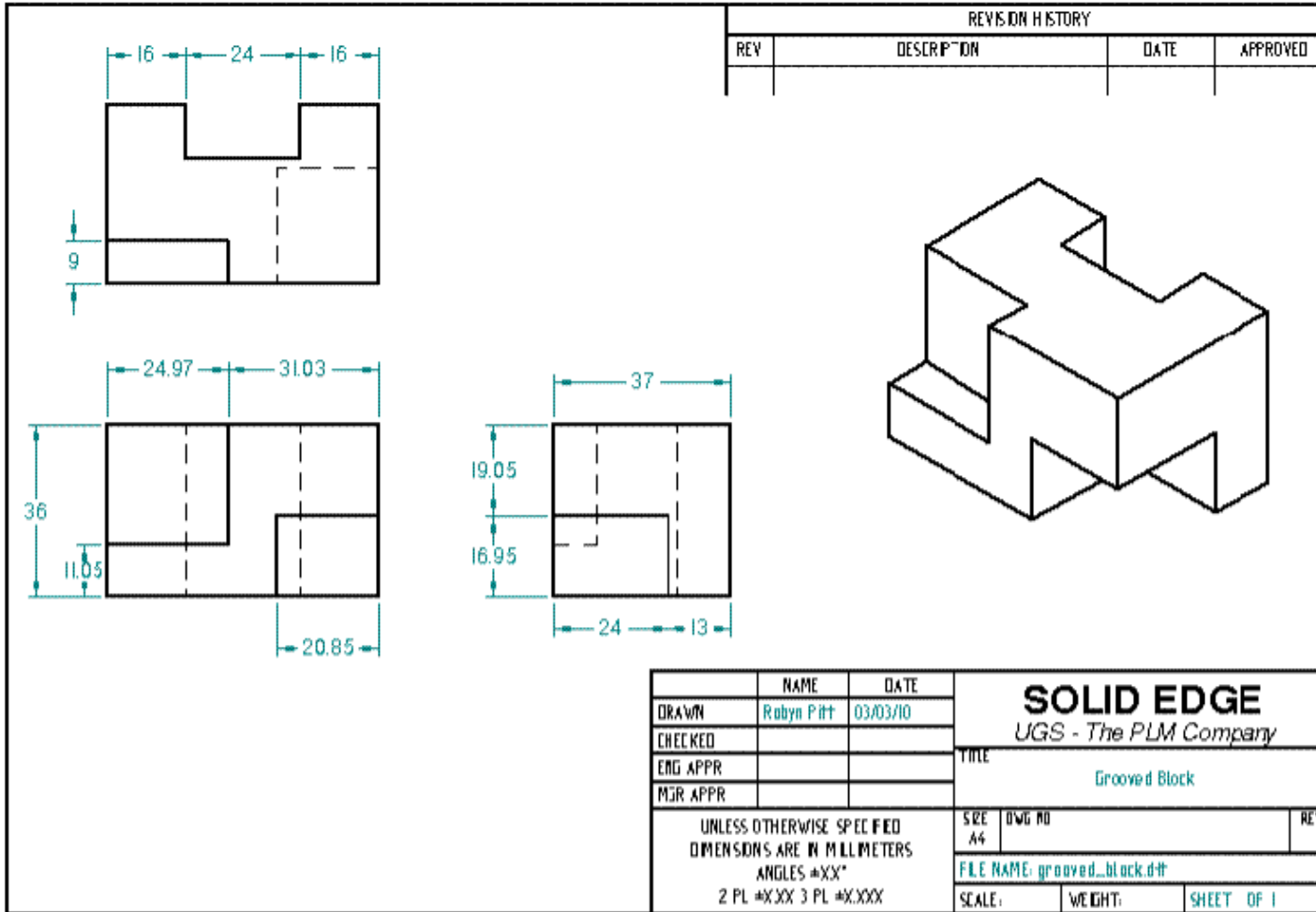
- **Task 3**

Produce an isometric and orthographic drawing for a product shown around you.

Stretch and challenge: Explain the difference between first and third angle orthographic drawings. How does this affect how hidden detail is shown on engineering drawings?

3.4.2 Understanding and producing engineering drawings

Background information



3.4.2 Understanding and producing engineering drawings

Lesson
Worksheet

Task 1: What information is shown on orthographic drawings?

Task 2: Why would an engineer need a sectional drawing?

Stretch & Challenge: Explain the difference between first and third angle orthographic drawings. How does this affect how hidden detail is shown on engineering drawings?

Task 3: Produce an isometric and orthographic drawing for a product shown around you.

1. SELECTING MATERIALS AND COMPONENTS

INTRODUCTION

Metals are important materials in our society. Found below the ground in the Earth's crust, they are commonly mined and then used in millions of products and structures that we use daily. Metals are generally materials with a good strength to weight ratio. They are split into 3 groups; Ferrous, Non-Ferrous and Alloys. Use this Learning Mate for revision and further research when completing your NEA and when preparing for your exam.

FERROUS METALS

All ferrous metals contain iron. As a result, most ferrous metals will rust when they come in contact with moisture unless they are treated. Ferrous metals are also mostly magnetic which is a useful trait when separating them from non-ferrous metals during the recycling process. Most ferrous metals are types of Steel. Steel is produced by mixing iron with other small compounds and metals to improve their working properties. For example, carbon is added to iron to improve its hardness.

CAST IRON

Properties: Hard, Brittle, Easy to Cast.
Common Uses: Kitchen pots and utensils, Machine casings, Post boxes.



WROUGHT IRON

Properties: Soft, ductile, magnetic, good tensile strength.
Common Uses: Galvanising, Heavy duty chains.



MILD STEEL

Properties: Strong, tough and durable. Easily machined.
Common Uses: Construction, Standard Components, Car bodies.



TOOL STEEL

Properties: Hard, Strong, Low Ductility
Common Uses: Garden Equipment, Workshop tools, Blades, Scissors.



STAINLESS STEEL

Properties: Hard, Very smooth, Shiny, Difficult to weld.
Common Uses: Cutlery, Kitchenware, Surgical equipment.



ALLOYS

Alloys are a mixture of 2 or more metals. One of the metals mixed must be a pure metal for it to be classed as an alloy. Alloys allow us to combine metals in order to improve their working properties and aesthetic appeal.

BRASS

Mixture: Copper 65%
Zinc 35%

Properties: Malleable and easy to cast. Easy to machine and Polishes well
Common Uses: Instruments, Plumbing, Ornaments, Fixtures and Fittings.



NON-FERROUS METALS

Non-Ferrous metals are metals which do not contain iron, are not magnetic and do not rust. Non-Ferrous metals are commonly used for their aesthetic appeal. Metals such as silver, gold and platinum are common in jewellery whereas copper is used in wiring due to its excellent conductivity.

COPPER

Properties: Flexible, Ductile, Malleable, Electrical Conductor.
Common Uses: Plumbing, Pipes, Wiring, Railway lines.



ALUMINIUM

Properties: Excellent Strength to Weight, Light, Ductile.
Common Uses: Bike frames, Sports equipment, Cans, Foil.



SILVER

Properties: Best thermal and electrical conductor. Very malleable and ductile.
Common Uses: Jewellery.



ZINC

Properties: Malleable, Ductile, Good Electrical Conductor.
Common Uses: Galvanising ferrous metals to prevent rusting.



TIN

Properties: Malleable, Ductile, Soft and Good Electrical Insulator.
Common Uses: Cans, Solder, Food storage, Foil.



BRONZE

Properties: Tough, Hardwearing, Corrosion resistant.
Common Uses: Bearings, Coins, Air/Water/Steam Valves.



GOLD

Properties: Very malleable and ductile. Highly resistant to corrosion.
Common Uses: Jewellery, Ornaments, Bullion



2. FORCES AND STRESSES ON METAL PRODUCTS

The products below are made from various metals. In their everyday use, these products are regularly having forces applied to them. These forces affect the way the product operates and its overall function and safety. Designers and manufacturers need to ensure that the materials they select for their products are able to withstand the forces and stresses the product will be subjected to. If they get this wrong it could have serious consequences.

TYPES OF FORCES AND STRESSES

Tension forces are pulling forces that cause an object to be stretched or pulled apart.

Bending forces act at an angle to an object and make it bend.

Compression forces are pushing forces that squeeze an object. Imagine a 'crushing' motion.

Shearing forces act across a material by creating a shearing action. Scissors are a good example.

When an object bends it is under **compression** and **tension** at the same time. See below...

Torsion forces are twisting forces that are applied to an object.

Compression and **tension**



SPECIALIST TECHNICAL PRINCIPLES



3. ECOLOGICAL AND SOCIAL FOOTPRINT



Deep Reading

One of the growing concerns right now is the increasingly worsening condition of our environment. If you read and listen to environment news, you will not just worry but also be scared of all the things that could potentially go wrong once we've exhausted all of our natural resources. One natural resource that is in high demand is metal. The increasing need for this material has made companies extract more to meet the demand. If they continue to this way, we will soon deplete and eradicate this natural resource forever.

Environmental Impact:

When metal is extracted from the ground, it has a huge impact on the environment. Look at what's happening in Brazil, the country that's fast becoming the world's primary supplier of gold. It is estimated that more than 2,000 tonnes of mercury has been released into the environment as a result of the modern Brazilian gold rush. What people don't know is that mercury is needed in the extraction of gold and other metals. An abundance of mercury in the soil and water has led to an increased level of the substance in fish, which is very toxic to both animals and humans.

The same is said of metal extraction itself. Metal extraction can drastically affect air quality in the surrounding areas, with high levels of dust and gas. There's also noise pollution which is affecting local communities and the natural habitats of animals.

Lastly, metal extraction disfigures the landscape. If companies continue to extract metal, the land will forever be disfigured, causing flooding and soil erosion in the area. It also causes large-scale natural habitat destruction, causing many species to be uprooted.

Economic Impact

It is a fact that mining, extracting, refining, and purifying metal costs a lot of money. There are different types of metal, and they need different methods of extraction. The methods of extracting metal do not come cheap, nor does refining and purifying it. Not only do you need a range of specialist equipment for the extraction, but you also need other elements such as copper, zinc, mercury, among others, for the purification and refinement processes. Some of these elements are very harmful and toxic not only to humans and animals but to nature as well, worsening the environmental impact of metal extraction. Aside from this, you also have to think of the transportation costs of the extracted metal, and the associated environmental impacts of transport. There's also the production and manufacturing to consider which releases high amounts of CO₂ into the Earth's atmosphere, contributing to Global Warming.

4. SOURCES AND ORIGINS OF METALS

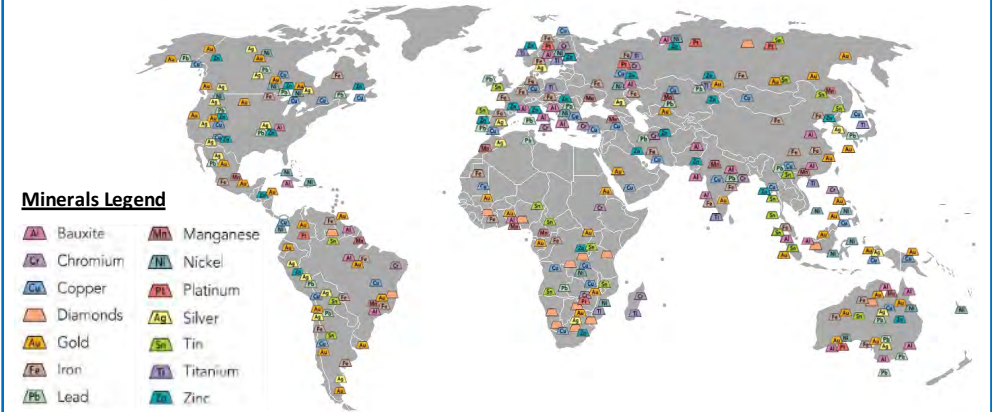
MINING AND EXTRACTION

Mining is the process of obtaining metals from the Earth's crust. There are two main types of mining for metals and ore; Surface Mining and Underground Mining. Both of the methods above have a detrimental impact on the environment and surrounding landscape. Surface Mining leaves huge scars in the landscape, ruining areas of natural beauty and sometimes animal habitats.

Underground Mining requires more energy and therefore more pollution is caused as a result. Large machinery is needed to Mine deep underground releasing CO₂ and contributing to Global Warming.



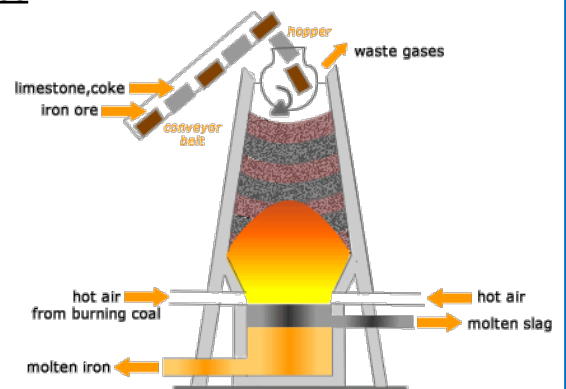
LOCATIONS AROUND THE GLOBE



THE METAL EXTRACTION PROCESS

Once the ores and raw materials have been mined they need to be separated from waste materials. This is typically done in a furnace however, other methods are used depending on the metal.

Blast Furnaces are commonly used when extracting Iron from Iron Ore. The furnace reaches approximately 1700°C. Iron melts at 1500°C and therefore becomes a liquid at this temperature. The pure metal runs free at the bottom of the furnace whilst the waste product known as Slag sits on top of the molten Iron and runs off in a different direction to prevent contamination.



Social Impact

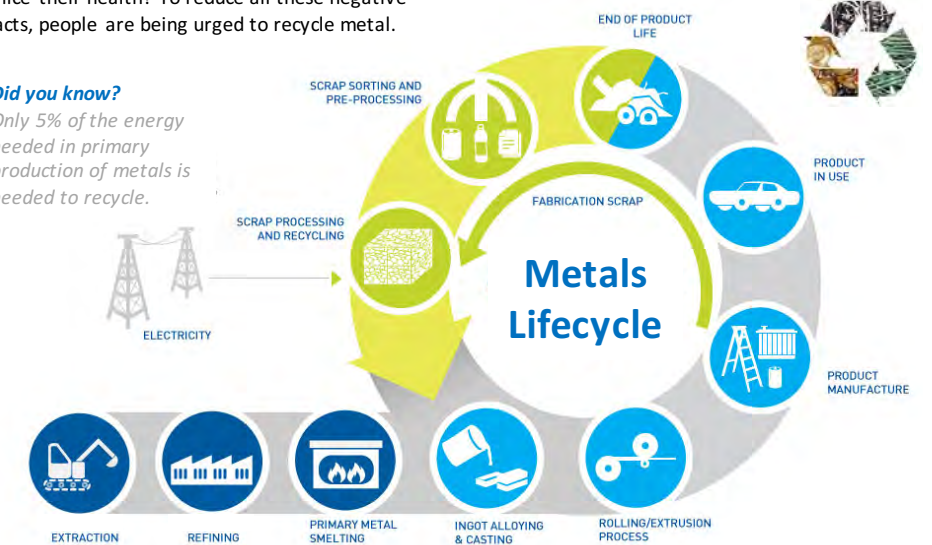
Communities that thrive near quarries and mining sites also suffer from noise, air, land, and even water pollution. In the long run, and most especially if the mining companies are not following safety and security protocols, it will pose detrimental and hazardous risks to the health of the people living in local communities. Yes, there are added jobs and increased salaries for the people as well as increased revenue to the community, but is it worth it to sacrifice their health? To reduce all these negative impacts, people are being urged to recycle metal.

Not only will this keep production costs down since there's no longer the need to refine and purify them, but this also prevents land devastation and natural habitat loss. In the end, it will be healthier for all.

Manufacturers, too, are now more aware of the negative impact of metal extraction. To help the environment, they make use of recycled metal in their products. Through their efforts, the negative impacts of metal extraction are being reduced.

Did you know?

Only 5% of the energy needed in primary production of metals is needed to recycle.



5. USING AND WORKING WITH METALS

DRILLING, CUTTING AND ABRADING

Drilling:

Pillar Drill – Drilling a hole into metal requires careful speed and control. Drilling a pilot hole before drilling larger holes is strongly advised. Too much pressure can cause the metal to warp or even shatter in some instances. A pillar drill is good for accuracy and is powerful enough to drill larger holes in thicker materials. The pillar drill allows you to set drill depth as a quality control measure.



Cutting:

Hacksaw/Junior Hacksaw – The hacksaw and Junior Hacksaw are common metal cutting hand tools that are used to cut straight lines. The hacksaw has a robust blade and can be used for thicker materials. Junior Hacksaws are used for lighter work.



Coping Saw – A coping saw is used to cut curved lines in thinner materials. The thin blade allows the user to follow a detailed path in order to cut complex shapes.



Mechanical Hacksaw- Powered saw for cutting thicker pieces of metal. Lubricant is added to the cut to cool the blade and to allow a smooth cutting motion. Less effort is required than a traditional saw.



Abrading:

Filing– Metal files can be used to smooth the edges of metals. Different shaped profiles and grades of cut are available for various tasks. Good for de-burring.

Wet and Dry Paper – Paper backed abrasive material used to clean up and smooth surfaces. Can be used either wet or dry. Different grades are available from 150 to 2000. The latter is so fine it has a polishing effect.

Polishing Mop – Used with a fine abrasive to buff metals to a high shine.

COMMON FIXINGS



6. STOCK FORMS AND SIZES

Stock Form	Description	Image
Sheet	Metric is the standard size for measuring metal stock forms. Sheet starts at 1mm thick and goes up to approx. 6mm.	
Rod	Rod is available from 3mm to well over 100mm diameter. Some rod can come already threaded, ready for components such as nuts to be attached.	
Bar	Flat bar sections normally start at 3mm thick going up to 20mm thick. Some sections can come in very long lengths if needed.	
Tube	Tubes require you to select an inner and outer diameter. Walls that are thin can lead to weak products. Too thick can lead to added weight and cost.	

7. SCALES OF PRODUCTION

ONE OFF PRODUCTION

In one-off production a **single product** is designed and made to a client's specification. **Labour and material costs are high**, and a high level of design and manufacturing skills are needed. Pieces of art are often one-off's.



MASS PRODUCTION

Mass production is the industrial scale manufacture of **large quantities** of products, usually on a **production line**. Standardised production methods mean it is suitable for products that are not redesigned very often.



BATCH PRODUCTION

In batch production **set quantities** of a product are made to order. Materials are cost-effective and manufacturing **costs are lower**. Items that have a **tendency to change quickly** are usually Batch produced.



CONTINUOUS PRODUCTION

Continuous production is the manufacture of an item **24/7 – 365**. The system is usually completely **automated using a production line**. Due to the scale on which the items are made, they are **extremely cost effective**.



MEASURING AND MARKING OUT

Equipment	Image	Description	Equipment	Image	Description
Steel Rule		Used to measure. '0' is at the very end of the rule	Engineers Square		Used for marking out at right angles
Vernier Calliper		Extremely accurate measuring device	Micrometer		Extremely accurate measuring device
Centre Punch		Marks dots on metal. Usually for drilling	Scriber		Very thin and accurate marking implement
Spring Divider		Used to mark very accurate circles and arcs	Odd-leg Callipers		Used to mark parallel lines on metals

8. SPECIALIST TECHNIQUES AND PROCESSES

SHAPING

MILLING

Milling machines can come in traditional and CNC (Computer Numerical Control) versions.

Traditional versions allow a cutting tool (similar to a large drill bit) make passes across a material. The machine is controlled manually where an operator will set the depth, width and length of the cuts it makes in the material.



CNC versions allow an operator to load a CAD file directly into the milling machine which will then process the CAD drawing and make passes based on the measurements in the file. This method is extremely accurate.

Video: <https://www.youtube.com/watch?v=lu84S4QbMos>

TURNING



The most common way of turning metal is using a Centre Lathe. The lathe is capable of loading a range of tools which cut in various ways.

The material is held in the chuck which is attached to the headstock. If using a longer piece of material a tailstock is required to hold the material centre while it is being turned.

As the material turns at a rapid speed, the tool moves in and begins to cut the material. Both Traditional and CNC versions of a Centre Lathe are available.

Video: <https://www.youtube.com/watch?v=bckCLOHXPdk>

HOT FORGING

Hot Forging is the process of heating a metal until it is in a malleable state.

In old times a blacksmith would heat the metal and then use a hammer to smash the material into shape over an anvil.

Modern versions of this common process involve heavy duty machinery pressing the malleable material into a range of moulds and dies to achieve the required shape.

Video: <https://www.youtube.com/watch?v=dMt1tqDI1nM>



CASTING

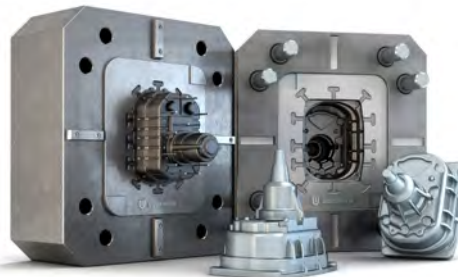
DIE CASTING

Casting involves heating metal into a molten state and pouring it into a mould.

Die Casting is the most common form of casting as it allows a manufacturer to cast multiple identical products at a rapid rate.

In this machine driven process, the molten metal is pushed into a set of metal moulds where it takes shape. The moulds are then cooled rapidly and the item is ejected.

Video: https://www.youtube.com/watch?v=Pj_mjiUQad8



SAND CASTING



Video: <https://www.youtube.com/watch?v=K8SYhISGxN4>

Sand Casting offers the most flexibility of the casting options. It enables complex shapes such as car engines, man holes and post boxes to be manufactured.

Firstly, a pattern is made which resembles the finished product. It is placed in the bottom of 2 flasks that contain a sand called delft clay. A parting powder is added to help remove the pattern once the sand has formed around it.

The top flask is then added and the pattern is removed leaving a cavity ready for the molten metal to be poured into via a runner. Hot air escapes through a riser.

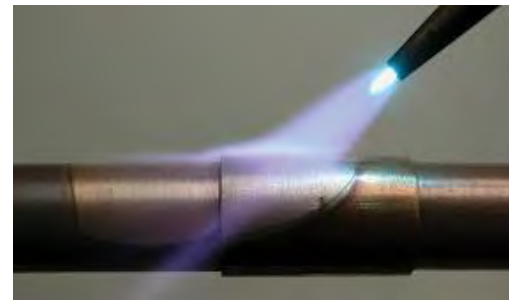
JOINING

BRAZING

Brazing is used to permanently join 2 or more pieces of metal together.

The metal is cleaned using emery cloth and flux is added to the metals to stop oxidation during the process. The metals are heated using a blow torch on a brazing hearth while a filler material called spelter is added.

The joint is then quenched and cleaned leaving a joint in the material.



WELDING

There are various methods of welding however, they all involve heating metal and fusing it together.

Welding is different from brazing as the materials actually fuse during welding. A filler material is still needed to form the joint however, the materials are heated to such high temperatures that they bond.

In MIG and TIG welding, an electric current is used to produce the heat needed for the process.



9. SURFACE TREATMENTS AND FINISHES

Name	Image	Description	Name	Image	Description
Painting Spray Primer and Paint		Used for aesthetics, Priming surfaces and Protection.	Hot Blackening		Dipped in chemicals and oil. Corrosion Resistance.
Powder Coating		Electrostatic powder is applied with heat & bonds to metal.	Polishing and Brushing		Buffed or uniformly scratched for an aesthetic finish.
Plastic Dip Coating		Hot metal dipped into plastic powder.	Sand Blasting		Sand fired under pressure for aesthetic patterns.
Anodising		Used on Aluminium. Decorative, durable and protects.	Electroplating		Adds another metal layer to surface using electrical current.
Galvanising		Zinc coating of ferrous metals. Helps to prevent rusting.	Metal Laquer		Sprayed onto the metal. Varnish like finish which creates sheen.

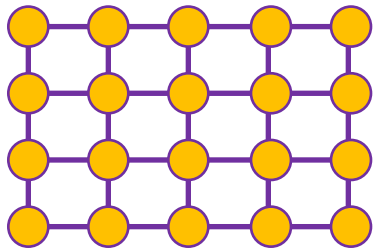
1. SELECTING MATERIALS AND COMPONENTS

INTRODUCTION

Plastics are mainly **synthetic materials** made from polymers traditionally derived from finite resources such as **coal, oil and gas**, but are increasingly being produced using **sustainable sources** such as **vegetable starches**. There are also naturally occurring plastics such as rubber. Use this sheet basis for revision and further research into plastics when preparing for your exam.

THERMOSETTING PLASTICS

Thermosets are more **rigid** and **once they have been formed and set once, they are stuck in that shape forever**. The polymer chains in thermosets have more **'cross links'** between them which stops the plastic moving when heated. As a result, thermosets are more **brittle and harder** than thermoplastics. Thermosets have **good resistance to heat** and make **good electrical insulators**. They are however **difficult to recycle** as they burn rather than melt.



ME

Melamine Formaldehyde

Properties: Lightweight, Hard, Brittle, Food Safe.
Common Uses: Kitchenware, Heat Resistant surfaces, Furniture.



ER

Epoxy Resin/Araldite

Properties: Good strength to weight, Strong resin, Expensive, Heat resistant, Good electrical insulator.
Common Uses: Bonding materials, PCB's, Waterproof coatings.



UREA FORMALDEHYDE

Urea Formaldehyde

Properties: Heat resistant, Good electrical insulator, Hard, Brittle.
Common Uses: Electrical fittings, casings, buttons and handles.



POLYESTER RESIN

Polyester Resin
Properties: Strong, Heat resistant, Good electrical Insulator.
Common Uses: Waterproof coatings, Flooring, Fibreglass lamination



PF

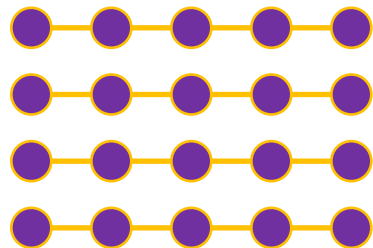
Phenol Formaldehyde/Bakelite

Properties: Very rigid, Hard and Brittle.
Common Uses: Electrical components, Mechanical parts, Old clocks, phones and radios.



THERMOPLASTICS

Thermoplastics are the most common types of plastics we see on a daily basis. They are generally the **most flexible**, especially when heated. This is due to their physical structure. Their polymer chains (see below) are loose which means they can slide past each other when heated. This allows them to be **reformed multiple times**. Thermoplastics are usually **very easy to recycle** due to the fact they can be remoulded multiple times.



PP

Polypropylene

Properties: Flexible, Tough, Lightweight, Food safe
Common Uses: Food containers, Stationary products, Kitchen products.



HIPS

High Impact Polystyrene

Properties: Flexible, Impact resistant, Lightweight, Food safe.
Common Uses: Food containers, Household Electronic casings.



HDPE

High Density Polyethylene

Properties: Lightweight, Rip and Chemical resistant.
Common Uses: Milk bottles, Pipes, Buckets, Bins, Household Bottles.



LDPE

Low Density Polyethylene

Properties: Very flexible, high strength to weight ratio.
Common Uses: Plastic bags, Piping, Plastic food wraps, Bottles.



PET

Polyethylene Terephthalate

Properties: Stable, easily blow moulded, resistant to chemicals, fully recyclable.
Common Uses: Bottles, Food Packaging



ABS

Acrylonitrile Butadiene Styrene

Properties: Hard, Tough, Rigid, High quality, Good insulator.
Common Uses: Children's toys, Electrical Casings, Car interiors.



PVC

Polyvinyl Chloride

Properties: Flexible, Tough, Chemical Resistant.
Common Uses: Pipes, Electrical wire.



PMMA

Acrylic/Perspex

Properties: Tough but Brittle.
Common Uses: Commonly used in Schools, Display Stands, Car Lights and Modern Baths.



2. FORCES AND STRESSES ON PLASTIC PRODUCTS

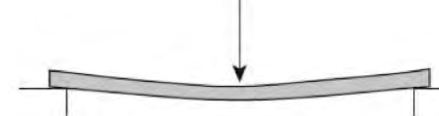
The products below are made from various plastics. In their everyday use, these products are regularly having forces applied to them. These forces affect the way the product operates and its overall function and safety. Designers and manufacturers need to ensure that the materials they select for their products are able to withstand the forces and stresses the product will be subjected to. If they get this wrong it could have serious consequences.

TYPES OF FORCES AND STRESSES

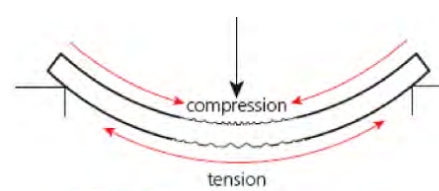
Tension forces are **pulling forces** that cause an object to be **stretched or pulled apart**.



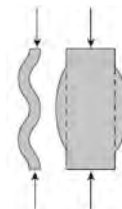
Bending forces act at an angle to an object and make it bend.



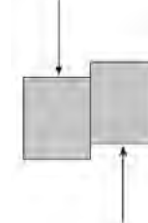
When an object bends it is under **compression** and **tension** at the same time. See below...



Compression forces are **pushing forces** that **squeeze an object**. Imagine a 'crushing' motion.



Shearing forces act across a material by creating a **shearing action**. Scissors are a good example.



Torsion forces are **twisting forces** that are applied to an object.



SPECIALIST TECHNICAL PRINCIPLES



3. ECOLOGICAL AND SOCIAL FOOTPRINT

theguardian

A million bottles a minute: world's plastic binge 'as dangerous as climate change'

Deep Reading

It is estimated that between 4 and 12 million metric tonnes of plastic makes its way into the ocean each year. This figure is only likely to rise, and a 2017 report predicted that by 2050 the amount of plastic in the sea will outweigh the amount of fish.

A normal plastic bottle takes about 450 years to break down completely, so the components of a bottle dropped in the ocean today could still be polluting the waters for our great-great-great-great-great-great-great-great-great-great-grandchildren.

We need to talk about plastic. A landmark study revealed that billions of people globally are drinking water contaminated by plastic particles. Almost 75% of tap water samples tested in the UK contained traces of plastic. Fish also ingest the small plastic pieces which then contaminates any seafood we eat.



A million plastic bottles are bought around the world every minute and the number will jump another 20% by 2021, creating an environmental crisis some say will be as serious as climate change.

The demand, equivalent to about 20,000 bottles being bought every second, is driven by a desire for bottled water and the spread of an 'on the go' culture around the world.

More than 480bn plastic drinking bottles were sold in 2016 across the world, up from about 300bn a decade ago. If placed end to end, they would extend more than halfway to the sun. By 2021 this will increase to 583.3bn, according to the most up-to-date estimates from Euromonitor International's global packaging trends report.

Most plastic bottles used for soft drinks and water are made from Polyethylene Terephthalate (PET), which is highly recyclable. But as their use soars across the globe, efforts to collect and recycle the bottles to keep them from polluting the oceans, are failing to keep up.

4. SOURCES AND ORIGINS OF PLASTICS

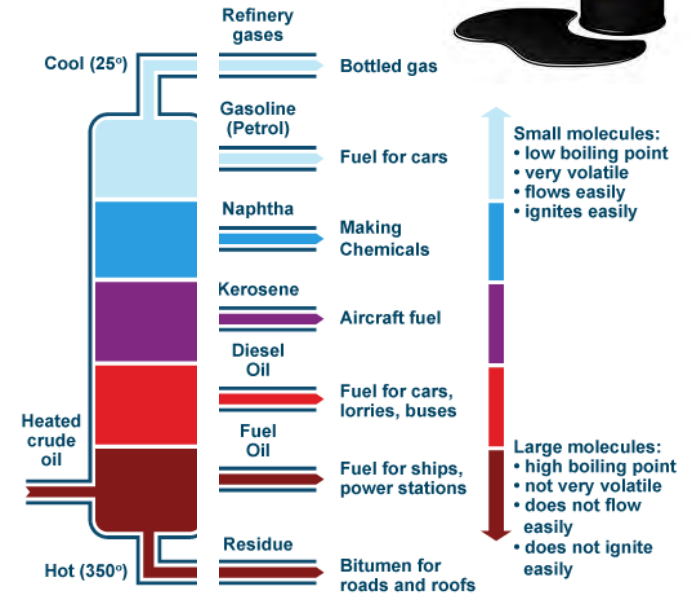
PETROCHEMICAL POLYMERS

FRACTIONAL DISTILLATION

Most plastics are created from Crude Oil.

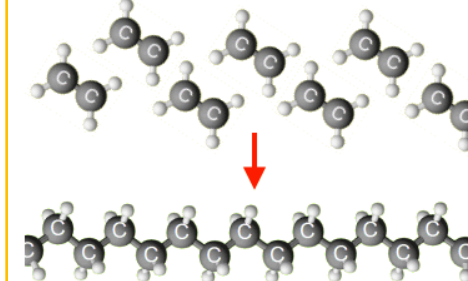
The production of plastic begins with a distillation process in an oil refinery.

The distillation process involves the separation of heavy crude oil into lighter groups called fractions. Each fraction is a mixture of chemical compounds made up of carbon and hydrogen (hydrocarbons), which differ in terms of the size and structure of their molecules. One of these fractions is called Naphtha which is the crucial element for the production of plastics.



POLYMERISATION

The main process used to produce plastics is called polymerisation which requires specific catalysts. In a polymerisation reactor, monomers like ethylene and propylene are linked together to form long polymers chains (see below).



BIOPOLYMERS

Biopolymers are natural polymers which can be made from **starchy vegetables** such as corn or plants containing lots of fibre, fat or carbohydrate.

Biopolymers are **fully Biodegradable** when put into landfill. The natural bacteria in the soil helps break down the plastic very quickly due to being exposed to moisture and high temperatures.

Biopolymers are **non-toxic** and are made from **renewable resources**, therefore having a **low environmental impact**.

The most common Bioplastics that you should research are PLA (Polylactic Acid), PCL (Polycaprolactone) and PHB Polyhydroxybutyrate.

THE SUSTAINABILITY OF PLASTIC PRODUCTS

Deep Reading

Most plastics are made from Crude Oil (see above). Crude Oil is a **Non-renewable/Finite resource** which means that we will eventually run out of it. End of life considerations are also important for plastic products as most plastics take so long to decompose.

Many responsible companies produce a **Product Life Cycle** Assessment which informs them of the **environmental impact** their products will have. The information they gather helps them decide how best to source, manufacture and dispose of their products to limit their environmental impact.

Extracting Crude Oil uses **extremely high levels of energy** which is created by **burning fossil fuels**. These fossil fuels release **high amounts of CO2** into the earth's atmosphere which **contributes to Global Warming**.

The situation is similar when **manufacturing plastic products**. The polymers need to be heated to high temperatures in order to mould them. This is again achieved by **burning fossil fuels**, which **releases more CO2**, and **contributes to Global Warming**.

At the **end of a plastic product's life** there are several options to consider. Firstly, plastic products can be **reused** as they're typically **easy to repair and maintain** which means they can survive longer than wooden or metal based products.

Most plastics are also **recyclable**, this means the material can be melted down and then put back into production to become a new product. This **saves the material from ending up in landfill** and also **prevents us from sourcing more plastics from crude oil**.

The final option is to throw the product into **Landfill**. This causes significant environmental issues as plastics **take hundreds of years to decompose** and since the material hasn't been recycled, we must then create new plastic products using **more crude oil**, putting even **more strain on the planet's non-renewable resources**.



5. USING AND WORKING WITH MATERIALS

DRILLING, CUTTING AND ABRADING

Drilling:

Pillar Drill – Drilling a hole into plastic requires careful speed and control. Drilling a pilot hole before drilling larger holes is strongly advised. Too much pressure can cause the plastic to crack. A pillar drill is good for accuracy and is powerful enough to drill larger holes in thicker materials.

**Cutting:**

Coping Saw – A coping saw is used to cut curved lines in thinner materials. The thin blade allows the user to follow a detailed path in order to cut complex shapes.



Scroll Saw/Band Saw - The Scroll Saw and Band Saw are both powered and can be used for cutting straight and curved lines. They can overheat and melt which clogs the blade.

Vinyl Cutter- The computer controls the movement of a sharp blade. This blade is used to cut out shapes and letters from sheets of thin self-adhesive plastic (vinyl).

Laser Cutter - One of the most **accurate** ways to cut plastics. The laser itself can follow a design generated on a **CAD (Computer Aided Design)** program to a very fine tolerance however, Laser Cutters must be setup properly considering the following:

- **Kerf Allowance**
- **Power and Speed Settings**
- **Focusing the Beam**
- **Clean Mirror and Lenses**

**Abrading:**

Filing– Metal files can be used to smooth the edges of plastics. Different shaped profiles and grades of cut are available for various tasks.

Wet and Dry Paper – Paper backed abrasive material used to clean up and smooth surfaces. Can be used either wet or dry. Different grades are available from 150 to 2000. The latter is so fine it has a polishing effect.

Abrasive Pads– Similar to abrasive paper, removes small surface scratches ready to be polished.



6. STOCK FORMS

Stock Form	Description	Image
Sheet	Metric is the standard size for measuring plastic forms. Sheet starts at 1mm thick. Sheet is commonly used when Line Bending, Vacuum Forming and Laser Cutting.	
Rod	Rod is available from 2mm to well over 100mm diameter. Rod is commonly used in plastic fixings as well as other plastic components.	
Tube	Tube is usually available from 5mm to around 1 metre in diameter. You also need to decide on the wall thickness. Tube is commonly used in piping.	
Powder/Granules	Powders and Granules are commonly used for Plastic Dip Coating, Injection Moulding and Extrusion	
Foam/Film	Foam and Film is commonly used in food packaging. Foam is incredibly lightweight is good for cushioning.	

7. SCALES OF PRODUCTION

ONE OFF PRODUCTION

In one-off production a **single product** is designed and made to a client's specification. **Labour and material costs are high**, and a high level of design and manufacturing skills are needed. Pieces of art are often one-off's.

**MASS PRODUCTION**

Mass production is the industrial scale manufacture of **large quantities** of products, usually on a **production line**. Standardised production methods mean it is suitable for products that are not redesigned very often.

**BATCH PRODUCTION**

In batch production **set quantities** of a product are made to order. Materials are cost-effective and manufacturing **costs are lower**. Items that **go out of fashion relatively quickly** are usually Batch produced.

**CONTINUOUS PRODUCTION**

Continuous production is the manufacture of an item **24/7 – 365**. The system is usually completely **automated using a production line**. Due to the scale on which the items are manufactured, they are **extremely cost effective**.

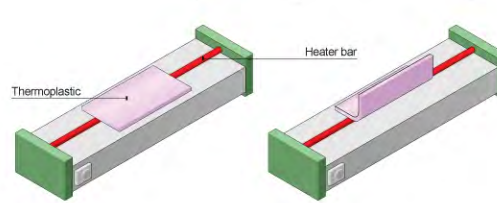


8. SPECIALIST TECHNIQUES AND PROCESSES

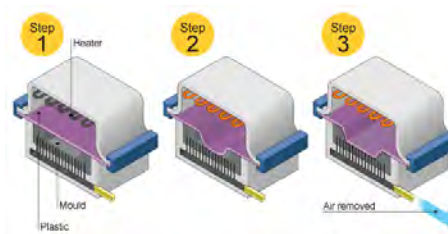
DE-FORMING AND REFORMING PLASTICS

LINE BENDING

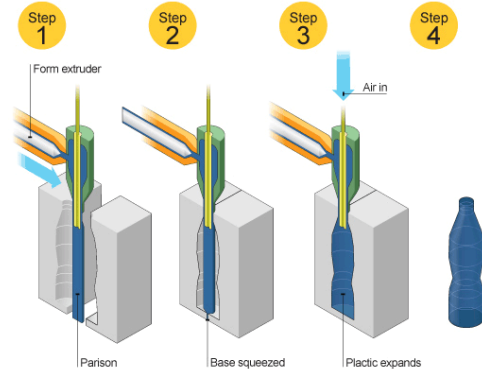
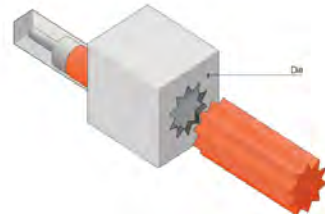
Strip heaters are a good way to **create a permanent fold in Thermoplastics** such as acrylic. You start by marking on the plastic using a marker. You place the marking over the heated wire and wait the allocated time (depending on thickness of material). Once removed, the plastic should be bent around a Jig to ensure accuracy and so any additional products are identical.

**VACUUM FORMING**

Vacuum Formed products include plastic egg boxes, bath tubs, buckets and yoghurt pots. A sheet of Thermoplastic is heated and pressed onto the **former** (mould) by an atmospheric pressure. The **vacuum sucks the plastic over the top of the former to take the shape**. The former must be removed after this process, therefore the shape of the former must be tapered to allow it to slide back out.

**BLOW MOULDING**

Blow Moulding feeds an **extruded** plastic tube known as a **parison** into a hollow mould such as the **mould** for a bottle. The parison is pinched at the bottom as the mould closes and filled with heated compressed air until the **parison inflates to fill the mould**. The plastic cools and is trimmed once it has been removed from the mould.

**EXTRUSION**

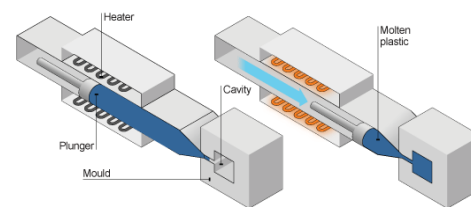
Extrusion is used to create a **continuous flow of plastic which is pushed through a die** to create a specific shape. Extrusion is used for cables, pipes, mouldings and even plastic film.

The extrusion process works similar to injection moulding except extrusion is continuous where as injection moulding uses a hydraulic press to push specific amounts of plastic into a mould.

INJECTION MOULDING

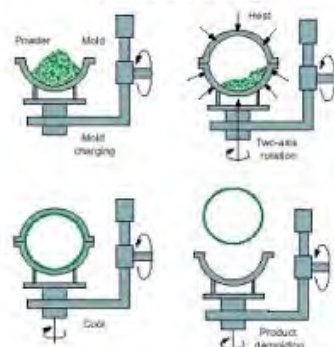
This process is ideal for **complex shapes**. Firstly a mould is made; these are generally constructed from steel in two parts. They need to be **very accurate** as any blemishes will be transferred to every item produced.

Injection moulding is used for intricate **plastic components** such as bottle tops, casings with clips and internal components of electrical products. Injection moulding works by melting plastic in a chamber and using a **hydraulic press** to push the molten plastic into the mould.

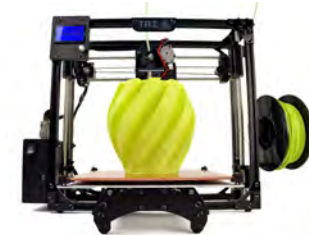
**ROTATIONAL MOULDING**

Rotational Moulding is a process that is ideal for the **manufacture of hollow products**. These include tanks holding liquids such as rainwater tanks and waste disposal containers, footballs, road cones, fenders and luggage trays. **Polyethylene and Polypropylene are ideal polymers** for this moulding process. It is particularly suitable for the **manufacture of batches from 100 to 5000 units**.

The mould opens and is filled with powdered polyethylene or polypropylene and closed. The mould is heated to 300°C. At the same time the mould rotates so that the powder is forced against the wall of the mould. The mould then cools slowly and solidifies.

**3D PRINTING**

3D Printing allows physical objects to be formed from reels of Thermoplastic. 3D Printers also use **CAD files** and coordinates the printer to follow the design by **building up layers**. 3D Printers are commonly used for **Rapid Prototyping**. This means that designers can model their designs from the actual material they will be made from, without having to pay lots of money for moulds to be made for processes such as Injection Moulding. 3D Printing is **unsuitable for large scale production** due to the speed in which it makes products and components.



ADDITION & JOINING METHODS

LAMINATING

Laminating involves **bonding strips or sheets of material together in layers**. It can be done with thick materials to create very strong structures or very thin materials to create tough and flexible products.

Plastics are often laminated with other materials such as woods and glass to **improve aesthetics and functionality**.

Laminated safety glass is now used in car windscreens. The sheet of plastic sits between the front and back layer of the windscreen preventing it from falling through in the event of a crack or smash.

**WELDING PLASTICS**

Plastics can be welded using either heat or chemicals. A chemical weld is the most common in schools by using either **Liquid Solvent Cement** or **Tensol 12**. Both substances dissolve the surface of the plastics being joined. **Heat welding plastic** involves using a special hot air gun which accurately heats the areas being welded together as well as a **plastic filler rod** that is applied to the weld joint.

**PLASTIC RIVETS**

Small plastic rivets which can be used as a quick and cheap alternative to screws and nuts for holding plastic components together. Some rivets come in two parts, the head and sleeve. The sleeve pushes through holes in the items to be attached, and the pin is pushed into the sleeve. The insertion of the pin makes the sides of the sleeve splay out, providing a secure grip.

**HEAT SEALING**

Heat sealers (also known as bag sealers) are machines that are used to seal various thermoplastics and are available in a range of different sizes. The sealers are ideal for use on plastic tubing as they close off the edges, ensuring that it protects the content inside. Heat sealing is used to make packaging air tight to help preserve products for longer.



9. SURFACE TREATMENTS AND FINISHES

Name	Image	Description	Name	Image	Description
Painting Spray Primer and Paint		Used for aesthetics, UV protection and Priming surfaces.	Heat Transfer Printing		Printed and transferred onto a surface with a heat press.
Vinyl Decals		Printed & cut self-adhesive vinyl, used for high quality graphics.	Hydro Graphic Printing		Printed on water soluble film which floats. Object is submerged.
Flocking		Fluffy finish created through static charge.	Electroplating and Electroless Plating		Plated with nickel, chrome, copper, tin or gold.
Embossing and Engraving		To raise or lower the material in order to enhance text.	Rubberising Spray		Slightly textured coating for grip. Has a matt finish.

Unit 3.1 - Solving Engineering Problems

Introduction

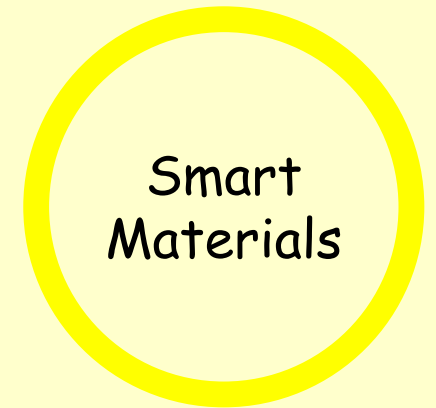
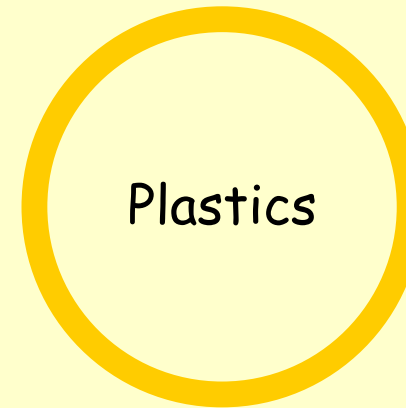
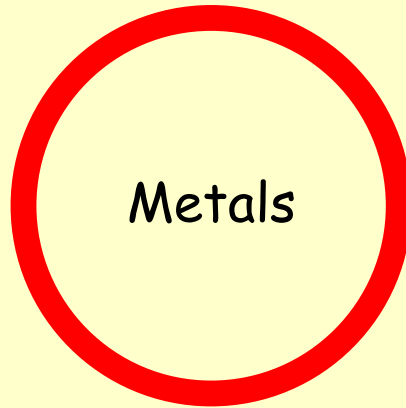
Unit 3 totals 40% of your overall GCSE and is the externally written exam. This exam is a 90-minute exam where you must answer questions on both the theory and practical knowledge you have picked up during the next 2 years.

Some of the topics will be covered as part of practical lessons and some will be covered during theory lessons such as this. The topics you need to know by the time you take your exam are;

- Materials,
- Communicating as Engineers,
- Planning, Equipment, Processes and Health & Safety,
- Design Briefs and Specifications,
- Environmental considerations, Engineering developments and Mathematical techniques.

Materials

We are going to start by looking at **materials**, more specifically we will focus on four key **classification** of materials.



For each of these four **classifications** we will look at the **raw materials**, **stock forms** and **material properties**.

Metals

Raw material is the phrase used to describe the basic materials that are either **removed from the ground** (e.g. Oil/Stone) or grown (e.g. Wood).

Metals are **extracted from ores** that occur naturally in the Earth's crust and needs processing into a usable form.

Metals have been used for thousands of years in the form of **Copper**, **Bronze** and **Iron** with materials such as **Aluminum** and **Steel** being more modern developments.

Once the **metal ore** has been obtained the metal itself will need to be **extracted** and some processing required to convert that material into a **commercially available form**.



*Bauxite
(Aluminium)*



Iron Ore

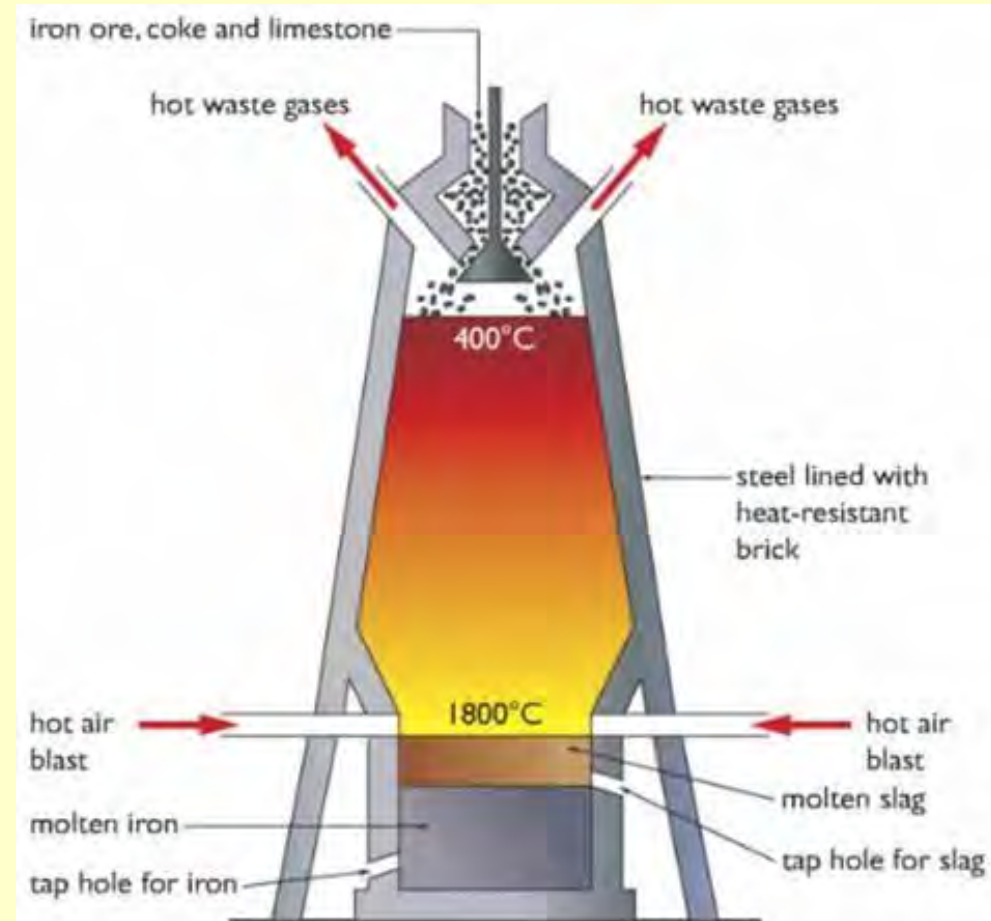
Metals

If the **ore** has a high enough content of metal, then it is **cost effective enough** to dig it up and start the process of extraction. **This process is called smelting.**

Smelting is the process of using a **blast furnace** to apply very **high temperatures** and **chemicals** to the ore, breaking down the ore to **molten iron, known as pig iron**, and a waste product called 'slag'.



Pig Iron



Metals



Your turn...

In your books put in today's title and date and **underline them**.

Raw Materials

Create a short paragraph explaining where metal comes from. **Include and highlight all the key words and processes.**

Example;

Metal starts as a rock in the Earth's crust known as **ores**. We mine the **ore**, removing it from the crust...

...the **pig iron** and **waste slag** comes out of the **blast furnace**...

Plastics (Polymers)

Most commercial plastics are derived from the fossil fuel **crude oil**, which can be found in pockets **under the Earth's surface**.

Fossil fuels are the decayed remains of plant and animal life that has decomposed over millions of years.

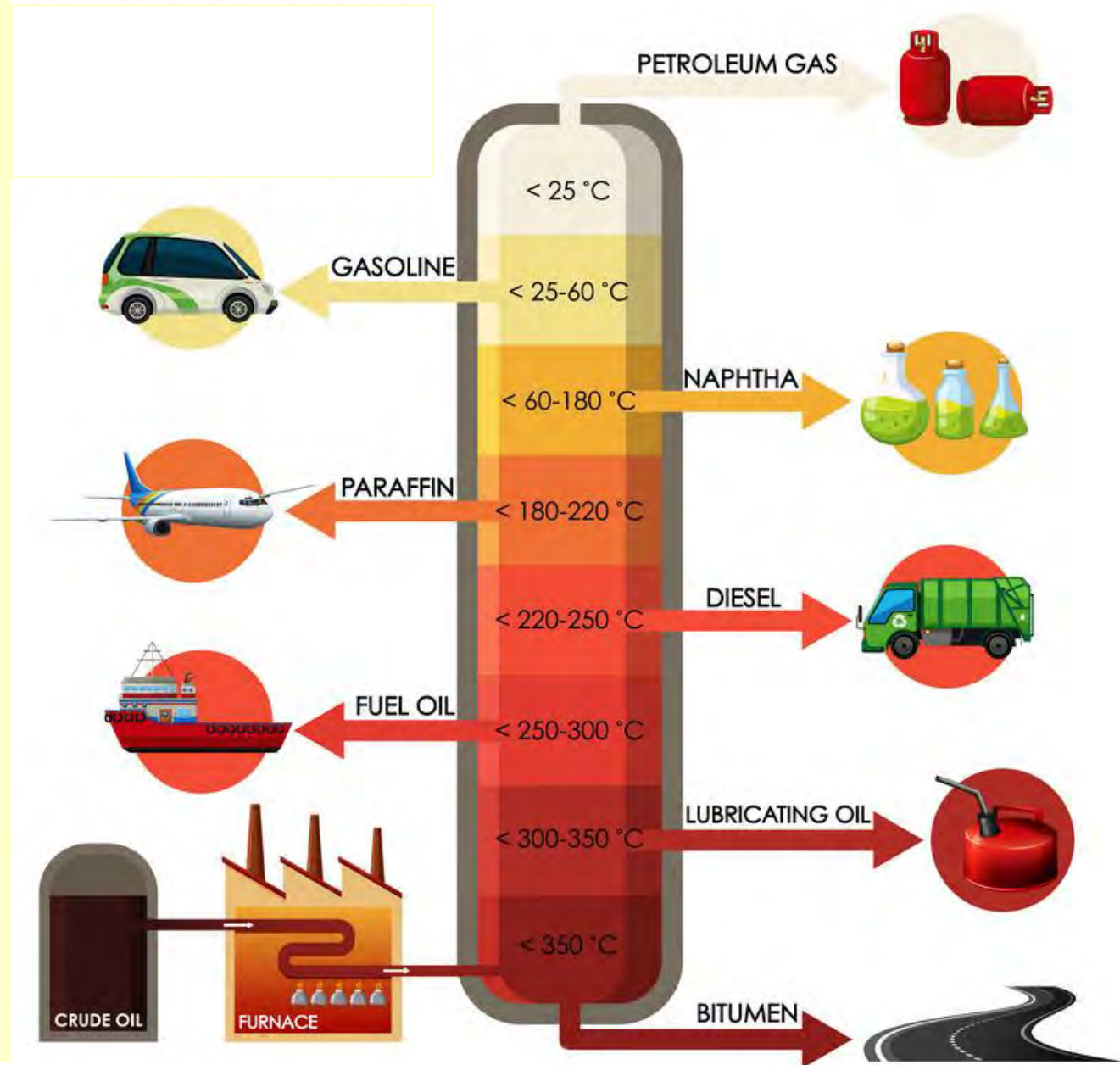
To reach the pockets of crude oil, we have to drill deep into the earth. The crude oil is then sent to an **oil refinery**.



Plastics (Polymers)

Here the oil is **refined** into usable chemicals such as diesel, petrol and Liquefied Petroleum Gas (LPG).

Plastics are developed from a chemical called **Naphtha** which is extracted and then **turned into plastic** through a chemical process called **polymerisation**.



Your turn...

Create a short paragraph, and quick sketch, explaining where plastic comes from. **Include and highlight all the key words and processes.**

Key Words

Raw material

Fossil fuel

Crude Oil

Extracted

Oil refinery

Refined

Naphtha

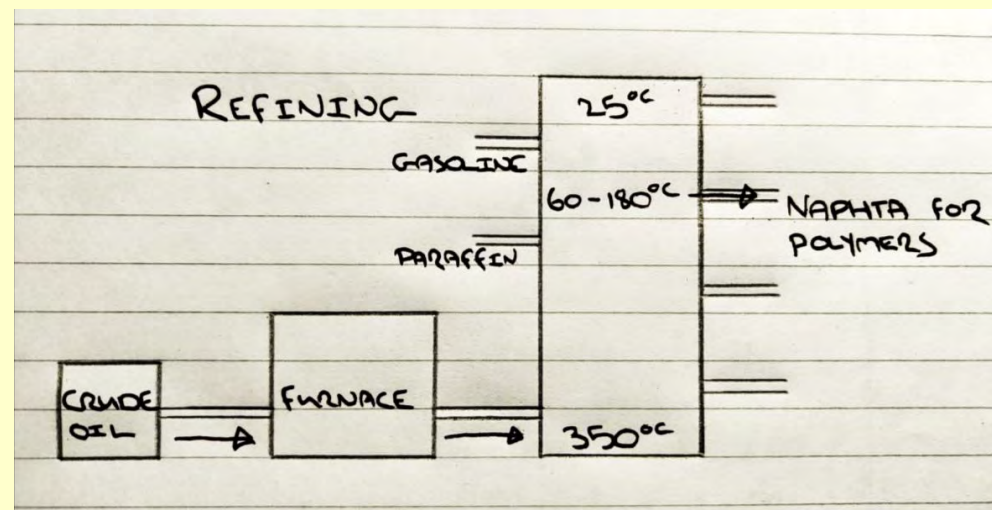
Chemical
process

Polymerisation

Example;

Plastic starts as a liquid under the Earth's surface known as crude oil. We extract the oil using a drilling process...

...the result is a substance called Naphtha which can then be chemically altered...



Exam Questions

The questions in your exam will be a mixture of short and longer answer questions. The questions at the end of each lesson have been on previous exam papers.

Attempt the questions then we will complete the answers together.

Mark your own work and make sure you fill in the correct answer answers if you get any wrong.

Mark them in a RED pen and record your answers.

1	9	.	1
Give the source or origin of your chosen material category.			
The sea		✗	Crude Oil
			[1 mark]

1	9	.	1
Give the source or origin of your chosen material category.			
Crude Oil		✓	
			[1 mark]

Total Marks

1

Exam Questions

1 9

Choose **one** of the material categories in the table below.

Metal based materials	Paper and boards	Polymers	Textile based materials	Timber based materials

My chosen material category is _____

1 9 . 1

Give the source or origin of your chosen material category.

Metals - Ores

Polymers - Crude Oil

[1 mark]

1 9 . 2

Name **one** process used to convert your chosen material category into a workable form.

Metals - Smelting

Polymers - Refining

[1 mark]

1 9 . 3

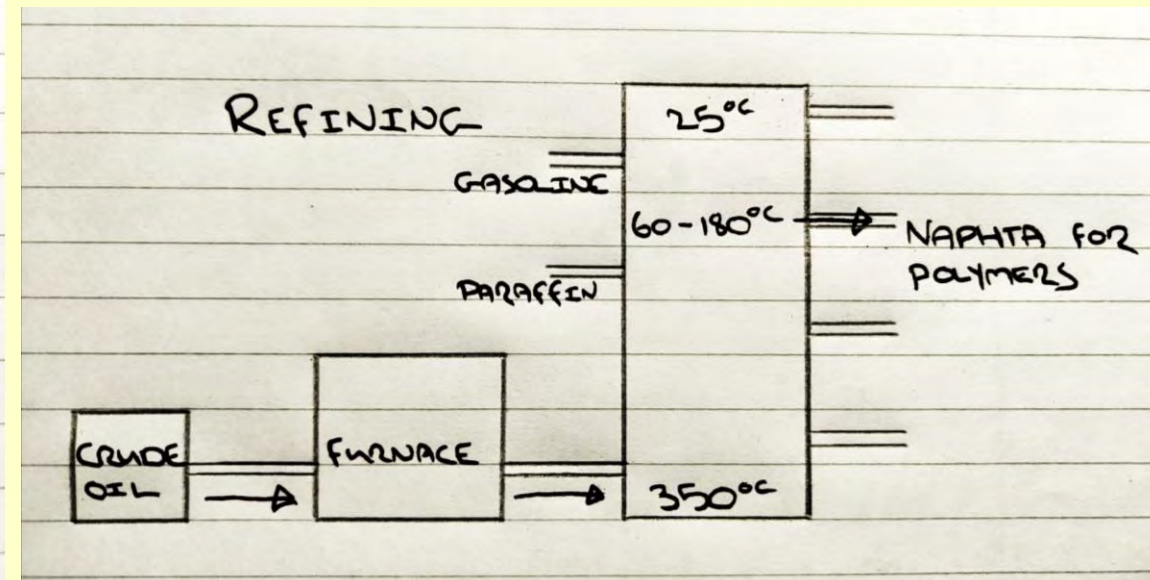
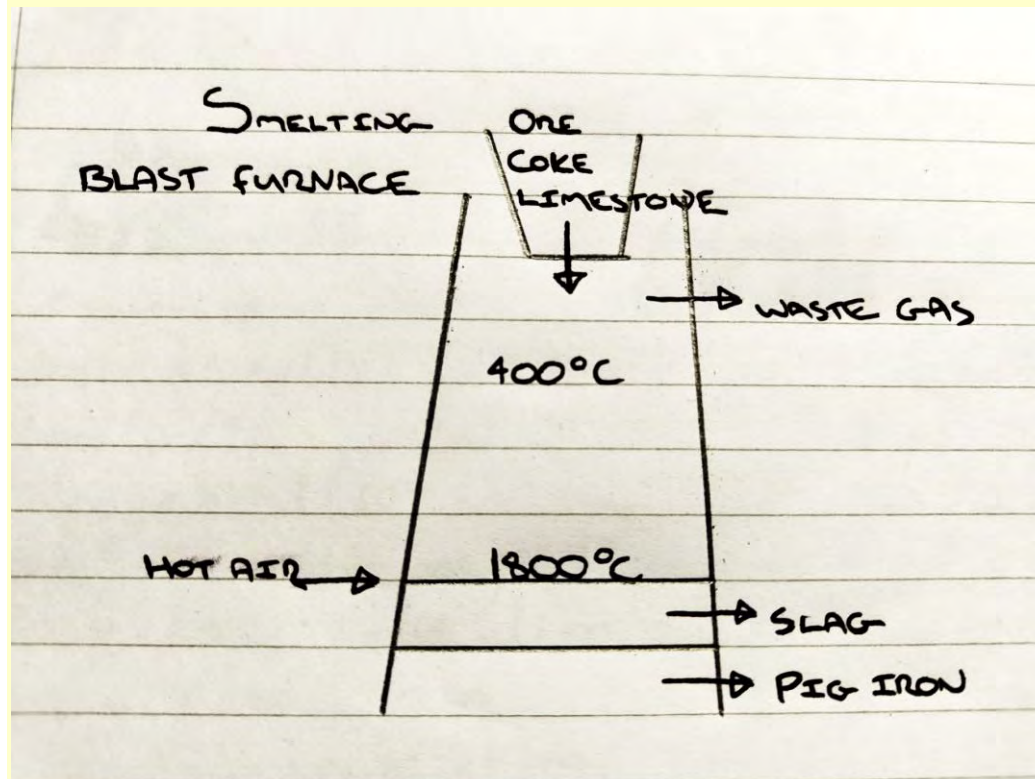
Using notes and/or sketches describe the process you have named above.

[4 marks]

Exam Questions

1 9 . 3 Using notes and/or sketches describe the process you have named above.

[4 marks]



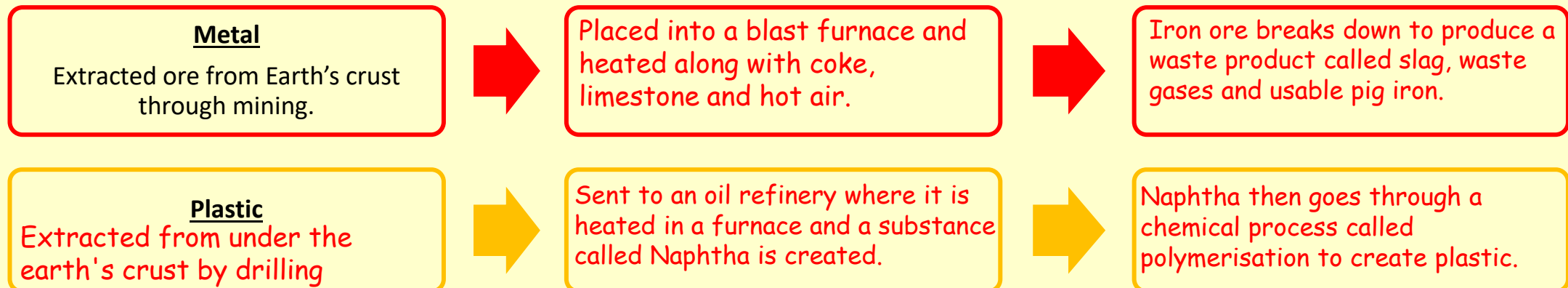
Unit 3.2 - Stock Forms

In your books put in today's title and date and **underline them**.

	<u>Stock Forms</u>

Answer the following question;

Copy the workflow charts below and complete the process of creating metal and plastic from their raw materials.

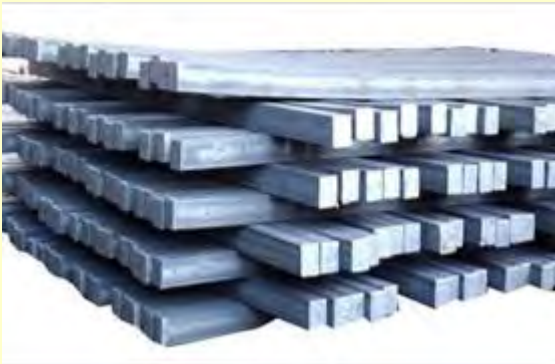


Stock Forms

When materials have been extracted and refined into **usable materials**, they are then **shaped** into forms known as **stock forms** (market forms). These **standardise** the **sizes and shapes** in which a material can be bought.

This **standardisation** helps the engineers, designers, architects etc with their decisions making process, allowing them to match their choices to readily available **stock forms**.

Working with **stock forms** also supports them to **cost** projects effectively as it is much easier to put a price on a stock form of material.



Metal ingots - usable material before shaping to stock form



Plastic pellets - version of usable material before shaping to stock form

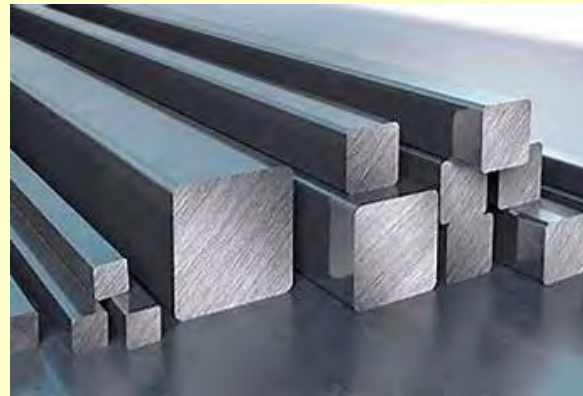
Metal Stock Forms

There is a huge range of different metals available, each with different properties, allowing them to be used for different purposes. The more common metals, such as **steel, aluminium, lead and brass**, are readily available in a **variety of stock forms**.

We generally classify the stock form of metal into three categories;



Sheet Metal



Metal Sections



Metal Extrusions

Sheet Metal

Sheet metal (metal sheets) are used in applications such as **washing machines**, fire extinguishers or even kitchen sinks. It is extensively used in a manufacturing process called **press forming** where the sheet is 'pressed' under high pressure between two dies, creating a formed shape of the die.

Sheet metal can be available in very large areas, but it is the **thickness**, or **gauge**, that defines a metal as sheet. Each **gauge** of thickness corresponds to a specific size in millimetres i.e. 18 **gauge** sheet metal is 1mm thick.



*Mild steel
press formed
kitchen sink*

Sample thickness										
Gauge:	16	18	19	20	21	22	24	26	28	30
										
Size in mm:	1.30	1.00	0.92	0.82	0.71	0.64	0.50	0.40	0.30	0.25

Metal Sections

Metal sections are a **stock form** that are individually known by the actual shape of the metal itself. We look at the **cross-section** shape of the metal and refer to the **stock form** based on this i.e. below is an image of metal bar, the **cross section** of which is a square shape, therefore we refer to it as 'square section' or square bar'.

There are lots of different **standardised sectional stock forms**. Some of the most common are shown below.



*Mild steel
square bar
stock form*



Round
section



Square
section



Hexagonal
section



Rolled Steel Joist
(RSJ)



Angle
section



U section



Square tube
(Box section)



Round tube
section



Chamfered
section

Metal Extrusions

Metal extrusions are a type of **stock form** that essentially the same as metal sections and are manufactured using the same extrusion process.

Metal extrusions differ from standard metal sections as they are often requested and designed for **specific jobs**, making the **cross-section** shape more **complicated** or the length much longer.



*Aluminium
Bi-folding
door sliding
track*

Your turn...

Draw and label the below examples of metal stock forms;

Labels

Square Section

Chamfered
Section

Angle Section

Box Section

Extrusion

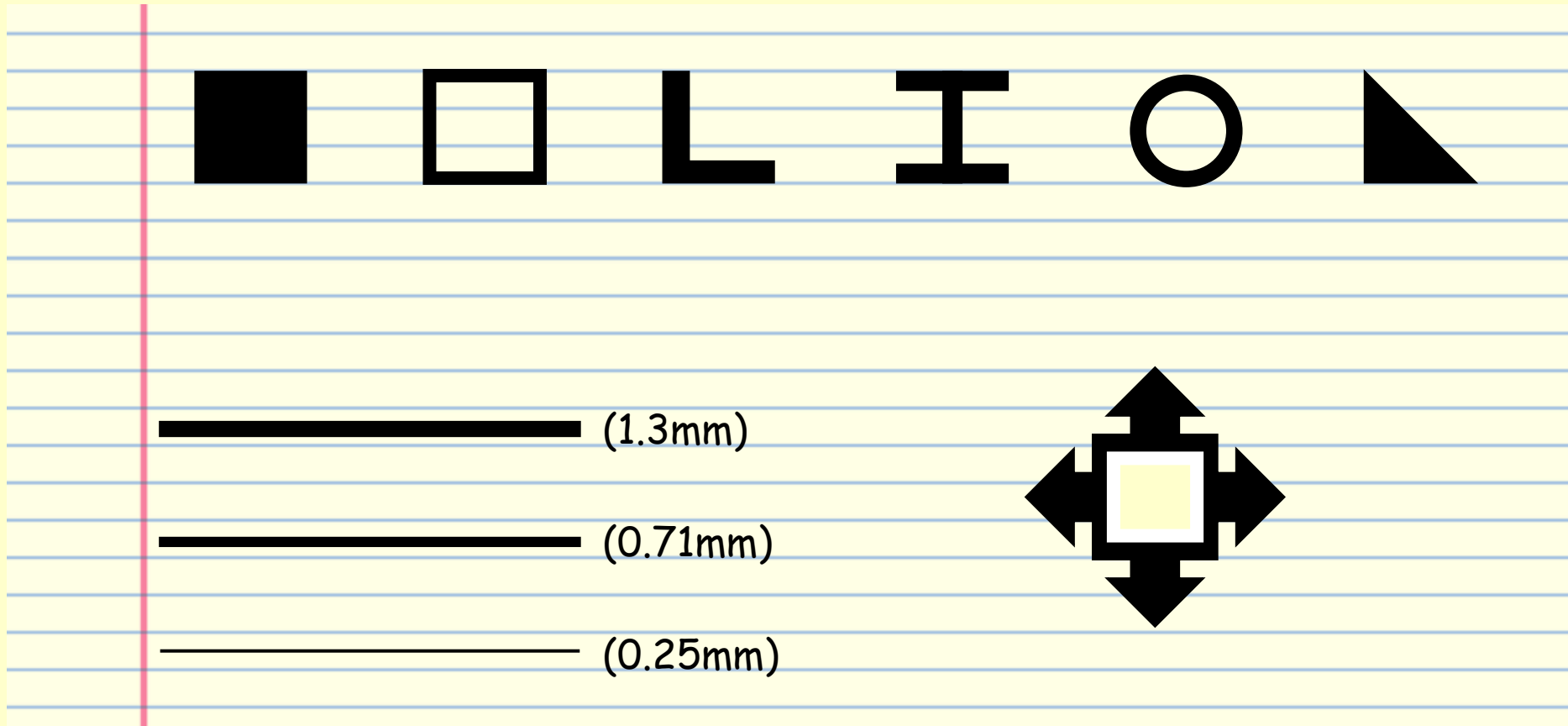
Sheet Gauge 30

Sheet Gauge 21

Sheet Gauge 16

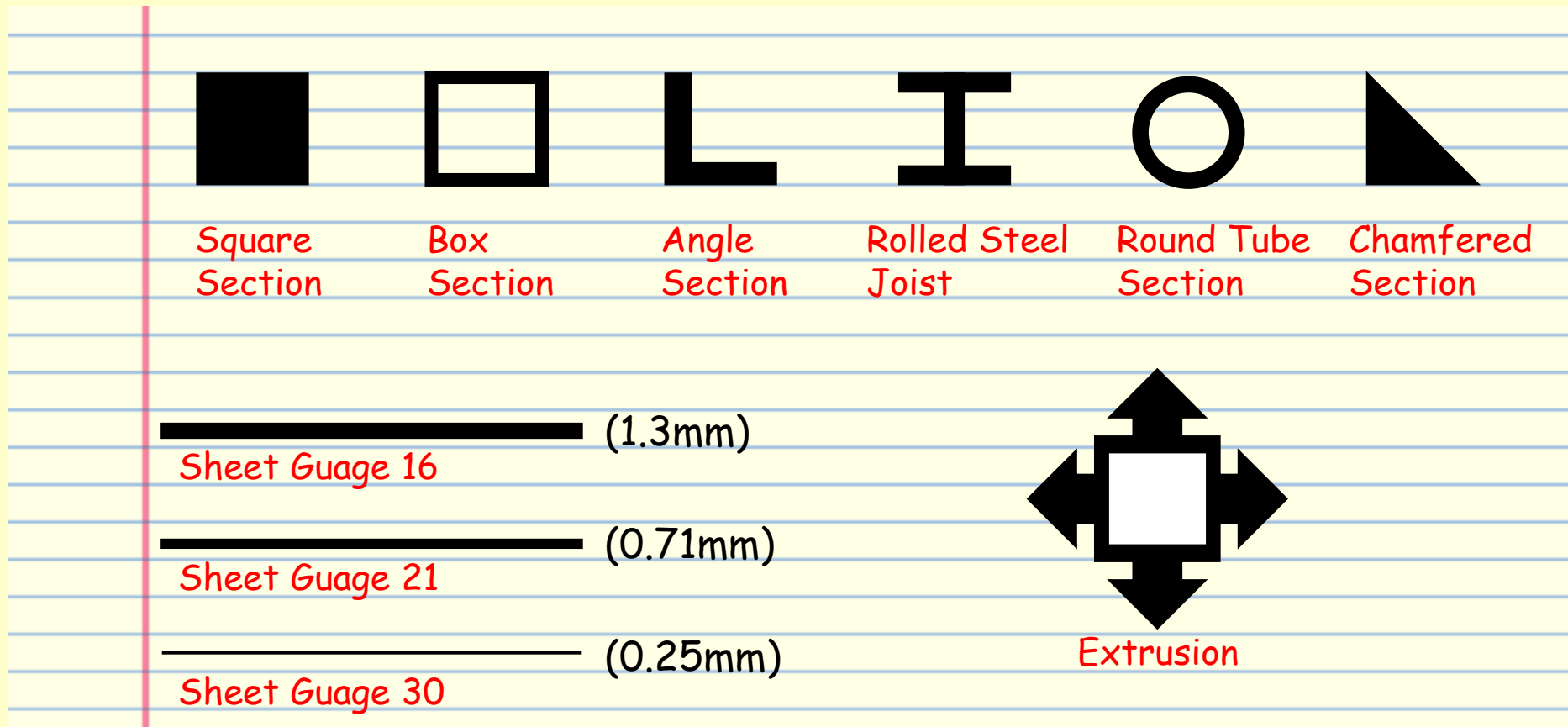
Rolled Steel
Joist

Round Tube
Section



Your turn...

Draw and label the below examples of metal stock forms;



Plastic Stock Forms

Plastic is an extremely versatile material with many different types of **plastic** available for many different purposes. The **stock forms** however do not differ too much from the metal **stock forms**.

We generally classify the **stock form** of **plastics** into the four categories below however, it is important to note there are other forms, due to the **versatility** of **plastics**, such as liquid or foams.



Plastic Sheet
and Films



Plastic Section
and Extrusions



Plastic Powders,
Pellets, Granules



Plastic Filament

Plastic sheets and films

Plastic sheets are measured by their actual **metric measurements**, generally starting at 1mm thick. They can be **formed or cut** to specific sizes for use in a variety of manufacturing processes. Common versions you may have used already are **HIPPS**, used in **vacuum forming**, or **acrylic** for the **laser cutter**.

Plastic films are in essence plastic sheets that are thin enough to be **rolled**. Useful for packaging, coverings, barriers, decoration etc.



5mm Cast
Acrylic



Plastic film
printed for
dog food
packaging

Plastic sections and extrusions

Plastics are also available in **sections** and **extrusions**, similar to metals, and are extremely common in modern living. Window frames, table edges and electrical trunking are all common examples found in classrooms.

Plastic extrusions are created by forcing **heated/liquid plastic** through a metal **die** with the desired profile. The **plastic** maintains its shape through a controlled cooling process and once cooled, is left with the wanted **cross-sectional shape**.



*PVC Pipe
created using
extrusion
process*

Plastic powders, pellets and granules

Plastic pellets and granules are the most common form of stock material used in industry. They are measured and costed by weight or volume and are used in injection moulding, extrusion, rotational moulding processes. They are heated until they liquify and then formed around a mould, solidifying as they cool.

Plastic powders are used more in compression moulding. This is where the powder is forced into a mould under high pressure and then heated to fuse the powder together (sintering).



HDPE
Pellets



PVC Powder

Plastic filament

Plastic filament is most commonly used in an **additive process** called 3D printing. It is bought in reels and fed into a 3D printer where it is **heated and extruded** through a nozzle.



3mm PLA
filament



3D Printer

Exam Questions

Complete the exam question below based on the Acrylic rod option;

The following are examples of different stock forms.

Stock forms				
Acrylic rod	Corrugated cardboard sheet	Aluminium sheet	Wool yarn	Medium Density Fibreboard (MDF)

14

Choose **one** of the stock forms in the table on **page 10**.

Name **one** of the primary sources it is made from.

In the box below, use notes **and/or** sketches to explain the process of changing it from primary source to stock form.

[5 marks]

Name of stock form

Acrylic Rod

Name of primary source

Crude Oil

Acrylic rod

- Crude oil is extracted from the ground
- Oil is transported by a tanker to an oil refinery
- Oil is put through a distillation process where heavy crude oil is separated into groups called 'fractions'.
- Polymerisation takes place
- Plastic is then extruded and then cut into small pellets.

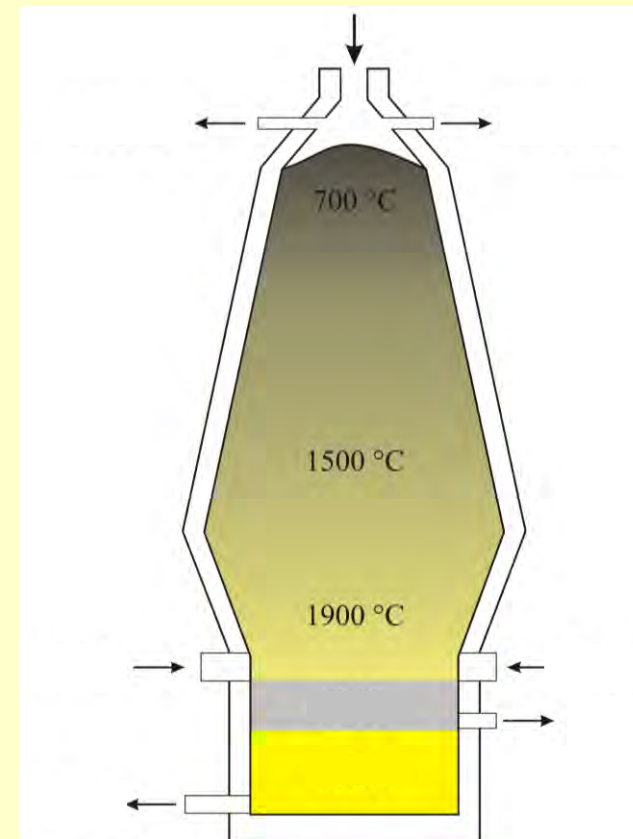
Unit 3.3 - Properties of Materials

In your books put in today's title and date and **underline them**.

Properties of Materials

Copy and label the below diagram;

Hot gases
Coke
Hot air
Iron Ore
Slag
Iron
Pig Iron
Limestone

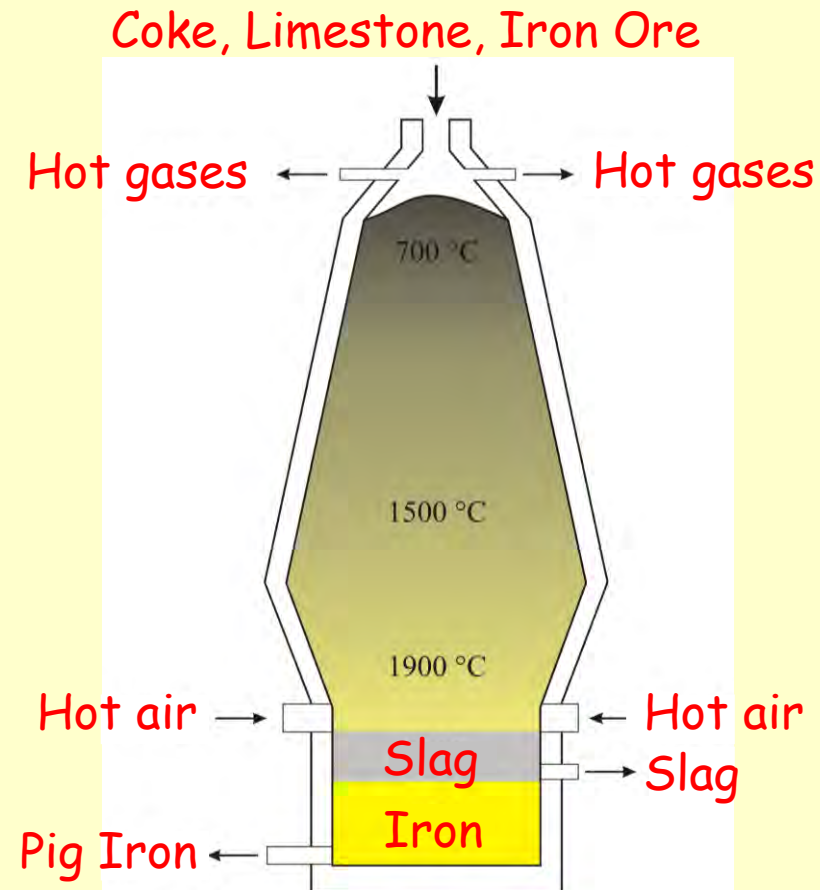


Unit 3: Lesson 3 Properties of Materials

In your books put in today's title and date and **underline them**.

Properties of Materials

Copy and label the below diagram;



Properties of materials

Understanding how different materials act is a fundamental skill needed by engineers. Engineers plan and design projects based on the properties they need, only then finding a suitable material.

PROPERTIES FIRST, MATERIAL SECOND

Material properties are a description of how the material reacts under different conditions. There are many different properties that can describe material reactions, with many being very complex. We are going to look at the most common with suitable examples of products they have been selected for.

MATERIALS &

WORKING PROPERTIES

Material Properties



Your turn...

Create the below table in your book, as we discuss the properties ensure you complete the table;

[illegible]

Properties of materials

Tensile strength

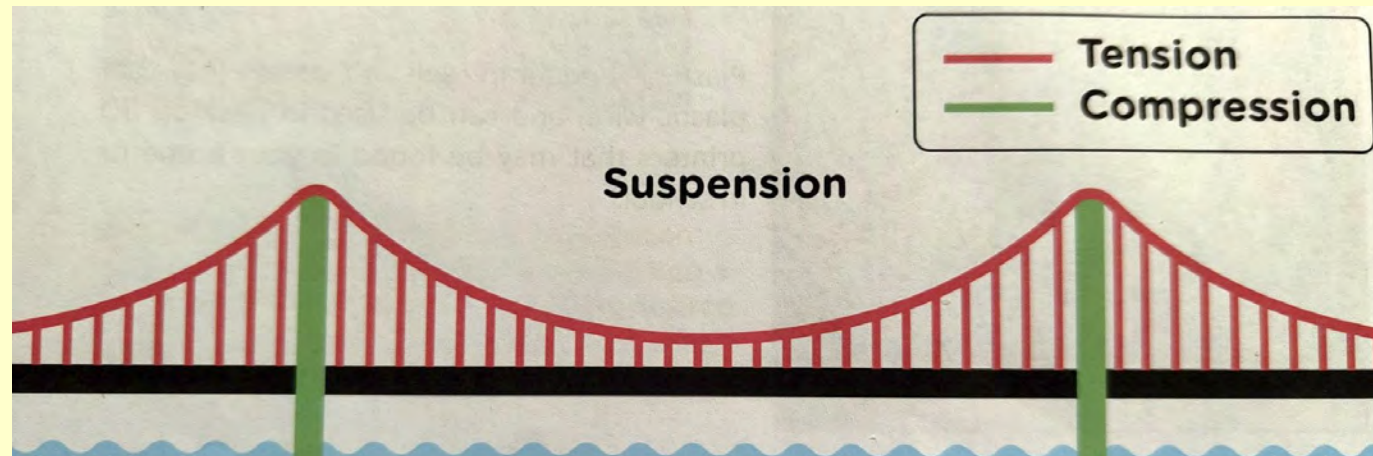
Describes how well a material **retains its strength when being stretched**.

In suspension bridges the cables hold the weight of the road and additional traffic and so need **high tensile strength**. **Steel** is a good material for this.

Compressive strength

Describes how well a material **maintains its strength when under heavy load or pressure**.

In suspension bridges the pillars hold the weight of the bridge itself, and the road and additional traffic. **Reinforced concrete** is a good material for this.



Properties of materials

Hardness

Describes how well a material **resists scratching, cutting or wear-and-tear**. Drill bits are used to cut through other hard material. **Tool Steel** is a good material for this due to its high carbon percentage.



Toughness

Describes the ability of a material to **not break when deformed, absorbing energy without fracturing**. Bus shelters are often hit and struck. **Polycarbonate plastic sheet** is a good material for these.



Malleability

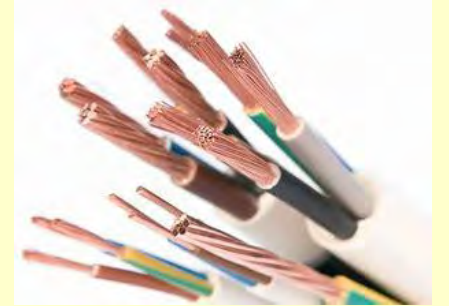
Describes the ability of a material to **be pressed, spread-out or hammered with ease**. Manufacturing jewellery involves bending and stretching for both design and size. **Gold** is a good material for this.



Properties of materials

Ductility

Describes how well a material **can be stretched and deformed without breaking**. Electrical wiring needs to be flexible and is often stretched. **Copper** is a good material for this and is also highly conductive.



Conductivity (Electrical)

Describes the ability of a material to **conduct an electrical current with little resistance**. High quality audio equipment will often use **gold** connectors. A more cost-effective method however is **copper** (as above).



Conductivity (Thermal)

Describes the ability and rate of a material to **conduct or transfer heat**. When cooking, an effective transfer of heat (from the hob) to the pan is very important. **Copper** is a very effective thermal conductor.



Properties of materials

Corrosion Resistance

Describes how well a material **can resist corrosion**. Many products are exposed continuously to water which will cause it to rust. **Stainless steel** is commonly used for products such as cutlery as it **resists rusting**.



Environmental Degradation

Describes the ability of a material to **resist corrosion and degradation in a specific environment**. Products left outdoors are subject to rust and UV exposure. **Aluminium** is used for as rotary washing lines as it **resists both**.



Elasticity

Describes the ability of a material to **regain its original shape after stretching or deformation**. Car tyres are under constant change from the road, turning, air pressure etc. A rubber compound has great elasticity.



Exam Questions

Complete the questions below;

Name the properties described;

1. Conduct an electrical current with little resistance,
2. Resists scratching, cutting or wear-and-tear,
3. Can be stretched and deformed without breaking,
4. Regain its original shape after stretching or deformation,
5. Retains its strength when being stretched.

Conductivity (Electrical)

Hardness

Ductility

Elasticity

Tensile

6. Describe environmental degradation,
7. Describe compressive strength,

Resists corrosion and degradation in a specific environment

Maintains strength under heavy load or pressure

8. Name the four key stock forms of plastic.

Plastic sheet and films

Plastic section and extrusions

Plastic powders, pellets and granules

Plastic filament

Unit 3.4 - Categories and Types of Materials Metals

In your books put in today's title and date and **underline them**.

Metals

Look at the pictures below. **Name a material(s)** and explain, using the **material properties**, why this material is a good choice for the product;



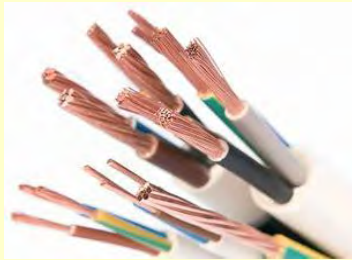
Unit 3.4 - Categories and Types of Materials Metals

In your books put in today's title and date and **underline them**.

Metals



Drill bits are often made from tool steel which has a high carbon content. This makes it ideal for drilling into other materials as it gives it the material property of hardness, meaning it can resist scratching and wear-and-tear.



Electrical wiring is made from copper. The wiring needs to be flexible and conduct electricity well. Copper can be stretched and deformed without breaking, making it ductile. It also has good conductive properties.

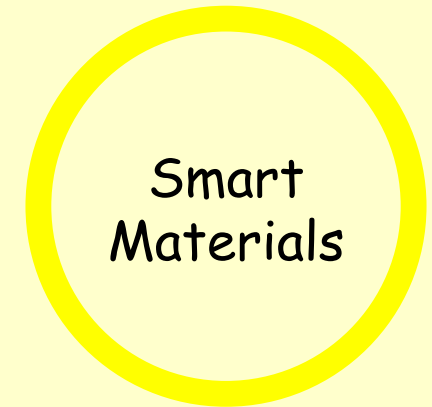
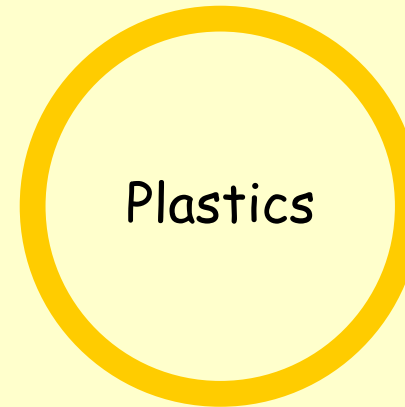
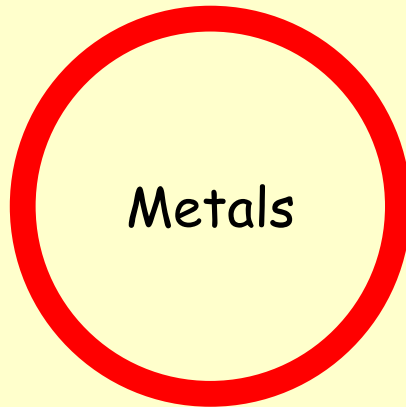


Suspension bridges are primarily made from steel and reinforced concrete. The steel has a high tensile strength meaning it can support the road, with the concrete pillars having good compressive strength meaning they can support both weight placed on it by the cables and road.

Metals

We now understand where materials come from, how they are prepared for projects (stock forms) and some of the properties used to describe different materials.

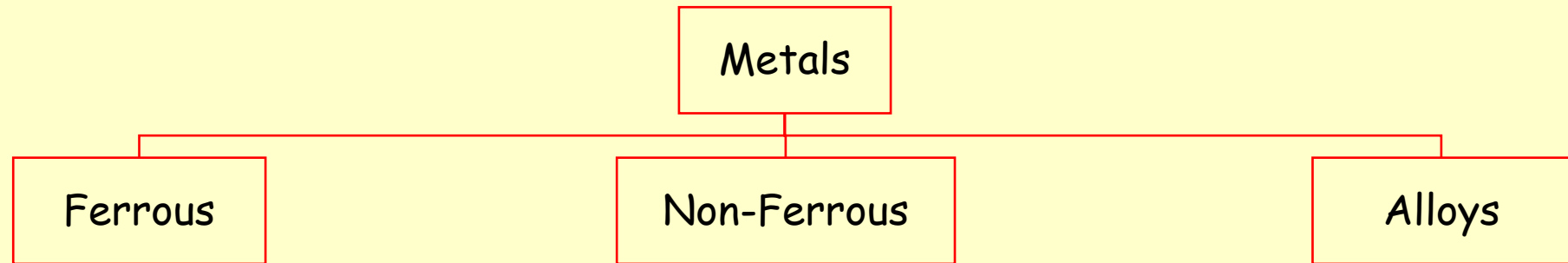
We are now going to look at the **categories of materials** a bit more in-depth. In the first lesson I told you there were four categories; **can you remember what they were?**



It is important to note that some materials **might fall into more than one category**, plastics for example are used often to also create composite materials.

Metals

We are firstly going to look at metals. These can be simply categorised into three areas;



Ferrous metals **contain iron**. Iron is a very soft metal and not very useful by itself. It is easy to remember by thinking about the periodic table - **Ferrous = Fe = Iron**.

Non-Ferrous metals **DO NOT contain iron**. Just as easy to remember by thinking about the periodic table again - **Non-Ferrous = No Fe = No Iron**.

Alloys are a **mixture of elements and metals**. They can be combined in many ways to produce an alloy with specific material properties.

Ferrous Metals

Ferrous metals come from **iron ore**, but on its own, **iron** is not very useful. To make it useful we must turn the **iron** into **steel** by adding small amounts of an element called **carbon**.

The result of the smelting process is an **iron** called **pig iron**. **Pig iron** is very **brittle** as it contains a **high amount of carbon**. By **refining pig iron** further, managing the mix of iron and carbon, we can create different types of **steel** with different **material properties**. Tool steel, for example (previously discussed) has a carbon content of 1.5-5%.

Ferrous metals can be identified in two ways. Firstly, **Iron rusts** when in contact with air and water. Secondly, **iron has magnetic properties**.



*Element
Carbon*



*Carbon Steel
Slab*

Non-Ferrous Metals

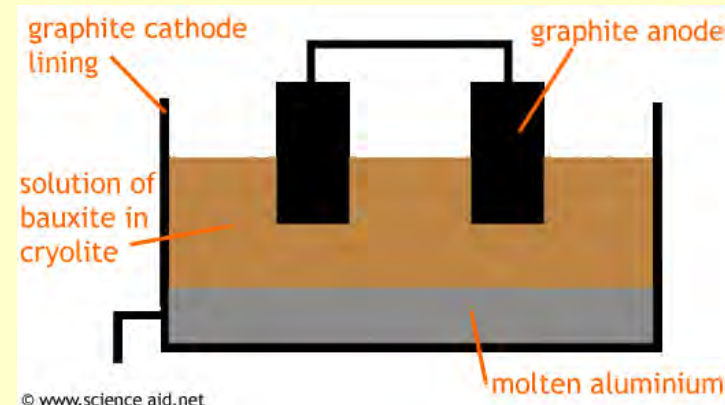
Non-Ferrous metals are metals that **DO NOT** contain iron.

There are many **non-ferrous** metals which have a variety of different properties. Some **non-ferrous** metals are **quite rare**, such as **gold**, but some are very common such as **aluminium**.

Non-ferrous metals are much more **expensive to extract and refine** compared to iron. This also makes the metal itself more **expensive to buy** and so they are not generally used in any big quantities of volumes even though their material properties may be useful. One exception to this is **aluminium** which is more common than iron.



Gold Ore



Aluminium extraction through electrolysis

Alloys

Alloys are elements that are melted, mixed together and then cooled. By managing this process, we can create **metals with specific properties**. **Alloys** are normally made with a '**parent metal**' which makes up most of the **alloy** mix. **Aluminium** is a very common **parent metal** for **alloys**.

We previously looked at **stainless steel** which is a ferrous metal that also **contains carbon** to increase its hardness properties. **Stainless steel** also includes the **alloying agents nickel and chromium**, both very resistant to corrosion. This then creates an **alloy** with increased hardness and corrosion resistance.



[How it's made - Alloy wheel](#)



[What is Stainless Steel? - YouTube](#)

Your turn...

You have two handouts listing some of the most common ferrous, non-ferrous and metal alloys. Read the first handout and use it to complete the second handout by extracting the key information/words.

Unit 3.4 - Categories of Materials Metals			
Ferrous Metal	Carbon content and other metals/elements	Material properties	Where it can be used
Mild steel	Mild steel is a very common and widely used steel. It is generally made from iron and a low carbon content (0.1-0.3% carbon).	Some of the more common properties of mild steel include toughness, good tensile strength and that it is easy to fabricate (shape, form and join) and weld.	It can be used for many applications, such as large building structures), as well as in a variety of products like cabinets, furniture, PC carcasses).
Tool steel	Tool steel is a very hard steel that is made using different manufacturing methods depending on what job it needs to perform. It can be made up from iron, a high carbon content (1.5-5%) and may include other metals.	Tool steel is very hard and therefore has great resistance to abrasion. It also holds its shape under high temperatures.	As a result of its hard properties, it is used for blades, chisels and machine parts.
Stainless steel (300 series)	Stainless steel can be made up from iron, a fairly high carbon content (0.03-1%) and often includes other metals, such as chromium.	Stainless steel is not only tough, but it also has fantastic corrosion resistance.	Due to its corrosion resistance, stainless steel is used for such as cutlery, surgical instruments and machine parts.

Unit 3.4 - Categories of Materials Metals			
Ferrous Metal	Carbon content	Other metals/elements	Properties
Mild steel	Low carbon content (0.1-0.3% carbon).	Iron	Toughness, Good tensile strength, Easy to fabricate.
Tool steel			
Stainless steel (300 series)			

Exam Questions

Complete the questions below;

Match the metal with the product (A9 = B9);

B6 A1 - Aluminium

B1 - Used in the aero-industry for expensive, lightweight engine components.

B5 A2 - Steel

B2 - Used by Aztecs for jewellery.

B2 A3 - Gold

B3 - Used for cooking utensils in modern cooking.

B1 A4 - Titanium

B4 - Used to make pipes and electrical cables.

B3 A5 - Stainless Steel

B5 - Used in the industrial revolution for bridge building and heavy machinery.

B4 A6 - Copper

B6 - Used for high performance cars, drink cans and aircraft wings.

Unit 3.5 - Categories and Types of Materials Plastics

In your books put in today's title and date and **underline them**.

Plastics

Copy and complete the table below;

Product	Metal	Ferrous/Non-ferrous	Properties
Twist drill	High Carbon Steel	Ferrous	Excellent strength, relatively cheap
Centre punch			
Radiator			
Electric cable			Ductility, electrical conductivity
Airplane wing		Non-ferrous	
Guitar string			

Unit 3.5 - Categories and Types of Materials Plastics

In your books put in today's title and date and **underline them**.

Plastics

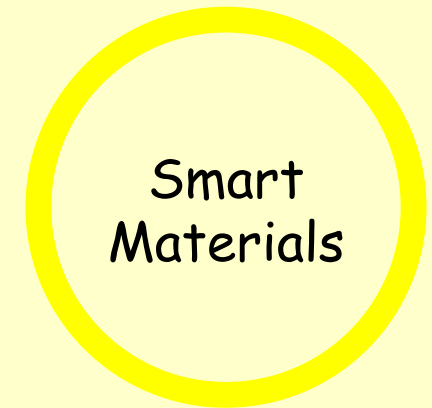
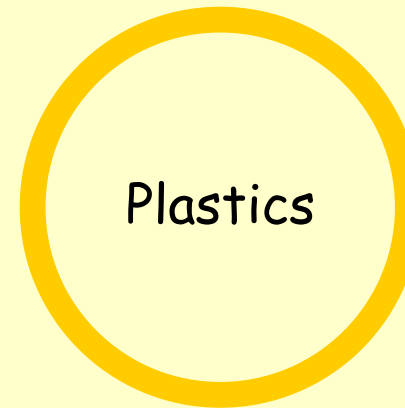
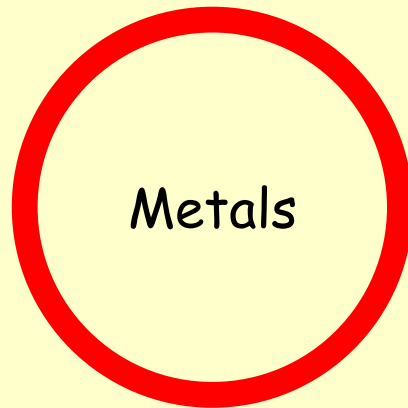
Copy and complete the table below;

Product	Metal	Ferrous/Non-ferrous	Properties
Twist drill	High Carbon Steel	Ferrous	Excellent strength, relatively cheap
Centre punch	Mild Steel	Ferrous	Toughness - Absorbs impact
Radiator	Aluminum, Steel, (Iron)	Non-Ferrous, Ferrous, (Ferrous)	Conductivity - Thermal (Durable)
Electric cable	Copper	Non-Ferrous	Ductility, Conductivity - Electrical
Airplane wing	Aluminium	Non-ferrous	Environmental degradation, Lightweight, Ductile
Guitar string	Steel Alloy (Nickel)	Ferrous	Tough, Ductile

Plastics

We now understand where materials come from, how they are prepared for projects (stock forms) and some of the properties used to describe different materials.

We are now going to look at the **categories of materials** a bit more in-depth. In the last lesson I reminded you that there are four categories; **can you remember all four?**

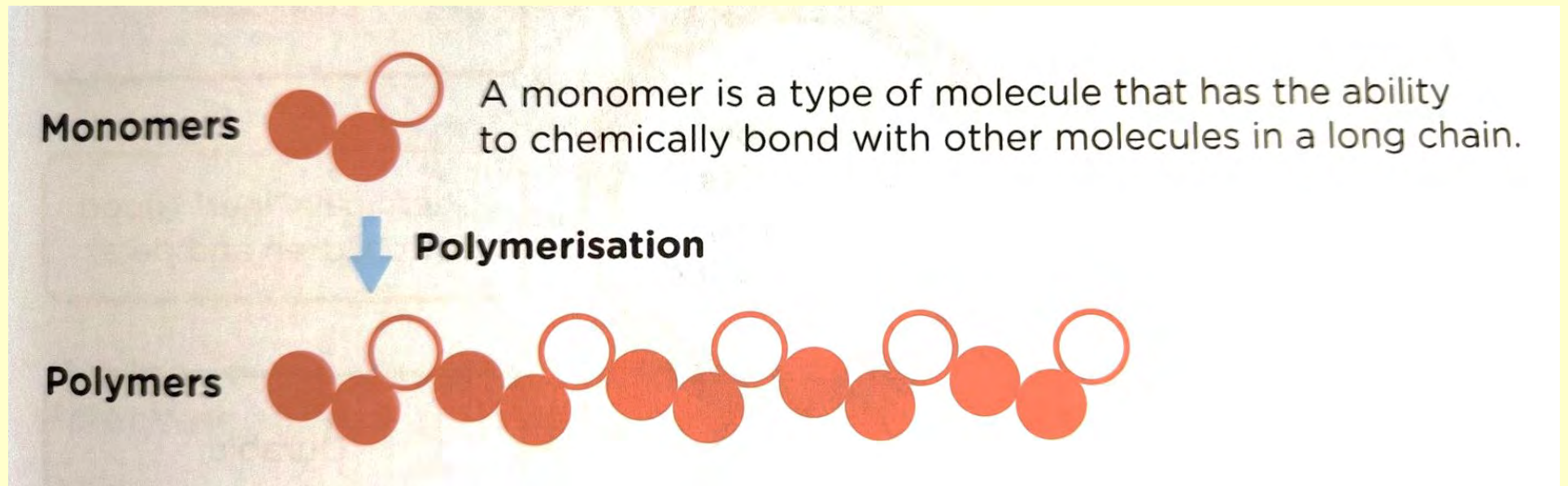


It is important to note that some materials **might fall into more than one category**, plastics for example are used often to also create composite materials.

Plastics

Plastics are also referred to as **polymers** (**Pol**ystyrene - Food packaging) and, as we know, are made from **naphtha** through a process called **polymerisation**.

Polymerisation turns **monomers** (mono - one) into **polymers** (poly - many). Effectively we join monomer molecules together to create polymers.



Plastics

Plastics are extensively used around the world due to their **versatility**. They can be manufactured at **low cost** and have **amazing properties** that natural materials cannot match.

Some of the benefits of plastic are;

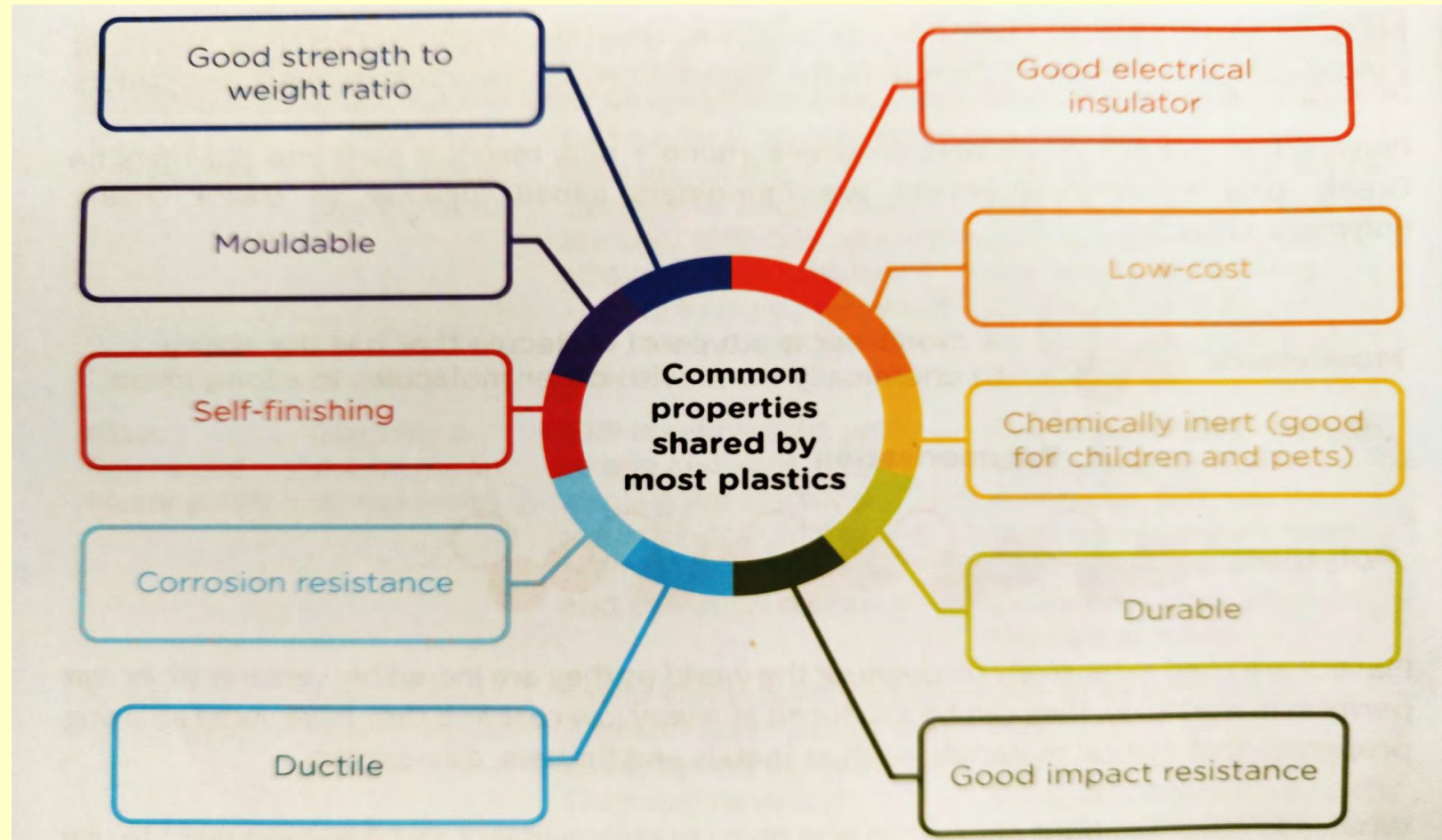
- Mould it into any shape,
- Very low environmental degradation,
- Manufacture in any colour,
- Finishes can be applied at manufacture,
- Strong and lightweight,
- Child safe, pet safe, food safe etc,
- Low cost,
- Rapid manufacturing (e.g. 3D Printing).

There is always however the environmental concerns to consider;

- Made from crude oil,
- Difficult to recycle.

Your turn...

Many **plastics** share some common properties, **complete your own version of the diagram below;**

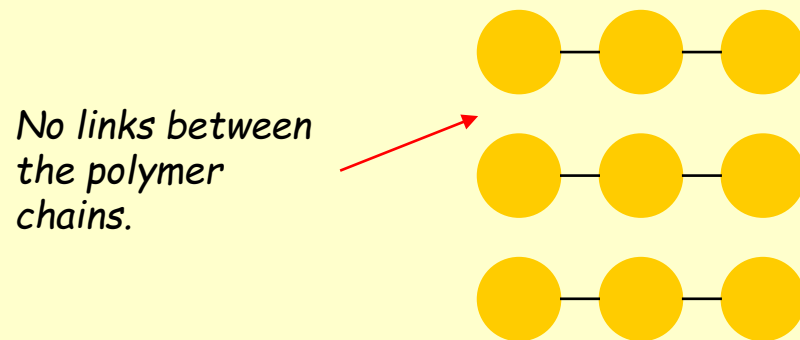


Plastics

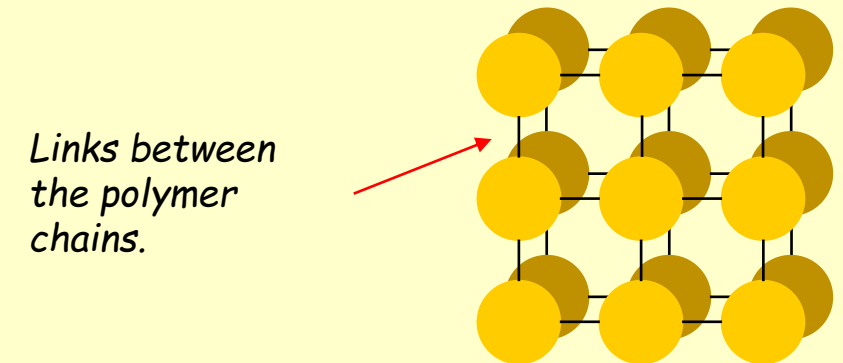
Generally, we use **two categories** to describe **plastics**;



Thermoforming plastics can be heated, moulded and then re-heated and re-moulded. They are also recyclable.



Thermosetting plastics cannot be re-formed once set and are more difficult to be recycled.



Your turn...

You have two handouts listing some of the most common thermoforming and thermosetting plastics. Read the first handout and use it to complete the second handout by extracting the key information/words.

Unit 3.4 - Categories of Materials Plastics

Thermoforming	Properties	Where it can be used
Acrylic	Good strength and stiffness, but can be brittle. Good optical clarity (easy to see through) and easy to fabricate (shape and make things from).	Acrylic has a vast range of uses, including clothing (thread), paints, signage and furniture.
Nylon	Nylon has very low friction capabilities, very good tensile strength and abrasion resistance.	Due to its low friction properties, nylon is commonly used for gears (cogs), clips, ropers and runners. It can also be formed into thread for clothing and luggage.

Unit 3.5 - Categories of Materials Plastics

	Name the material	Thermoforming Thermosetting	Properties
	Nylon	Thermoforming	Low friction, Good tensile strength, Abrasion resistant.
			

Exam Questions

Complete the questions below;

Write the five titles below in your books then list the correct materials under each title;

	Ferrous	Non-Ferrous	Alloy	Thermoforming	Thermosetting
Medium Carbon Steel			Stainless Steel		Phenol Formaldehyde
Aluminium			ABS		Tin
Cast Iron			Solder		Urea Formaldehyde
Polypropylene			Brass	Copper	Polypropylene
Urea Formaldehyde		Aluminium	Polyester	Polystyrene	Brass
Polystyrene		Copper	Phenol Formaldehyde	ABS	Solder
		Tin		Polyester	
Medium Carbon Steel		Lead	Cast Iron	Acrylics	Lead
Titanium		Titanium	Acrylics	PVC	Stainless Steel

Product	Metal	Ferrous/Non-ferrous	Properties
Twist drill	High Carbon Steel	Ferrous	Excellent strength, relatively cheap
Centre punch			
Radiator			
Electric cable			Ductility, electrical conductivity
Airplane wing		Non-ferrous	
Guitar string			

Product	Metal	Ferrous/Non-ferrous	Properties
Twist drill	High Carbon Steel	Ferrous	Excellent strength, relatively cheap
Centre punch			
Radiator			
Electric cable			Ductility, electrical conductivity
Airplane wing		Non-ferrous	
Guitar string			

Unit 3.6 - Categories and Types of Materials Composites and Smart Materials

In your books put in today's title and date and **underline them**.

Composites and Smart Materials

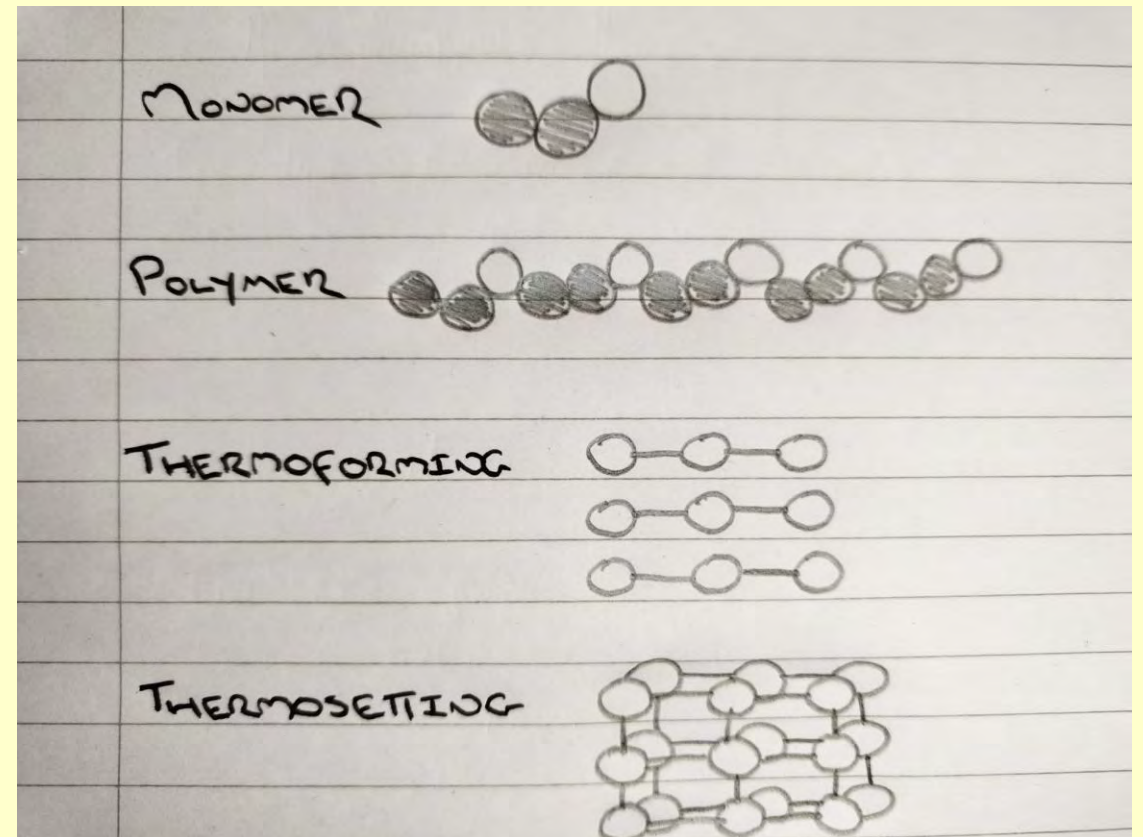
Draw and label the following;

A monomer molecule.

A polymer chain.

Thermoforming polymer chain.

Thermosetting polymer chain.



Composite Materials

Composite materials are a combination of materials manufactured to create a new material with specific properties.

Composite materials are generally bonded together during the manufacturing process with either an adhesive or resin.

Carbon fibres are the most common material used to form composites. They are mixed with a plastic resin and baked. This produces a new composite material called Carbon Fibre. Its properties include a **high strength to weight ratio** and high rigidity, but it can also be brittle.



Carbon Fibre



Composite Materials

There are five key composite materials that you will need to memorise. Let's take a look at what they are used for.

Used for...



Properties...

Excellent strength to weight ratio

Can be stiff/rigid

Corrosion resistant

Mouldable

Made from...

Carbon fibre sheets

Resin (epoxy resin)

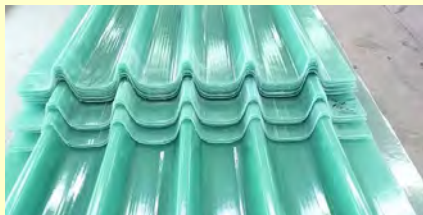
Name...

Carbon Fibre Composites

Composite Materials

There are five key composite materials that you will need to memorise. Let's take a look at what they are used for.

Used for...



Properties...

High strength

Rigid

Corrosion resistant

Made from...

Glass fibre sheets

Resin (epoxy resin)

Name...

Glass Reinforced Plastic
(GRP)

Composite Materials

There are five key composite materials that you will need to memorise. Let's take a look at what they are used for.

Used for...



Properties...

High strength to weight ratio

Can be stiff/rigid

Lightweight

Made from...

Kevlar fibres/sheets

Resin (epoxy resin)

Name...

Kevlar Composites



High heat resistance

High impact resistance

Composite Materials

There are five key composite materials that you will need to memorise. Let's take a look at what they are used for.

Used for...



Properties...

Good strength to weight ratio

Can be stiff compared to natural timber

Low-cost

Made from...

Timber

Adhesives

Name...

Engineered Timber



Durable

Composite Materials

There are five key composite materials that you will need to memorise. Let's take a look at what they are used for.

Used for...



Properties...

Excellent compressive strength

Very durable

Mouldable

Low-cost

Fire resistant

Made from...

Cement

Sand

Aggregates (gravel)

Steel reinforcing bars

Name...

Reinforced concrete

Your turn...

Complete the composites handout;

Unit 3.6 - Categories of Materials Composites

Composite Name	Made From	Properties	Uses
Carbon Fibre Composites	• •	• • Can be stiff / rigid • •	• • • Sport equipment - Tennis rackets
Glass (GRP)	• • Resin (Epoxy Resin)	• • •	• • • Electrical cabinets
	•	•	• Bullet / stab vests

Smart Materials

Smart Materials are also known as intelligent materials. **They change their material properties in response to changes in the environment.**

One of the best examples of a smart material is commonly referred to as 'reactor light'.



Reactor light glasses respond to sunlight to change into sunglasses.

These glasses have a photochromic lens that changes their property when the environment changes. Environment gets brighter - lens darkens.

Photo = Light

Chromic = Colour

Light changes the colour



Smart Materials

Based on photo = light and chromic = colour. What do you think thermochromic pigments do?

Thermochromic pigments change their properties based on the environment also, however this time it is **colour changes** due to **temperature changes**. Thermochromic pigments can be applied to paints, inks, plastics etc. They are often used with indicators such as batteries and thermometers, or with safety in mind, such as babyspoons.



Duracell powercheck



Colour changing baby spoon

Smart Materials



Smart Materials

Nitinol is a **Shape Memory Alloy (SMA)** that will change its shape if there are changes in temperature in the immediate environment. **Nitinol is an alloy of nickel and titanium** and is commonly used for medical purposes. Heart stents for example are made from **Nitinol** - they are cooled, inserted into arteries and then expand as they are warmed by the body temperature of the patient. Other uses include flexible glasses or braces.



SMA Glasses



Nitinol braces

Smart Materials

D30 is a rubbery foam substance that reacts against an incoming force. It is very flexible and so it can be moulded into many forms, most commonly human forms. Once it is struck it becomes rigid with **very high impact resistance**, this makes it ideal for **protective equipment** such as sportswear, bike/skateboard helmet and pads etc.



Photochromic- Changes due to light. Glasses to sunglasses.

Thermochromic- Changes due to temperature. Thermometer,

SMA Smart Memory alloy- Changes back to original shape due to temperature. Glasses frames

D30- Foam /Putty state under normal conditions. Hardens under impact.
Amour.

Exam Questions

Complete the questions below;

1. A smart material changes its properties according to changes in the environment in which it is functioning.

2. Name two smart materials.

Photochromic, Thermochromic, Shape Memory Alloy (SMA) Nitinol, D30

3. Name two composite materials and give a use for each material.

Carbon Fibre Composites, Glass Reinforced Plastic (GRP), Kevlar Composites, Engineered Timber, Reinforced concrete

4. Explain the difference between an alloy and a composite.

Any alloy is made from two or more metal based materials/elements heated and mixed. A composite is made from materials that are bonded together.

Unit 3.7 - Bought-in Components and Finishes

In your books put in today's title and date and **underline them**.

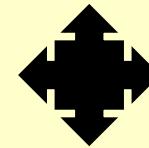
Bought in Components and Finishes

Complete the questions below;

1. Name the following stock forms:



RSJ



Extrusion



Sheet/Film



Pellets

2. Give a metal suitable for the following products:

Drill bit - **Tool Steel**

Electric cable - **Copper**

Airplane wing - **Aluminium**

3. Name the property: *Describes the ability of a material to not break when deformed, absorbing energy without fracturing.* **Toughness**

Bought-in Components

A **bought-in component** is any component needed to complete a project that has been **purchased from a different company** than the original engineers.

It is common practise for engineers to use **bought-in components** in projects. The engineers will create a solution to a problem, design the product itself and dictate things such as the production processes. **They can then buy-in standardised components to assemble the solution, cutting down time and costs for all involved.** Think about IKEA and their use of standardised knock down fittings - Different products, same components.



*Example component set
from IKEA*

Bought-in Components

If an engineer was asked to develop seating for a football stadium they could;

- Use mild steel for the structure - easy to shape and join (fabricate), low cost,
- Use polypropylene polymer chairs - durable and corrosion resistant.

Then they could simply state in their planning that they are to be assembled using 40mm M12 Hex Bolts. These can be bought from numerous suppliers.

This of course is a very simplified example!



40mm M12
Hex Bolt



*Polypropylene stadium
seating on a mild steel
frame.*

Bought-in Components

Depending on the materials being fabricated there are numerous **bought-in components** available to engineers. When working with metal-based solutions then the most common are **hinges, screws, nuts, bolts and rivets**.



Polymers also use a similar range of **bought-in components** (hinges, screws, nuts and bolts), however **due to the properties of plastics these can look quite different**. Plastics can be moulded into more intricate shapes and many thermoformed plastics retain their plasticity when cooled. They can also be joined using adhesives.



Your turn...

In your books create your own definition of brought-in components.

Give an example different from the ones we have discussed.

Sentence Starters;

Brought-in components are...

Some companies use brought-in components. These are...

An example of using brought-in components could be...

Create a list of what you think might be the advantages of using brought-in components.

Advantages of brought-in components

- Less time designing fixings for the product,

Bought-in Components

There are two key advantages of using bought-in components, both of which are very important to companies regardless of the project at hand. Make sure you have recorded both advantages in full.

Save money - Removing the need to manufacture the components also removes the need for additional machinery. This in turn reduces the overheads for the business. It also reduces the number of staff needed both to operate the machines and train the operators. Production space and warehouse space can be reduced.

Quality - Bought-in components are generally manufactured by businesses who specialise in the components themselves. This ensures that the quality and consistency of each component is of the best quality. It is not uncommon to purchase components from many specialised companies.

Finishes

Once a material has been manufactured it often goes through a process called 'finishing'.

The **finishing process** is dependent on the material, and the role the material plays in any project or product. There are three main reasons why materials will go through a **finishing process**;



Protection

*UV resistance,
corrosion resistance*

Aesthetics

*Make it more
appealing to look at*

Functionality

*Applying surfaces for
extra grip etc*

Your turn...

Read the descriptions of metal finishes on the hand out. Draw a line to match them to the correct picture.

Answers -

Read the remainder of the handout and stick it in your book.

Finishes for metal	
	Hot dip galvanising - Used on ferrous metals such as steel to prevent corrosion. The metal is dipped into a bath of molten zinc which coats the surface, making it corrosion resistant. The thickness of the zinc layer is controlled by an electric current.
	Abrasive sheets - Non-ferrous metals are often scratched or dirty when they have finished being manufactured/processed. Sheets such as 'wet and dry' are used to smooth and finish the surface. Sheets range from very coarse (60 grit) to very fine (7000 grit).
	Painting - Following an undercoat of primer, paint can be applied to metal for both aesthetic and protective reasons. Available in a variety of colour it needs to be continually applied if used outdoors. Bridges, ships, buildings all have paint applied.
	Plastic dip coating - Mainly used on ferrous metals to protect from corrosion and provide an easy grip surface. The metal is heated then dipped into a plastic powder which melts onto the surface of the metal. Garden hooks, tool handles are commonly dip coated.
	Enamelling - This is the process of covering metal surfaces with a fine glass powder that is then heated until it melts onto the metal. This creates a glass, shiny barrier on the surface of the metal for both aesthetics and corrosion resistance. Some commonly enamelled products are cups, plates and jewellery.
	Powder coating - Similar to dip coating but instead of the metal being heated and dipped, the powder is sprayed onto the metals. Many white goods such as fridges and washers are powder coated, it can also be used to protect outdoor products such as bike frames.
	Anodising - This process is mainly used on Aluminium. Anodising uses an electrochemical process to increase the thickness of the naturally protective oxide layer of the aluminium. Coloured dyes can be added to the process to create more aesthetic looking products. It is commonly used on bike parts, watches etc. Any aluminium product used outdoor.
	Buffing - Otherwise known as polishing, it is used on many surfaces to remove any smudges that appear through the manufacturing process. It can be used following other finishing processes such as painting. It uses a cloth and can be done by hand, or, by using a buffing machine which works at high rotations per minute (RPM).

Finishes - Plastics

Metals and woods can have finishes applied after the manufacturing process, for plastic however, it is much more common to **apply the finish during the manufacturing process**. This is what we refer to as **self-finishing**.

The **self- finishing** nature of plastic means that companies do not have to buy extra machinery, space or workforce, thus maintaining their low cost.

The finish of the plastic is dependent on the mould used during manufacturing. **Any texture is created as part of the mould, the heated plastic will then take this shape**. The only exception to this is when the plastic needs to be painted for aesthetic purposes, for example car body parts.



Car body part being painted

Exam Questions

Complete the questions below;

1. List the five standard components given for metals.

Hinges, screws, nuts, bolts, rivets.

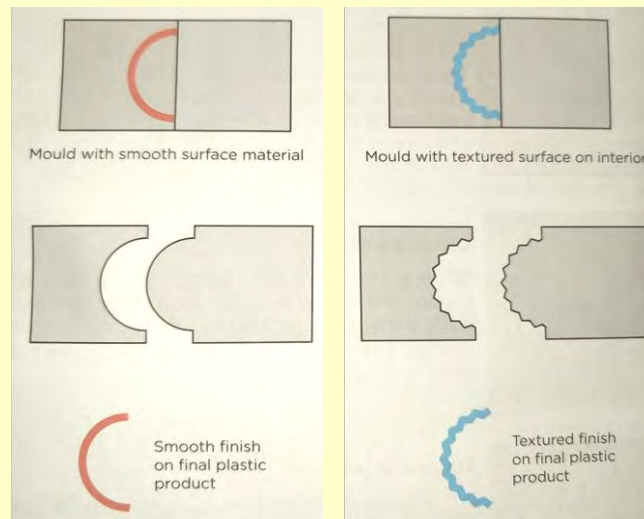
2. Name five finishes for metals.

Painting, Plastic dip coating, Powder coating, Hot dip galvanising, Abrasive sheets, Buffing, Anodising, Enamelling

3. Name the four finishes for woods.

Varnish, Paint, Oils and Waxes, Stains and Preservers

4. Explain using a diagram how plastics are self-finished.



Unit 3.8 - Testing

In your books put in today's title and date and **underline them**.

Testing

Complete the questions below;

1. Explain the property *toughness*, give an example product in your answer.
Describes the ability of a material to not break when deformed, absorbing energy without fracturing. Bus shelters are often hit and struck. Polycarbonate plastic is a good material for these.
2. Explain the property *hardness*, give an example product in your answer.
Describes how well a material resists scratching, cutting or wear-and-tear. Drill bits are used to cut through other hard material. Tool Steel is a good material for this due to its high carbon percentage.
3. Name a suitable plastic for the pictured images below;



Urea Formaldehyde



Nylon



Carbon Fibre



Kevlar

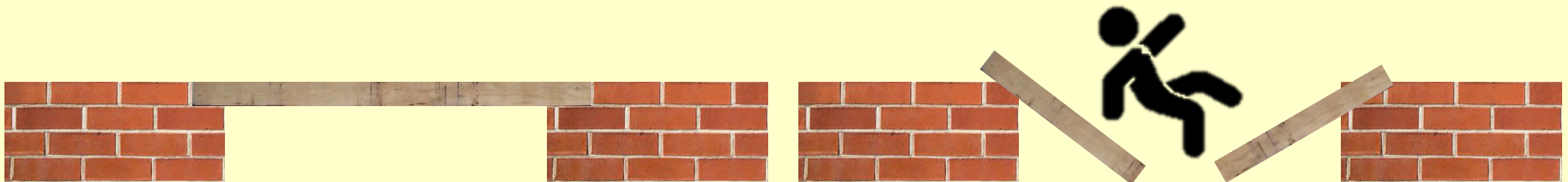
Testing Materials

At the start of this chapter, we explained the principle of '*Properties First - Material Second*'. An engineer will decide what **properties** are needed for the material before selecting the material itself.

Through **testing** we can **accurately predict** how materials will react to certain conditions, this allows the engineer to **select materials based on the properties demonstrated**.

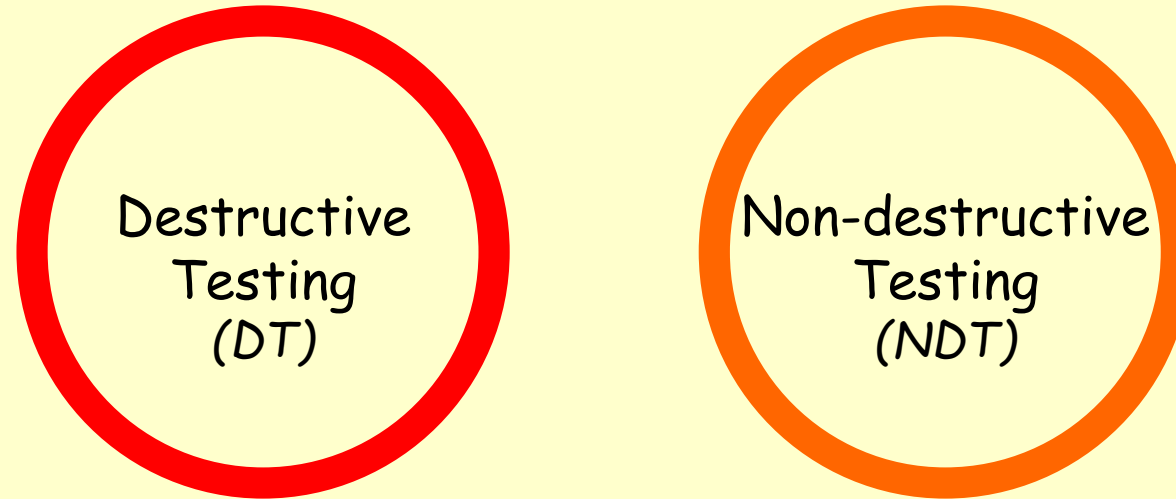
A bridge is often used to span a gap. An engineer might measure and cut a material to lay over the gap.

This material might be fine until a person tries to walk over it. The material is then **having a force applied to it** (the weight of the person). If the material does not have the **required properties**, then the material will fail. To avoid this, we test the materials first.



Testing Materials

Testing is normally performed in two ways;



Destructive testing is where the **material** is tested until the point that it 'breaks' or **fails**.

Non-destructive testing is where the **material** is tested **without** causing the material to **fail**.

Two companies at the forefront of their industries, Space X and Mercedes AMG Petronas, spend millions of pounds on testing every aspect of their products.





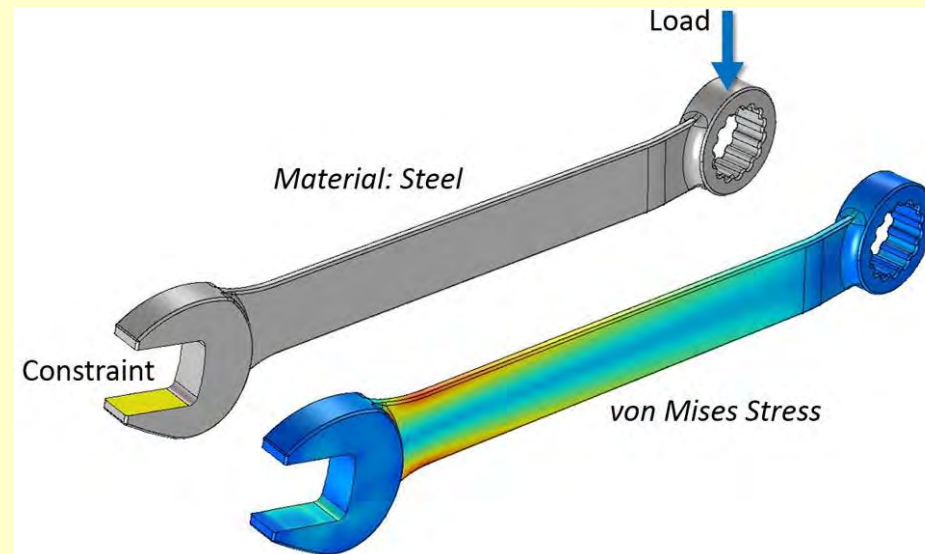
HOW IT WORKS

NON-DESTRUCTIVE TESTING

Testing with CAD (Computer Aided Design)

There are numerous ways to **test**, both destructive and non-destructive, the properties of materials. Many engineers are now very highly trained in **CAD** and can use the software to **test their product models before any physical model has been produced**.

Once a CAD model has been made, the engineer can specify the material and test it in a virtual world. The software holds information on the material and its properties, most importantly it also knows the failure limits. **This type of testing, or simulated testing, is called Finite Element Analysis (FEA).**



Example FEA screenshot

Testing with CAD (Computer Aided Design)

FEA also allows engineers to edit and re-test their design continuously. This enables them to adapt to changing specifications and also allows them to include what is known as a **Factor of Safety (FoS)**.

For example, an engineer might have a brief to design a bike frame to hold a person weighing 200kg. They would then test their design using FEA until failure.

The engineer would then use this data and tweak their design, perhaps making the frame slightly thicker, then re-test until the frame holds a rider of 400kg. **This is known as adding in a factor of safety.**

In this example the new frame now has a FoS of 2. How did I work this out?

Initial weight specified = 200kg, Safe weight tested through FEA = 400kg, $200\text{kg} \times 2 = 400\text{kg}$

All engineered products (bridges, cars, aeroplanes) include a FoS incase of unexpected loads.

Workshop Testing

In a workshop environment there are some simple tests that you can conduct for certain properties of materials.

All of the tests are listed on the handout. You will now have a go at performing a couple of the tests below. **You should know how to explain these tests using notes and a diagram.**

The properties that you will be testing for are;

- **Tensile Strength** - How well a material retains its strength when being stretched,
- **Hardness** - The ability of a material to resist scratching,
- **Toughness** - The ability of a material to not break when deformed,
- **Malleability** - The ability of a material to be pressed, spread out or hammered with ease,
- **Ductility** - The ability of a material to be stretched and deformed without breaking,
- **Electrical Conductivity** - The ability to transmit/conduct electrical current,
- **Thermal Conductivity** - The ability of a material to conduct or transfer heat,
- **Elasticity** - The ability of a material to regain its original shape once it has been stretched.

End of Chapter Assessment

This concludes all the topics we need to complete in Unit 3, Chapter 1. Next lesson we will complete and end of chapter assessment.

To help you revise there is a revision booklet with mock questions. It is important to take the time to **revise properly**. Read the information in the booklet and try to complete each question. The answers are in the back of the booklet for you to mark your own revision.

Using the correct vocabulary and spelling is important in your assessment. Make use of the key word list on the front of the booklet, for example a rock is not an ore, just like ferris [wheel] is not the same as ferrous.

There are also QR codes so you can re-watch the videos we have used in lesson.

You will have 30 minutes to complete the assessment and the pass mark is 60%.

Surname	Centre Number	Candidate Number
First name(s)		4



LEVEL 1/LEVEL 2 AWARD

9793/01



TUESDAY, 12 JANUARY 2021 – MORNING

ENGINEERING – Unit 3 Solving Engineering Problems (VOCATIONAL)

1 hour 30 minutes

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	24	
2.	16	
3.	20	
Total	60	

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ADDITIONAL MATERIALS

In addition to this paper you may require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. Where the space is not sufficient for your answers, continue at the back of the booklet, taking care to number the continuation correctly.

INFORMATION FOR CANDIDATES

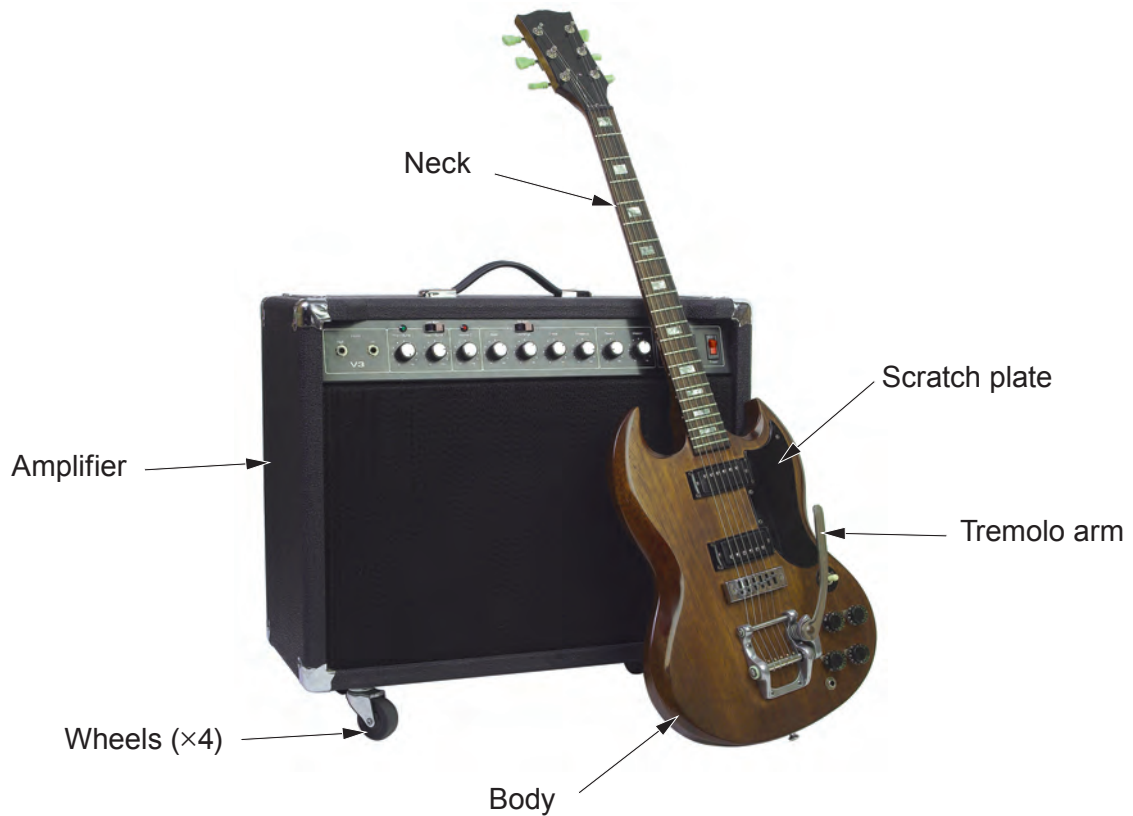
The total number of marks for this paper is 60.

The number of marks is given in brackets at the end of each question or part-question.

You are reminded of the necessity for good English and orderly presentation in your answers.

*Answer **all** questions in the spaces provided.*

1. The image below shows an electric guitar and amplifier.



Several parts on an electric guitar are manufactured using CAM (Computer Aided Manufacture).

- (a) (i) Give **one** advantage of using CAM to manufacture the parts. [1]

.....

- (ii) Give **one** disadvantage of using CAM to manufacture the parts. [1]

.....

- (b) The Scratch plate has been manufactured from 2 mm thick HIPs (High Impact Polystyrene).

State **two** properties or characteristics of HIPs that make it a suitable material to manufacture the scratch plate. $2 \times [1]$

Property/Characteristic 1:

.....

Property/Characteristic 2:

.....

- (c) Describe **two** ergonomic considerations that could affect the design of the electric guitar. $2 \times [2]$

Description 1:

.....

Description 2:

.....

- (d) The main body of the Amplifier has been manufactured from a wood effect composite material.

Explain why a composite material would be used to manufacture the Amplifier body. $[2]$

.....

.....

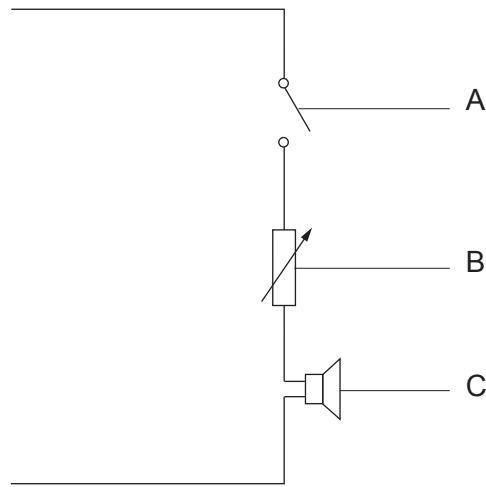
- (e) Name a suitable material for the wheels of the Amplifier and justify your choice. $2 \times [1]$

Name of material:

Justification:

.....

(f) The electronic circuit shown below, is part of the main circuit of the Amplifier.



(i) Complete the table below.

Component	Name of component	Function in the circuit
A	.....	.....
		
	[1]	[1]
B	.....	.....
		
	[1]	[1]
C	.....	.....
		
	[1]	[1]

- (ii) Using notes and sketches, explain the soldering process of any component to a circuit board. [6]

Examiner
only

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24

2. Engineers are often asked to develop new products to enhance the environment we live in. Shown are three examples of different modern bollards that can be seen in high streets and town centres.



- (a) Describe **two** ways in which modern technology has had an impact on the design and function of modern bollards. 2 × [2]

.....

.....

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- (b) Discuss **two** different Health and Safety issues that should be considered in the design of modern street bollards. 2 × [2]

Issue 1:

.....

.....

Issue 2:

.....

.....

- (c) Write **two** justified specification points a design engineer would have to consider when designing a new bollard. [4]

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- (d) Evaluate how using recycled plastics, as in the black bollard shown, can lessen the environmental impact. [4]

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3. The pictures below show two pieces of equipment, usually found in a workshop.

- (a) (i) Complete the table below by correctly naming **each** piece of equipment and write a description of its use.

Engineering equipment	Equipment name	Equipment use
	 [1]	 [1]
	 [1]	 [1]

- (ii) The health and safety signs shown below are displayed in a workshop to remind pupils of the specific dangers.

State the meaning of each sign.

[2]

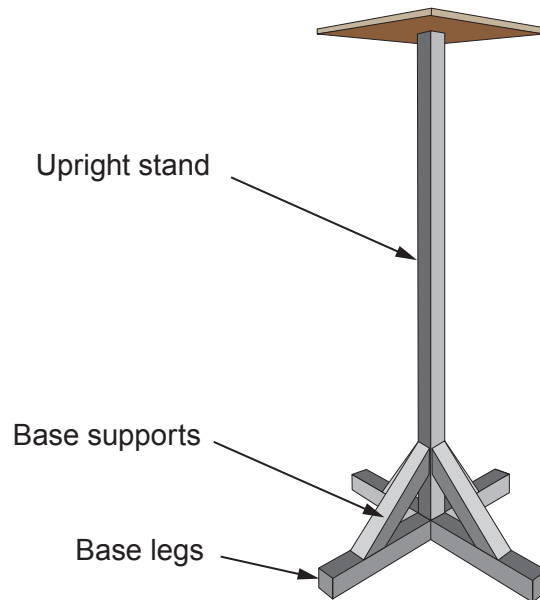


Meaning:



Meaning:

- (b) A group of students want to manufacture a bird table for their school garden area. It will be manufactured from 40 mm × 40 mm mild steel square tube and plywood board.



Description / Part	Number Required	Size (each)
Base legs	4	250 mm
Base supports	4	200 mm
Upright stand	1	1500 mm

The mild steel square tube costs 82 pence per 100 mm length.

You must show all your calculations.

- (i) Calculate how much mild steel is required to make **one** bird table.
Show all calculations.

[2]

.....

.....

.....

.....

.....

- (ii) Calculate the overall cost of making **one** bird table.
Show all calculations.

[2]

.....

.....

.....

.....

.....

- (iii) A new supplier has reduced the cost of the mild steel by 20%. What would be the new cost of making **one** bird table?
Show all calculations.

[2]

.....

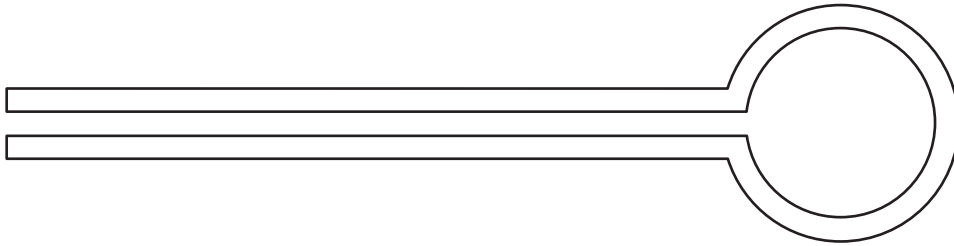
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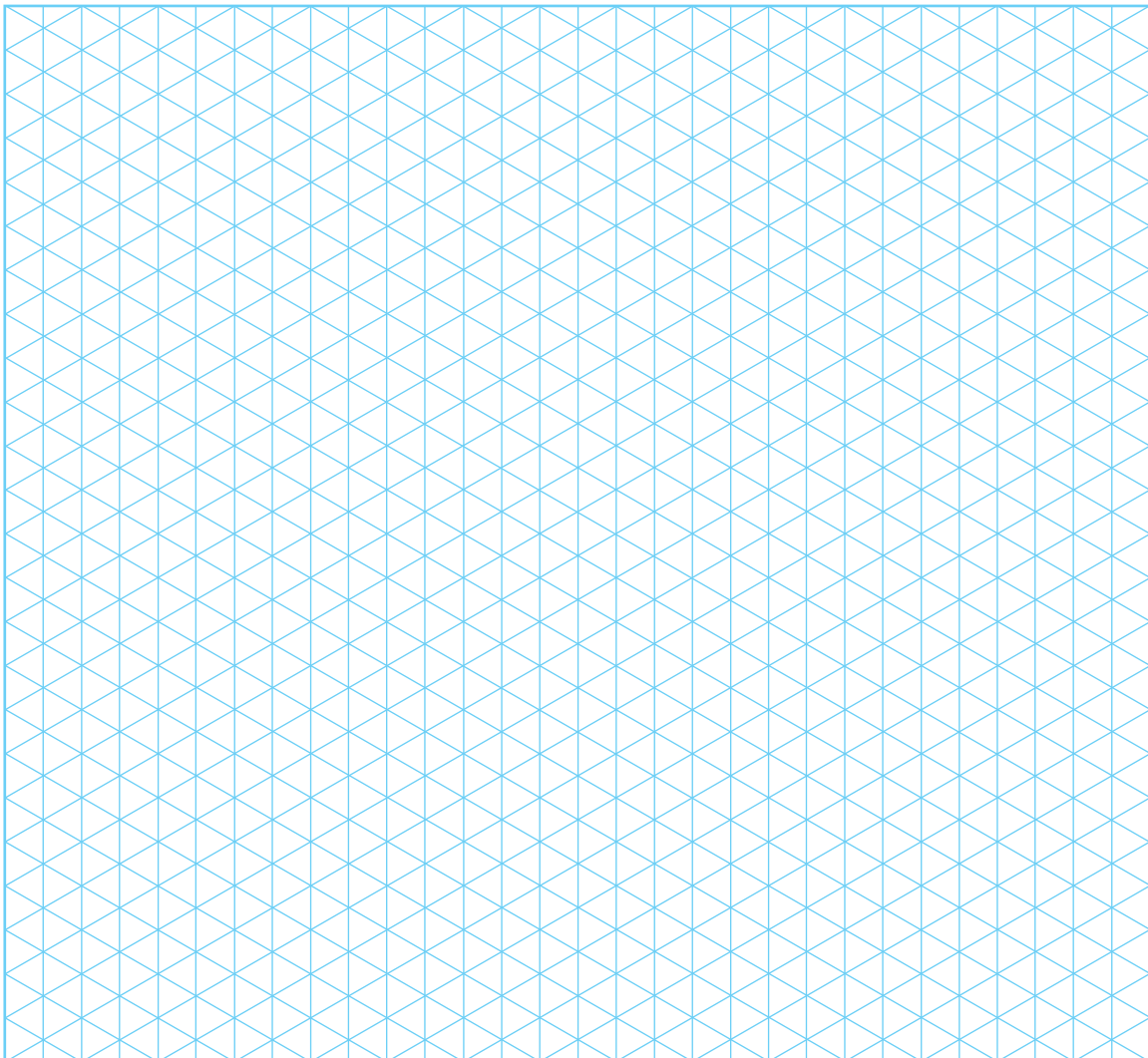
.....

- (c) Below is an orthographic projection of a folding bar.



In the space below sketch the folding bar in isometric.

[8]



END OF PAPER

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LEVEL 1 & 2 MARKING SCHEME

WINTER 2021

**LEVEL 1 & LEVEL 2
ENGINEERING - UNIT 3
9793/01**

INTRODUCTION

This marking scheme was used by WJEC for the 2021 examination. It was finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conference was held shortly after the paper was taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conference was to ensure that the marking scheme was interpreted and applied in the same way by all examiners.

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LEVEL 1 & 2 ENGINEERING
UNIT 3 - SOLVING ENGINEERING PROBLEMS
WINTER 2021 MARK SCHEME

Question	Answer	Marks
1. (a) (i)	One mark available. Consistent shape to all designs. Accurate cut on every guitar body. Faster to manufacture than by using conventional tools. Every finished product is identical. Accept any reasonable answer that is appropriate.	1
(ii)	One mark available. One error on the design could delay production. High initial set up cost. Expensive software. Staff training costs. Accept any reasonable answer that is appropriate.	1
(b)	Two marks available. Easy to cut using CAM. Available in a range of colours. Tough when struck with the plectrum/hand. High quality finish (aesthetic reason) Accept any reasonable answer that is appropriate.	2
(c)	Four marks available. Length of neck. Size of machine tuning heads. Width of neck. Shape of body. Thickness of guitar body. Size / diameter of volume/tone knobs. Position of strap holders. Lower body cutaway. Accept any reasonable answer that is appropriate.	4

Question	Answer	Marks												
(d)	Two marks available. Cheap material. Can be covered with a high quality finish product (PVC) Can be routed easily. Can be cut to any shape/size. A tough material. Good strength to weight ratio. Accept any reasonable answer that is appropriate.	2												
(e)	Two marks available. Rubber – hardwearing/durable Nylon - hardwearing/durable/self-lubricating Accept any reasonable answer that is appropriate.	2												
(f) (i)	Six marks available. <table border="1"> <thead> <tr> <th>Component</th><th>Name of component</th><th>Purpose in circuit</th></tr> </thead> <tbody> <tr> <td>A</td><td>Switch</td><td>Allows electricity to flow through the circuit.</td></tr> <tr> <td>B</td><td>Variable resistor</td><td>Used to change the volume on the amplifier Accept current or voltage.</td></tr> <tr> <td>C</td><td>Speaker</td><td>Converts electrical signal to sound waves accept - gives out sound.</td></tr> </tbody> </table> Accept any reasonable answer that is appropriate.	Component	Name of component	Purpose in circuit	A	Switch	Allows electricity to flow through the circuit.	B	Variable resistor	Used to change the volume on the amplifier Accept current or voltage.	C	Speaker	Converts electrical signal to sound waves accept - gives out sound.	6 x 1
Component	Name of component	Purpose in circuit												
A	Switch	Allows electricity to flow through the circuit.												
B	Variable resistor	Used to change the volume on the amplifier Accept current or voltage.												
C	Speaker	Converts electrical signal to sound waves accept - gives out sound.												
(ii)	Six marks available Insert components on to printed circuit board. Apply heat from soldering iron on to leg of component and copper track. Once both are heated up, apply solder to the area. Solder should flow around the legs of the component. Trim component legs. Award up to 3 marks for the quality of sketching. Very basic sketches that are recognisable and appropriate to the processes (1 mark). Good sketches showing some detail that has the processes covered. (2 marks) Detailed well executed sketches that clearly indicates the processes. (3 marks) Award up to 3 marks for the quality of appropriate annotation.	6												

Question	Answer	Marks
2. (a)	Four marks available To direct flow (pedestrians). To direct flow (cars/bikes/automobiles). To control the flow of traffic. Provide security outside buildings. Highlight hazards on the road. Display certain traffic signs. Provide illumination. Designed using a CAD/CAM systems for the purposes of manufacturing. Accept any validated reason that answers the question.	2 x 2
(b)	Four marks available Reflective surfaces can be applied to bollards to make them more visible. Some bollards can now be controlled to sink into the road to allow flow of traffic or direct the follow of traffic. Designed to stay intact when hit by a car to protect pedestrians. New materials/finishes used to help them be seen in all type of weather/time of day. Accept any validated reason that answers the question.	2 x 2
(c)	Four marks available Visibility of the bollard – colour/reflective stickers. Height of bollard. Diameter of bollard. Material used. How do emergency services get past them, if required? Obstruction? Accept any validated reason that answers the question.	4
(d)	Four marks available Material won't degrade, splinter or rust, making them long lasting products. Colour pigment used, instead of paint. Lifespan of around 40 before they need to be replaced. Lightweight – They can easily be moved/adjusted manually. Manufactured from old bottle caps and bottle crates. Less waste materials to land file. Answers related to recycling of materials is acceptable. Accept any validated reason as a benefit to the user.	4

Question	Answer	Marks
3. (a) (i)	Equipment name – Welding machine Use – Used with heat treatment processes (welding) Equipment name – Machine vice or Drill Vice Use – Used to hold materials securely when using a pillar drill. Accept any reasonable answer that is appropriate.	4 x 1
(ii)	Two marks available Wear safety goggle/glasses. Eye protection required. Laser in use.	2 x 1
(b) (i)	Two marks available 4 x 250mm + 4 x 200mm + 1 x 1500mm 1000mm + 800mm + 1500mm = 3300mm 1 mark for processes if the final answer is incorrect.	2
(ii)	Two marks available 3300 = 33 x 100mm lengths 33 x 0.82p = £27.06 Cost of materials for one bird table - £27.06 1 mark for processes if the final answer is incorrect.	2
(iii)	Two marks available £27.06/5 = £5.41 £5.41 x 4 = £21.64 New cost = £21.64 1 mark for processes if the final answer is incorrect.	2
(c)	Up to eight marks available <i>Note: The sketch must be an isometric drawing.</i> A recognisable isometric drawing. 2 A clear gap between the two arms of the folding bars and a representation of the circular element. 2 A proportionally correct drawing. 2 A neat drawing representative of the folding bars. 1 A clearly defined quality drawing showing all the details of the folding bar. 1	8



LEVEL 1 & 2 MARKING SCHEME

WINTER 2022

**LEVEL 1 & LEVEL 2
ENGINEERING - UNIT 3
9793/01**

INTRODUCTION

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LEVEL 1 & 2 ENGINEERING
UNIT 3 - SOLVING ENGINEERING PROBLEMS
WINTER 2022 MARK SCHEME

Question	Answer	Marks
1. (a) (i)	Two marks available. Non-slip material. Can be shaped into complicated shapes. Prevents sweat from going all over the treadmill. Polypropylene. Accept any reasonable answer that is appropriate.	2
(ii)	One mark available. Saves space in the home. Takes up less space. Allows user to exercise, in a small apartment.	1
(b) (i)	Three marks available. Aluminium section Strong (strength) – Able to withstand the weight of the user. Lightweight – Able to move the treadmill from room to room. Toughness – Able to withstand knocks and bumps when it's moved. Accept any reasonable answer that is appropriate.	1 2
(ii)	Three marks available. Polypropylene High impact strength. Tough. Hardness. Lightweight. Accept any reasonable answer that is appropriate.	1 2

Question	Answer	Marks
(c)	Four marks available. Safety features: Stand/tracks either side of the running track, to allow user to stand on the treadmill when it's still in motion. Handrails available to hold on to, for balance. Variable speed available on the machine, to allow user to get accustomed to the speed. Accept any reasonable answer that is appropriate.	4 x 1
(d)	Three marks available. Washer Bolt Wing nut	1 1 1
(e)	Eight marks available. Place aluminium in a machine vice. Mark position of hole on the aluminium, using a scribe. Centerpunch aluminium. Drill hole, using a 5.5mm drill bit. Position M6 tap in the hole. Turn tap wrench accordingly (clockwise turn, then anti clockwise for clearance). Test thread. 4 marks for sketches and diagrams. 4 marks available for notes.	8 x 1

Question	Answer	Marks
2. (a)	Six marks available Joystick and one button on 1980's version. Modern controller wireless / cable-free. Lots of buttons on modern one. Modern one separates into smaller / different controllers. Modern one ergonomically designed. Restriction of functions on older one. Option of one, or two controllers, depending on the game. Accept any validated reason that answers the question.	6
(b)	Six marks available Longer battery life. USB connections to charge. Longer play time. Shorter charge-up time. Cables no longer required/tidier to play. Accept any validated reason that answers the question.	6
(c)	Four marks available Advantages: Real-life feel to playing the game. Accurate movements within the game. The speed of the game play could be a lot faster (setting up the game, saving). Disadvantages: Long term effect of electronic implants unknown. Cost of surgery. Minimum age limit? Users could get addicted to the games, but would be unable to 'switch off'. How would it be charged/powered? Accept any validated reason that answers the question.	2 x 2

Question	Answer	Marks
3. (a)	Equipment name – Micrometer: Used to measure small objects / diameter.	1 + 1
	Equipment name – Twist drill bit: Used to bore/make holes in materials.	1 + 1
(b) (i)	One mark available Personal Protective Equipment	1
(ii)	Two marks available Overcoat/apron Goggles/face shield Heat resistant gloves Accept any reasonable answer	1+1
(c) (i)	Up to two marks available 9 lengths 103 x 9 (103+103 etc) = 927mm	2
(ii)	One mark available. 1000mm – 927mm= 73mm of waste.	1
(iii)	Two marks available. 927mm/1000mm = 92.7% Or 900mm/1000mm = 90%	2
(d)	Three marks available 200mm x 200mm = 40,000mm ² 50mm x 200mm = 10,000mm ² 40,000mm ² -10,000mm ² = 30,000mm ² 30,000mm ² x 4mm = 120,000mm ³ Some may use the formula for area of a trapezium. $A = \frac{a + b}{2} \times h$	3
(e)	Five marks available	3
	Sectional view to be in line with front view	1
	Correct parts hatched.	1



LEVEL 1 & 2 MARKING SCHEME

SUMMER 2022

**LEVEL 1 & LEVEL 2
ENGINEERING - UNIT 3
9793/01**

INTRODUCTION

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LEVEL 1 & 2 ENGINEERING
UNIT 3 - SOLVING ENGINEERING PROBLEMS
SUMMER 2022 MARK SCHEME

Question	Answer	Marks
1. (a)	Two marks available. One mark per appropriate reason. Reasons for choice: 'T' nuts - Durable - Tough - Good strength to weight ratio - Impact resistant - Corrosion resistant Hand holds/grips - Can be moulded to various shapes/sizes. - Hardwearing material. - Available in a range of colours. - Smooth/rough surface finish can be applied when manufacturing. Accept any reasonable answer that is appropriate.	2
(b)	Four marks available. Two marks per advantage that includes a description. No description – 1 mark Advantages: - Consistent shape every time a block is produced. - Consistent wall thickness every time. - Low cost of tooling for making the initial mould. - Manufactured as one-piece, requiring fewer joining techniques. High strength, with fewer stress points. Accept any advantage that is appropriate.	4
(c)	Three marks available. 1 mark per detailed relevant specification point. Strong (strength) – Able to withstand the weight of the user. Toughness – Able to withstand knocks and bumps when in use. Size – Different sized hand holds/grips can be manufactured for variation.' Surface finish – Different surface finishes applied, to suit beginners/advanced climbers. Justification is required for the full mark. One word answers – 0 marks Accept any specification point answer that is appropriate.	3

Question	Answer	Marks										
(d)	Three marks available. <table><tr><th>Material</th><th>Classification</th></tr><tr><td>Mild steel</td><td>Ferrous</td></tr><tr><td>Acrylic</td><td>Thermoforming, Thermoplastic [1]</td></tr><tr><td>Polyester resin</td><td>Thermoset, Thermosetting [1]</td></tr><tr><td>Aluminium</td><td>Non-ferrous [1]</td></tr></table> Accept only correct answers.	Material	Classification	Mild steel	Ferrous	Acrylic	Thermoforming, Thermoplastic [1]	Polyester resin	Thermoset, Thermosetting [1]	Aluminium	Non-ferrous [1]	3
Material	Classification											
Mild steel	Ferrous											
Acrylic	Thermoforming, Thermoplastic [1]											
Polyester resin	Thermoset, Thermosetting [1]											
Aluminium	Non-ferrous [1]											
(e)	6 marks available. Place bar in a machine vice/lathe. Set up die and die holder. Add cutting compound to bar. Place die onto the end of the bar Make sure its perpendicular/straight/level Turn carefully in a clockwise direction until thread starts to be cut. Gently turn anti-clockwise to remove burr. Continue cutting the thread to required depth, remembering remove burr. Remove and clean die and die holder. Reset the die to give a quality thread and repeat process. 3 marks for sketches and diagrams. 3 marks available for notes. 0 marks awarded for incorrect process. Accept any reasonable point that is appropriate.	6 x 1										
(f)	Two marks available. Destructive test – Applying a test to break down a particular material to determine its physical properties, such as strength, toughness, flexibility and hardness. Non-destructive test – Applying a test to an object or material that does not affect its future use. It does not destroy the object/material. Accept any reasonable difference that is appropriate.	2										
(g)	4 marks available. Temporary fixing method – Two parts can be taken apart and joined together again, a number of times. E.g the hand holds/grips would be attached with a steel bolt. This will allow the hand holds/grips to be changed or replaced. Permanent fixing method - Once two parts have been joined together, they cannot be taken apart or changed. E.g the steel sections that make the backing/core frame for the climbing wall would be welded together. (Does not need to relate to the climbing wall – different examples can be used) Accept any appropriate answer that includes an example.	4										

Question	Answer	Marks
2. (a) (i)	Four marks available Development of mobile phone applications (apps), to include: - Development of touch screen technology. Better game play interaction (both hands needed to play games). - Development in microchip technology (speed, power, size). More film/tv show apps available. Allows user to watch films/tv shows. - Development of smaller/lighter components that have allowed the mobile phones to be made thinner. - Development of battery technology to play watch longer. Accept any appropriate technological advancement that answers the question. They must be about the products not the mobile phone.	2 x 2
(ii)	Two marks available - Bulky when mobile phone is in the user's pocket. Does not allow the user to use a protective case to prevent possible damage to the mobile phone, if dropped. • Difficult to remove • Difficult to wirelessly charge Accept any appropriate disadvantage that answers the question.	2
(c)	Two marks available Answers could be linked to: - Engineers can share information (data/designs/ideas/photos) - Speed of sharing information. - Collaboration on the same design at the same time. Accept any validated reason that answers the question.	2
(d)	Four marks available Answers could be linked to: - Disassembly of old mobile phone. - Use old parts in future models. - How can parts be recycled? - Incentives to recycling a mobile phone. - Precious metals can be reused – accept examples e.g. Olympic medals. Answers need to be related to the end of the products' life. Accept any validated reasons that answers the question.	4

Question	Answer	Marks																		
(e)	Four marks available Answers should be linked to safety and standards. - BSI applies a standard to help improve the quality and safety of products before they get to the consumer. - As the standard and quality of products improve, it also improves the safety of future products.	4																		
3. (a) (i)	Two marks available. Centre Punch – Used to mark the centre of a hole to be drilled/to make a mark. (Do not accept 'To make a hole') Outside Calipers – Measure the outside diameter of a piece of round material. One mark per description of use	2																		
(ii)	Three marks available PPE equipment Correct speed Cutter securely held. Piece to be milled must be held securely. Appropriate guards must be fitted to machine. Cutting /coolant liquid (Award a maximum of 1 mark for reference to personal protection) One mark per safety precaution.	3																		
(iii)	4 marks available 1 mark for the tool name 1 mark for the description Tools could include: Vernier Callipers, Micrometer, Depth Gauge, Thread Gauge, Steel Rule/Ruler (accept rule), Engineers Square, Spirit level Description should be appropriate to the tool named. Accept any reasonable answer	4																		
(b) (i)	Up to 6 marks available To achieve the full 6 marks, both the side and plan views / projections need to be completed. <table border="0"> <tr> <td>Side view</td> <td>Drawn in line with the front view / projection</td> <td>1 mark</td> </tr> <tr> <td></td> <td>Horizontal holes (hidden detail)</td> <td>1 mark</td> </tr> <tr> <td>Plan view</td> <td>Drawn in line the front view / projection</td> <td>1 mark</td> </tr> <tr> <td></td> <td>Vertical holes (hidden detail)</td> <td>1 mark</td> </tr> <tr> <td></td> <td>All construction lines clearly drawn</td> <td>1 mark</td> </tr> <tr> <td></td> <td>Neatness of the drawing</td> <td>1 mark</td> </tr> </table>	Side view	Drawn in line with the front view / projection	1 mark		Horizontal holes (hidden detail)	1 mark	Plan view	Drawn in line the front view / projection	1 mark		Vertical holes (hidden detail)	1 mark		All construction lines clearly drawn	1 mark		Neatness of the drawing	1 mark	6
Side view	Drawn in line with the front view / projection	1 mark																		
	Horizontal holes (hidden detail)	1 mark																		
Plan view	Drawn in line the front view / projection	1 mark																		
	Vertical holes (hidden detail)	1 mark																		
	All construction lines clearly drawn	1 mark																		
	Neatness of the drawing	1 mark																		

Question	Answer	Marks
(b) (ii)	5 marks available. Up to 5 marks available You cannot double penalise. If they get one or more of the initial areas wrong but use the wrong answer for total area and volume don't double penalise. If no unit but all working correct take off one mark. Divide shape into a rectangle and a semi-circle Area of rectangle ($a = h \times w$) $30\text{mm} \times 85\text{mm} = 2550\text{mm}^2$ 1 mark Area of semi-circle ($\pi r^2 / 2$) $3.14 \times 15^2 / 2$ $3.14 \times 225 = 706.5\text{mm}^2$ $706.5\text{mm}^2 / 2 = 353.25\text{mm}^2$ 1 mark Area of holes ($\pi r^2 \times 2$) $3.14 \times 1.5^2 \times 2$ $3.14 \times 2.25 = 7.06\text{mm}^2$ $7.06 \times 2 = 14.12\text{mm}^2$ $2550\text{mm}^2 + 353.25\text{mm}^2 = 2903\text{mm}^2$ 1 mark $2903\text{mm}^2 - 14.12\text{mm}^2 = 2888.88\text{mm}^2$ 1 mark Volume = area x thickness $2888.88\text{mm}^2 \times 3\text{mm}$ $= 8666.64\text{mm}^3$ 1 mark	5

End of mark scheme

Surname	Centre Number	Candidate Number
First name(s)		4



LEVEL 1/LEVEL 2 AWARD

9793/01



WEDNESDAY, 12 JANUARY 2022 – MORNING

ENGINEERING – Unit 3 **Solving Engineering Problems** **(VOCATIONAL)**

1 hour 30 minutes

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	24	
2.	16	
3.	20	
Total	60	

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010001

ADDITIONAL MATERIALS

In addition to this paper you may require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. Where the space is not sufficient for your answers, continue at the back of the booklet, taking care to number the continuation correctly.

INFORMATION FOR CANDIDATES

The total number of marks for this paper is 60.

The number of marks is given in brackets at the end of each question or part-question.

You are reminded of the necessity for good English and orderly presentation in your answers.

Answer **all** questions in the spaces provided.

1. The image below shows a modern treadmill, it has a moving strip on which one walks or runs.



- (a) (i) Complete the table below, suggesting a suitable material or reason for using the material, for **each** part of the treadmill.

Part	Material	Reason for choice
Handrail cover	Neoprene / foam	 [1]
Water bottle holder	 [1]	Can be injection moulded to the required shape, quickly.

- (ii) Give **one** advantage to the user of being able to collapse the treadmill after its use. [1]

.....

.....

(b) Circle the correct material used to manufacture the following part.

(i) The treadmill frame is made from: [1]

brass aluminium

List **two** material properties required for the manufacture of the treadmill frame. [2]

Property 1:

Property 2:

Circle the correct material used to manufacture the following part.

(ii) The transport wheels are manufactured from: [1]

nylon acrylic

List **two** material properties required for the manufacture of the transport wheels. [2]

Property 1:

Property 2:

(c) Describe **two** safety features of the treadmill. $2 \times [2]$

Safety feature 1:

.....

.....

.....

Safety feature 2:

.....

.....

.....

- (d) The treadmill is manufactured from a number of different parts and components.

Name the following components, used in the manufacturing of the treadmill.

Component / part	Name of component / part
	 [1]
	 [1]
	 [1]

- (e) The treadmill uses an internal M6 thread on the frame for assembly. Using notes and sketches, show the process of preparing and cutting an **internal M6 thread** in the treadmill frame. [8]

Examiner
only

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2. The world of engineering is greatly influenced by developments in technology. One area that has seen many changes is the development of computer controllers.

Below are two computer controllers. The one on the left is a basic controller, from the 1980s. The one on the right is a modern hi-tech controller.



1980s controller



Modern hi-tech controller

- (a) Compare and contrast the ergonomic differences in the design of both controllers. [6]

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- (b) Explain how the development of wireless and battery technology, has improved the modern hi-tech controller. [6]

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- (c) Design engineers are developing methods of controlling computer games through the use of implants in the human body.

Discuss **one** advantage and **one** disadvantage of electronic implants.

2 × [2]

Advantage:

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.....

Disadvantage:

.....

.....

3. The pictures below show two pieces of equipment, usually found in a workshop.

- (a) Complete the table below by correctly naming **each** piece of equipment and write a description of its use.

Engineering equipment	Equipment name	Equipment use
	 [1]	 [1]
	 [1]	 [1]

- (b) (i) One element of Health and Safety is 'Personal Protective Equipment' (PPE). Is the following sentence **True** or **False**? (Circle the correct answer.) [1]

'PPE is a regulatory requirement of Health and Safety'. **True or False**

- (ii) Give **one** example of PPE and explain its use in a school workshop.

Example: [1]

Explanation:

..... [1]

- (c) The upright laptop stand shown is made from round aluminium tubular section. The external diameter of the aluminium is 50 mm.



The round aluminium tubular section is purchased as a 1 metre length and then cut down to 100 mm lengths on a centre lathe using a parting off tool.

The thickness of the parting off tool is 3 mm which results in wastage for each cut.

- (i) How many upright stands can be manufactured from each 1 metre length? [2]

Show all your calculations.

.....

.....

.....

.....

- (ii) Following machining of the aluminium tubular section, how much will remain? [1]

Show all your calculations.

.....

.....

- (iii) What percentage of the aluminium tubular section is used overall?

[2]

Examiner
only

Show all your calculations.

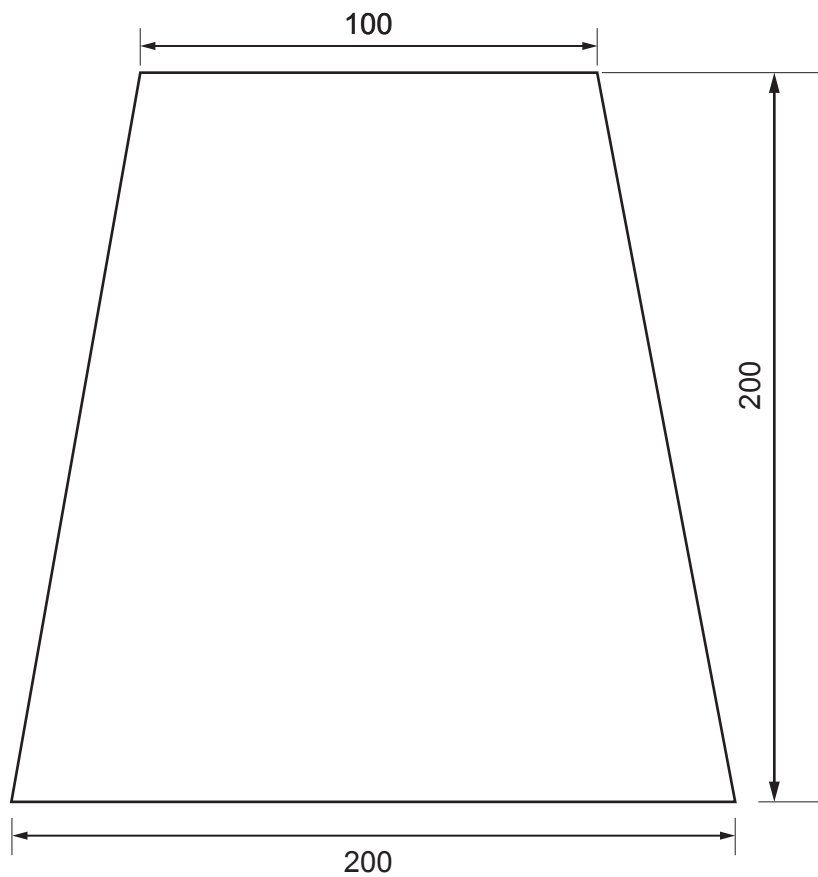
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- (d) The base of the stand is manufactured from 4 mm aluminium. Below is a plan view of the aluminium base.



ALL DIMENSIONS IN mm

Calculate the total volume of aluminium used to manufacture each base.
Note: Ignore the fillet/rounded corners on the base.

[3]

Examiner
only

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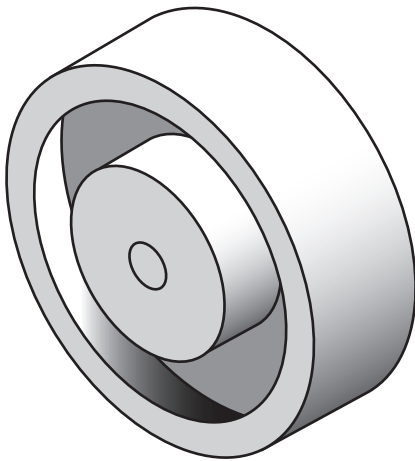
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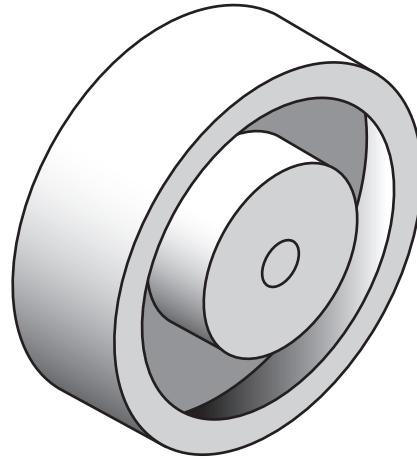
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- (e) The original design of the upright stand used wheels to move the laptop around. The wheels were made from polypropylene and are injection moulded.

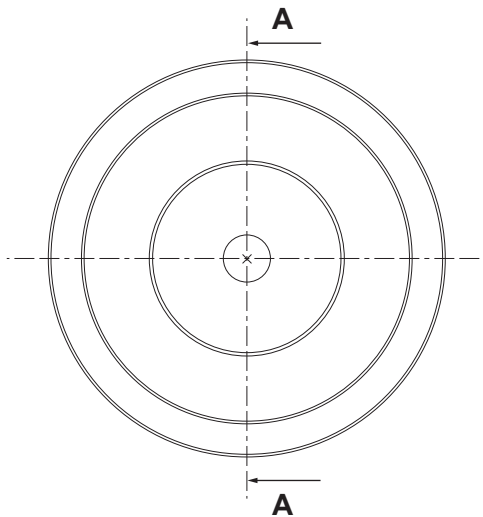


Left view



Right view

Sketch a sectional view of the wheel labelled **A–A**, to the right of the drawing, below. [5]
Note: Assume any missing dimensions.



END OF PAPER

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Surname	Centre Number	Candidate Number
First name(s)		4



LEVEL 1/LEVEL 2 AWARD

9793/01



Z22-9793-01

THURSDAY, 26 MAY 2022 – MORNING

ENGINEERING – Unit 3 Solving Engineering Problems (VOCATIONAL)

1 hour 30 minutes

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	24	
2.	16	
3.	20	
Total	60	

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ADDITIONAL MATERIALS

In addition to this paper you may require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The total number of marks for this paper is 60.

The number of marks is given in brackets at the end of each question or part-question.

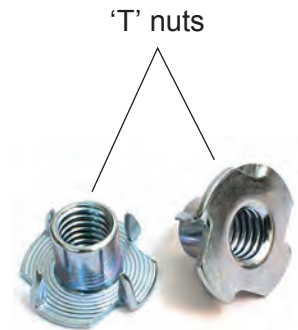
You are reminded of the necessity for good English and orderly presentation in your answers.



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Answer **all** questions in the spaces provided.

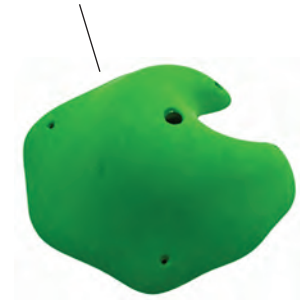
1. The images below show a range of indoor climbing walls, fixtures and fittings.



'T' nuts



Hand holds/grips



Climbing blocks

- (a) Complete the table below giving reasons for the material used for the named parts.

2 × [1]

Named parts	Material	Reason for choice
'T' nuts	Stainless steel	..... .....
Hand holds/grips	Polyurethane	..... .....



- (b) The climbing blocks in the first picture have been manufactured by a plastic moulding process.

Describe **two** advantages of using a plastic moulding process to manufacture the blocks. [4]

Advantage 1:

.....

.....

Advantage 2:

.....

.....

- (c) Some advanced climbing walls have hand holds/grips to assist and increase the difficulty to the user.

Write **three** detailed specification points that the design engineer would consider when designing the hand holds/grips. [3]

Specification point 1:

.....

.....

Specification point 2:

.....

.....

Specification point 3:

.....

.....

- (d) Complete the table below, by giving the correct classification for **each** named material used in the manufacturing of the climbing wall. 3 × [1]

Note: The first material has been completed.

Material	Classification
Mild steel	Ferrous
Acrylic	.....
Polyester resin	.....
Aluminium	.....



- (e) The climbing walls are assembled using nuts and bolts. Explain, using notes and diagrams, how you would cut an external M8 thread on an 8 mm diameter mild steel bar. [6]

- (f) The climbing wall must be thoroughly tested for safety purposes. Explain the difference between a destructive and a non-destructive test. [2]

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- (g) The climbing wall uses different forms of fixtures and fittings for all parts of its construction. Explain, using examples, the difference between a temporary and a permanent fixing method. [4]

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2. The world of engineering is greatly influenced by developments in technology.

Below are two different types of attachment to a mobile phone.



- (a) Describe **two** technological advances in the development of mobile phones that have created a need for the products shown. [4]

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- (b) Discuss **one** disadvantage to the user of having one of these products attached to a phone. [2]

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- (c) Explain how the development of mobile phone technology has supported engineers in global manufacturing. [2]

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- (d) Discuss the environmental issues that might occur when disposing of mobile phones. [4]

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- (e) Describe the importance of the role of the British Standards Institution (BSI) when approving products like the mobile phone before going on sale to the general public. [4]

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3. Shown below are two pieces of equipment used in an engineering workshop.

(a) (i) Complete the table below by correctly writing a description of its use. $2 \times [1]$

Engineering equipment	Equipment name	Equipment use
	Centre Punch	..... .....
	Outside Callipers	..... .....

(ii) State **three** safety precautions you should apply before you use a milling machine. $3 \times [1]$

Precaution 1:

Precaution 2:

Precaution 3:

(iii) Name **two** measuring tools that are used for quality control and describe how they are used. $2 \times [2]$

Measuring tool 1:

Description:

.....

Measuring tool 2:

Description:

.....



- (b) This is a picture of a small brass pin tag.



Description of brass tag:

100 mm $\times$ 30 mm wide.

Thickness of the material is 3 mm.

Both drilled holes are 3 mm diameter.

- (i) Complete the third angle orthographic drawing to produce a fully functioning **working** drawing.
You must show all required features and details.

[6]



- (ii) Calculate the total volume of the brass tag after it has been manufactured. [5]

You must show all your calculations.

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END OF PAPER



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LEVEL 1 & 2 MARKING SCHEME

SUMMER 2023

**LEVEL 1 & LEVEL 2
ENGINEERING - UNIT 3
9793/01**

INTRODUCTION

This marking scheme was used by WJEC for the 2023 examination. It was finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conference was held shortly after the paper was taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conference was to ensure that the marking scheme was interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conference, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about this marking scheme.

LEVEL 1 & 2 AWARD IN ENGINEERING

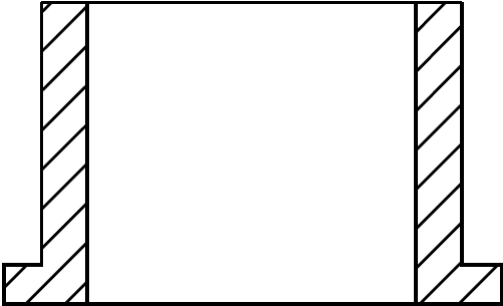
UNIT 3 – SOLVING ENGINEERING PROBLEMS

SUMMER 2023 MARK SCHEME

Question	Answer	Marks												
1. (a) (i)	Two marks available. <table border="1"> <thead> <tr> <th>Part</th><th>Material</th><th>Classification</th></tr> </thead> <tbody> <tr> <td>Door</td><td>ABS</td><td>Thermoplastic</td></tr> <tr> <td>Shelf</td><td>Mild steel*</td><td>Ferrous</td></tr> <tr> <td>Adjustable foot</td><td>Nylon</td><td>Thermoplastic</td></tr> </tbody> </table> *Accept any appropriate material i.e. Chrome steel. Steel: No marks. Needs to specify a type of steel.	Part	Material	Classification	Door	ABS	Thermoplastic	Shelf	Mild steel*	Ferrous	Adjustable foot	Nylon	Thermoplastic	2
Part	Material	Classification												
Door	ABS	Thermoplastic												
Shelf	Mild steel*	Ferrous												
Adjustable foot	Nylon	Thermoplastic												
(ii)	Four marks available. Malleable material to manufacture the curved pipes. Eco-friendly to use copper/can easily be recycled. Cost-effective fabrication costs. Ductile. Corrosion resistance. Thermal conductivity Accept any reasonable answers that are appropriate. One word answer max 1 mark	2 x 2												
(b)	Two marks available.	2 x 1												
(i)	Non-ferrous = Brass or Copper,													
(ii)	A metal that does not contain iron. Do not accept 'magnetic' or 'can rust'													

Question	Answer	Marks
(c)	Four marks available.	2 x 2
(i)	Non-destructive test – Where the materials or products are tested without damaging the material or product.	
(ii)	Visual check. Looking for scratches on materials. Door mechanism. X-ray. Checking adjustable feet. Pressure testing. Temperature check. Switching the mini fridge on and off. Checking lights work. Door seal. Accept any reasonable explanation with the non-destructive test. “Switch it on to see if it gets cold” (2 marks) “Switch it on to see if it works” (1 mark) Answers relating to adding weight – 0 marks.	
(d)	Two marks available. The answer must be in form of a description one worded answers will only gain one mark. Self-tapping screws could be used on the door of the hinge for maintenance and cleaning. Nuts and bolts could be used to hold moving parts such as motors. Accept any appropriate answer.	2
(e) (i)	Up to eight marks available. Placing the die in the die wrench Add cutting grease (Threading compound) Place the bar in a vice. File the edge of the round bar. (Lead) Check for squareness. Place carefully over the round bar Gently turn in a clockwise direction. Check to see the metal is being cut. 1/2 to 3/4 of a turn and remove burr by turning anti-clockwise. Repeat process to the desired depth. Accept fixed or split die. Accept the process of cutting a thread on a lathe.	8
(ii)	Two marks available. Component 1 – Motor Component 2 – Resistor	2 x 1

Question	Answer	Marks
2. (a)	Six marks available. Connectivity to mobile phones – user can look back at their progress on an application (Bluetooth/WiFi) Development of GPS technology to record movement – user can track their route accurately. Development of applications (apps) that can record the number of calories burned. Development of physical activity tracker applications. Accept any validated reason that is appropriate.	6
(b)	Four marks available. Hinder the user from hearing instructions in a workshop environment. Hinder user from hearing oncoming traffic on the roads. Damage to hearing. Pain in the ears. Ear infections. Poorly manufactured earbuds would force the user to turn up the volume. Accept any validated reason that answers the question. 2 marks for identifying the risk i.e., too deep 2 marks for identifying the hazard to the user	4
(c) (i)	Two marks available. Increase sales for the manufacturing company. More choice for the consumer. Accept any validated reason that answers the question. No credit for user-centred responses.	2
(ii)	Four marks available. Safety to the user while light conditions are not great. Better/clearer view of the part that's being worked on. Eliminates the need to have an external light source. Continuous and consistent light source when working on a machine. Stops the user from placing their head close to the drilling process. Keeps both hands free to complete a process. Accept any validated reason that answers the question. No marks for repeated answers	2 x 2

Question	Answer	Marks
3. (a) (i)	Four marks available. Ensure the guard is in place. Ensure that work is secure/in a machine vice/hand vice/clamped before drilling. Wear appropriate PPE. Familiarisation of the emergency stop Accept any valid reason that answers the question. "Keep hands away" 0 marks "Keep hands away from moving parts" 1 mark Max 1 mark for PPE	4 x 1
(ii)	Four marks available. Equipment name – Side cutters, wire cutter, side cutting pliers, wire snippers. ONLY Equipment use – To cut/strip electrical wire Equipment name – Solder sucker/ de-soldering pump Equipment use – remove surplus/excess solder from an electronic joint.	4 x 1
(b)	Six marks available. The through holes should be drawn without hatching. Hatched lines should be at 45. Areas hatched (1 mark) Using a straight edge / rule to draw sectional view (neat and not free hand) Correct orientation and placement of sectional view  Award up to 6 marks	2 1 1 1 1

Question	Answer	Marks
(c)	Up to six marks available. Before machining: Area = $3.14 \times 10^2 = 314.00\text{mm}^2$ Volume = $314.00\text{mm} \times 30\text{mm} = 9420\text{mm}^3$ After machining: Area = $3.14 \times 4^2 = 50.24\text{mm}^2$ Volume = $50.24 \times 30 = 1507.2\text{mm}^3$ Subtracting the smaller number from the larger number = $9420\text{mm}^3 - 1507.2\text{mm}^3 = 7912.8\text{mm}^3$ Accept answer in the range 7912.8 and 7916.81mm³ Answer in correct unit of measure (mm³)	1 1 1 1 1

Surname	Centre Number	Candidate Number
First name(s)		4



LEVEL 1/LEVEL 2 AWARD



9793/01

THURSDAY, 25 MAY 2023 – AFTERNOON

ENGINEERING – Unit 3 Solving Engineering Problems (VOCATIONAL)

1 hour 30 minutes

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	24	
2.	16	
3.	20	
Total	60	

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ADDITIONAL MATERIALS

In addition to this paper you may require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid. You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The total number of marks for this paper is 60.

The number of marks is given in brackets at the end of each question or part-question.

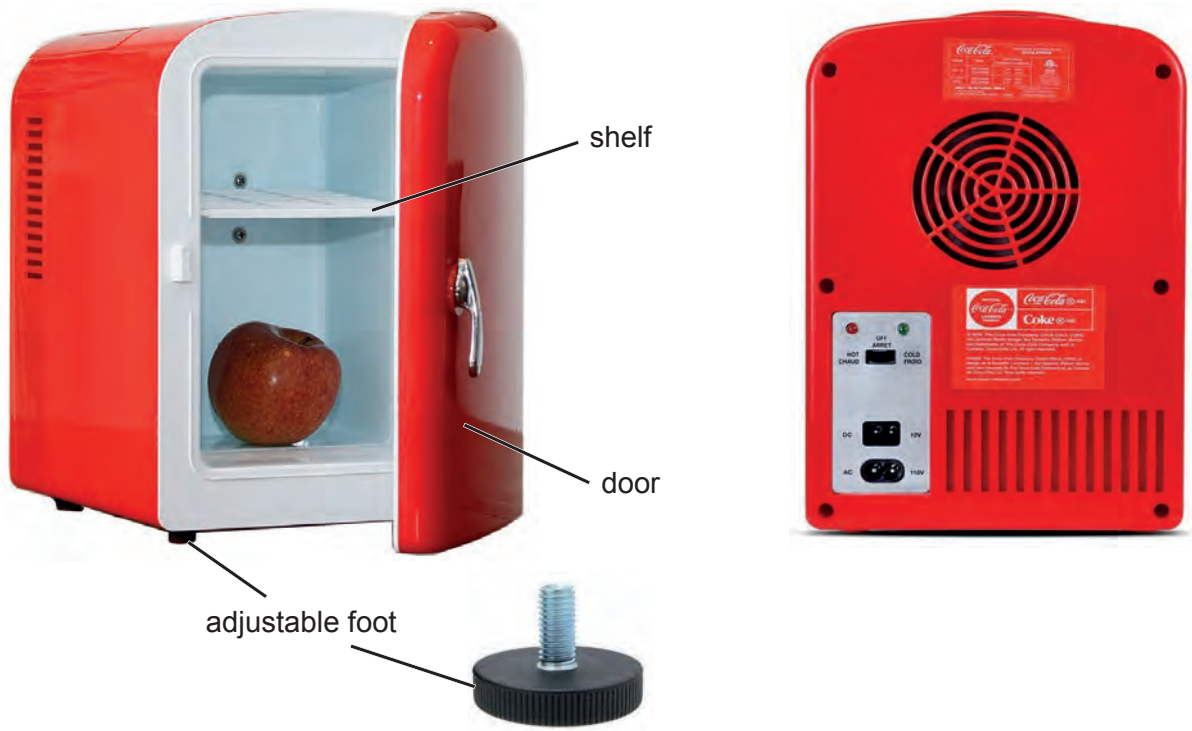
You are reminded of the necessity for good English and orderly presentation in your answers.



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Answer **all** questions.

1. The image below shows a mini fridge that can be used in a bedroom.



- (a) (i) Complete the table below, suggesting a suitable material or classification for **each** of the labelled parts. The first one has been completed for you. 2 × [1]

Part	Material	Classification
Door	ABS	Thermoplastic
Shelf	.....	Ferrous
Adjustable foot	Nylon	.....



- (ii) The function of the mini fridge is to cool the contents. The cooling system is made up of different parts and materials, including copper for the pipes.

Give **two** reasons why the properties, or characteristics, of copper make it a suitable material for use in the cooling system. 2 × [2]

Reason 1:

.....

Reason 2:

.....

- (b) Look at the following list of metals.

Mild steel

Brass

Copper

Cast iron

- (i) From the list above, give **one** example of a non-ferrous metal. [1]

.....

- (ii) State the meaning of the term **non-ferrous metal**. [1]

.....

- (c) Materials are often tested for their suitability on a product such as the mini fridge.

- (i) Explain the meaning of a non-destructive test (NDT). [2]

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- (ii) Describe a NDT you would perform on the mini fridge. [2]

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- (d) Describe any temporary joining method that could be used in the construction of the mini fridge. [2]

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.....

- (e) The adjustable foot is used to level the mini fridge.

- (i) Describe the process of cutting and producing an external thread on a mild steel bar . [8]
You may wish to add sketches to support your description.





- (ii) The following components are necessary for a fridge to work efficiently.

Name **each** electrical component.

[2]

Electrical component symbol	Name of component
	
	



9793
010007

-



- [6]



The modern trend is to use earbuds while listening to music as they have many advantages to the user.



(b) Describe a cause for concern when wearing earbuds, in terms of Health and Safety. [4]

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- (c) The safety glasses below have light emitting diodes (LEDs) built into them.



- (i) Describe the advantage to the **manufacturer** of having LEDs on the glasses. [2]

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- (ii) Give **two** justified reasons why modern safety glasses would benefit from having LEDs. 2 × [2]

Reason 1:

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Reason 2:

.....

.....



3. The picture below shows a typical pillar drill, usually found in a workshop.



- (a) (i) List **four** safety precautions you should take when using a pillar drill. 4 × [1]

Precaution 1:

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Precaution 2:

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Precaution 3:

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Precaution 4:

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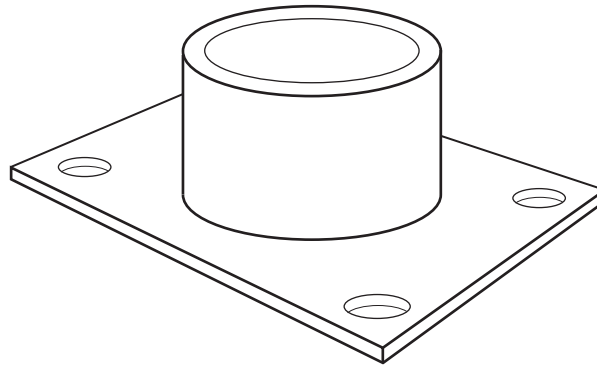
- (ii) Complete the table below by correctly naming **each** piece of equipment and writing a description of its use.

4 × [1]

Engineering equipment	Equipment name	Equipment use
		
		



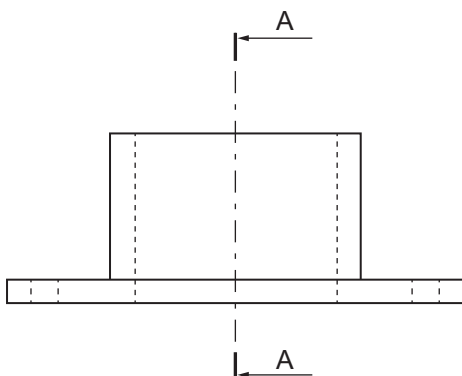
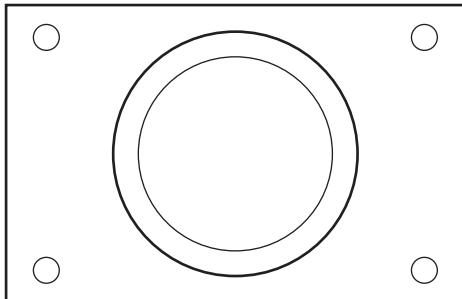
- (b) This is a picture of a cast bracket, used to hold wooden posts in place.



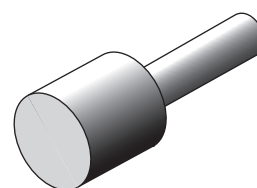
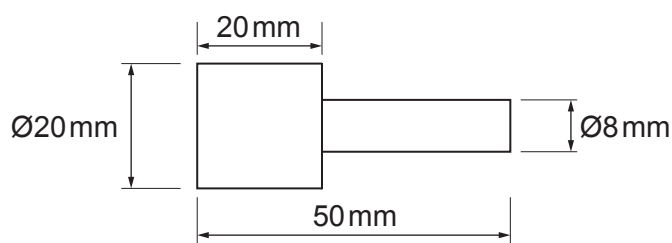
Complete the orthographic drawing below by drawing the side view as a sectional drawing, labelled A–A.

[6]

The front and plan views have been completed.
You must show all required features and details.



- (c) This is a picture of a small pin, produced from round aluminium bar. The part is turned on a centre lathe.



Calculate the amount of aluminium waste material that has been removed from each 50 mm length.

[6]

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LEVEL 1 & 2 MARKING SCHEME

SUMMER 2024

**LEVEL 1 & LEVEL 2
ENGINEERING - UNIT 3
5799U30-1**

About this marking scheme

The purpose of this marking scheme is to provide teachers, learners, and other interested parties, with an understanding of the assessment criteria used to assess this specific assessment.

This marking scheme reflects the criteria by which this assessment was marked in a live series and was finalised following detailed discussion at an examiners' conference. A team of qualified examiners were trained specifically in the application of this marking scheme. The aim of the conference was to ensure that the marking scheme was interpreted and applied in the same way by all examiners. It may not be possible, or appropriate, to capture every variation that a candidate may present in their responses within this marking scheme. However, during the training conference, examiners were guided in using their professional judgement to credit alternative valid responses as instructed by the document, and through reviewing exemplar responses.

Without the benefit of participation in the examiners' conference, teachers, learners and other users, may have different views on certain matters of detail or interpretation. Therefore, it is strongly recommended that this marking scheme is used alongside other guidance, such as published exemplar materials or Guidance for Teaching. This marking scheme is final and will not be changed, unless in the event that a clear error is identified, as it reflects the criteria used to assess candidate responses during the live series.

LEVEL 1 & 2 AWARD IN ENGINEERING

ENGINEERING – UNIT 3

SUMMER 2024 MARK SCHEME

Question	Answer	AO1	AO2	AO3	Total Mark												
1.	Look at the pictures below. They show two different tall bicycles. A tall bicycle is a type of bicycle that is made by people as a hobby. Typically (Usually), they are two conventional (standard) bicycle frames that are connected together.																
(a)	The main body of the tall bicycle is made from two different frames.																
(i)	State a possible method for joining both frames together. - Possible methods include any type of welding process, brazing or mechanically joined.	1			1												
(ii)	State two safety features that should be built into the design of these bicycles. Safety features could include any of the following: - User should have a method to balance the bike when stopped. - Over-steering should be compensated for. - The bike should not be too top-heavy and should be lightweight. - Fully working brakes. - Place for lights to be mounted.	2			2												
(iii)	Complete the table below. Suggest a suitable material or identify a suitable property for each of the parts. <table border="1"><thead><tr><th>Part</th><th>Material</th><th>Reason for choice</th></tr></thead><tbody><tr><td>Handlebar grips</td><td>Rubber</td><td>- Can be shaped easily, - Available in a range of colours - Good tensile strength - Elasticity - Corrosion resistant - 'Grippy'</td></tr><tr><td>Seat post</td><td>- Aluminium - Carbon fibre - Titanium Do not accept 'Steel'</td><td>Light and hardwearing material</td></tr><tr><td>Spokes</td><td>Stainless steel</td><td>- Corrosion resistant - High tensile strength - Affordable</td></tr></tbody></table>	Part	Material	Reason for choice	Handlebar grips	Rubber	- Can be shaped easily, - Available in a range of colours - Good tensile strength - Elasticity - Corrosion resistant - 'Grippy'	Seat post	- Aluminium - Carbon fibre - Titanium Do not accept 'Steel'	Light and hardwearing material	Spokes	Stainless steel	- Corrosion resistant - High tensile strength - Affordable	3			3
Part	Material	Reason for choice															
Handlebar grips	Rubber	- Can be shaped easily, - Available in a range of colours - Good tensile strength - Elasticity - Corrosion resistant - 'Grippy'															
Seat post	- Aluminium - Carbon fibre - Titanium Do not accept 'Steel'	Light and hardwearing material															
Spokes	Stainless steel	- Corrosion resistant - High tensile strength - Affordable															

Question	Answer	AO1	AO2	AO3	Total Mark
(iv)	State two possible reasons for using a surface finish on the main body of the tall bicycle. Reasons could include: - To protect the frame from corroding or rusting - To make the tall bike aesthetically pleasing - To personalise the tall bicycle - To increase functionality	2			2
(b)	Use notes and sketches. Describe a simple test that can be performed to test the tensile strength of the brake lever. Quality of sketching: - award one mark for a simple solution that includes a single sketch. - award two marks for an appropriate solution that includes more than one sketch showing the method. - award three marks for a wholly appropriate solution that includes a detailed set of sketches. Quality of notes: - award one mark for a few single word annotations that are largely accurate. - award two marks for simple annotations that are accurate. - award three marks for detailed annotations that are accurate. Indicative content could include: - A method for holding/clamping the brake lever. - A method of attaching weights/pressure on the brake lever. - A method of measuring a change in the brake lever before it breaks. 3 marks for sketches and diagrams. 3 marks available for notes. 0 marks awarded for incorrect process.	3	3		6
(c)	Identify two semi-permanent joining methods. Describe where they would be used on the tall bicycle. - Nut and bolt (brake mechanism, wheel attachment, pedal, handlebar stem, crank arm) - Self-tapping screws (water bottle cage, brake levers) - Quick-release mechanism (seat adjustment, wheel) - Hex bolts (various) - Threaded holes and set-screws / Allen screws	6			6

Question	Answer	AO1	AO2	AO3	Total Mark								
2.	Look at the picture below. It is a picture of a pair of paperweights in the shape of a dice. These were made as part of an engineering project in a school workshop. They are made from 18 mm square section metal. Each face has a number of pips (dots), ranging from 1 to 6. The pip locations are marked and then drilled on a bench or pillar drill.												
(a) (i)	Name a suitable metal to make the dice from. State two properties that make it a suitable metal. - Aluminium: lightweight, easy to shape (file/drill/mark/cut), bright/shiny finish, malleable, corrosion resistance. - Mild steel: easy to shape (file/drill/mark/cut), low cost, heavy (good for paperweight), can be purchased in square section.	3			3								
(ii)	Describe a method to ensure that every pip is drilled to the same depth every time, using a bench or pillar drill. - Use of a Stop. - Use of a jig. - Fixture. - Use of a depth gauge		2		2								
(iii)	Complete the table. Name each tool and piece of equipment. State its use. <table border="1"><thead><tr><th>Name</th><th>Use</th></tr></thead><tbody><tr><td>Bench vice Do not accept 'Vice'</td><td>To securely hold work pieces to carry out a range of engineering processes such as using hand tools, measuring/marketing out, cutting, filing, and hacksawing.</td></tr><tr><td>Hand file Flat file Metalwork file Half-round file Do not accept 'File'</td><td>Used to accurately cut and remove small amounts of material by hand. Shape, deburr etc</td></tr><tr><td>Digital Calliper (NOT VERNIER)</td><td>To measure a range of dimensions and features of a component. Internal, external, linear, depths, steps, Øs</td></tr></tbody></table>	Name	Use	Bench vice Do not accept 'Vice'	To securely hold work pieces to carry out a range of engineering processes such as using hand tools, measuring/marketing out, cutting, filing, and hacksawing.	Hand file Flat file Metalwork file Half-round file Do not accept 'File'	Used to accurately cut and remove small amounts of material by hand. Shape, deburr etc	Digital Calliper (NOT VERNIER)	To measure a range of dimensions and features of a component. Internal, external, linear, depths, steps, Øs	6			6
Name	Use												
Bench vice Do not accept 'Vice'	To securely hold work pieces to carry out a range of engineering processes such as using hand tools, measuring/marketing out, cutting, filing, and hacksawing.												
Hand file Flat file Metalwork file Half-round file Do not accept 'File'	Used to accurately cut and remove small amounts of material by hand. Shape, deburr etc												
Digital Calliper (NOT VERNIER)	To measure a range of dimensions and features of a component. Internal, external, linear, depths, steps, Øs												

Question		Answer	AO1	AO2	AO3	Total Mark
2	(b)	Use notes and sketches. Show how you would create a chamfer on each edge of the dice. Quality of sketching: • award one mark for a simple solution that includes a single sketch. • award two marks for an appropriate solution that includes more than one sketch showing the method. • award three marks for a wholly appropriate solution that includes a detailed set of sketches showing the method to creating a chamfer. Quality of notes: • award one mark for a few single word annotations that are largely accurate. • award two marks for simple annotations that are accurate. • award three marks for detailed annotations that are accurate. Filing by hand: - Place soft jaws in the metalwork vice. - Place metal cube in soft jaws/vice. - Place hand file on the edge of the metal cube. - Make sure the file is held at a 45-degree angle. - Start filing the metal, applying the same amount of pressure on the hand file. Using a milling machine to create a chamfer can also be awarded marks. 3 marks for sketches and diagrams. 3 marks available for notes. 0 marks awarded for incorrect process.	2	4		6

Question		Answer	AO1	AO2	AO3	Total Mark
2	(c) (i)	Use the squares below. Accurately mark where the drill marks should be located. Follow the instructions given. 1 pip One mark should be drawn in the square. It should be at the point where two diagonal lines, drawn diagonally from corner to corner, cross. 5 pips Five marks should be drawn in the square. The centre pip should be drawn as per the '1 pip' face. The remaining four pips should be drawn on two diagonal lines, drawn between two corners. The four pips should be equal distance from the centre pip.		4		4 (1+3)
	(ii)	Calculate how many lengths of square section metal will have to be ordered. This is for all 32 learners in the class to produce a dice. 1 length = 400mm $400\text{mm} / 18\text{mm} = 22.22$ 22 cubes to be cut from each length. 2 lengths needed for all 32 learners in the class to produce a die.		3		3
	(iii)	State three typical safety precautions that must be carried out before starting the drilling operation. Answers could include: - Long hair must be tied up and out of the way. - Loose clothing needs to be tucked in / secured. - Safety glasses must be worn. - Chuck keys must be removed. - Work must be secure. - Guards must be in place. - Set correct RPM. - Ensure area is well lit.	3			3

Question	Answer	AO1	AO2	AO3	Total Mark
3.	Look at the picture below. It shows a type of machine that is usually seen in an engineering workshop.				
(a) (i)	Name the machine shown and name one engineering process that can be carried out on it. Name of machine – milling machine (vertical, universal) Engineering process - Milling is a process performed with a machine in which the cutters rotate to remove the material from the work. Consider all types of cutter and feature produced such as: • Producing a flat surface • Reducing the thickness of a component • Cutting/producing a slot or recess • Producing a flat-bottomed hole/counterbore • Face Milling • Shoulder Milling • Side Cutting • Plunge Milling	2			2
(ii)	List four sequential steps you would carry out to cut 2mm off the surface of a piece of square section aluminium block on this machine. Set up cutting tool. Put correct cutting tool into the collet chuck. Set correct RPM speed of machine in relation to the material being cut and the size of the cutter. Clamp work to the bed of the milling machine. Ensure that all guards are in place. Position cutting tool near the edge of the material. Switch machine on. Level the cutting tool with the surface of the material. Remove cutting tool from surface of material and raise bed to set depth cut. Turn table traverse/cross feed handle for the desired cut. Once cut has been made, return to initial (datum) point, and move bed for the next cut. Repeat process until the whole cut is completed. The steps must be sequential.	4			4

Question		Answer	AO1	AO2	AO3	Total Mark
3.	(iii)	State two methods of maintaining/prolonging the life of the cutting tool on the machine. - Use an appropriately sized cutting tool for the specific task. - Ensure the machine is set at the correct speed for the task. - Move/feed the bed/material at a suitable speed into the cutting tool so that the tool doesn't overheat on the material. - Ensure chips are kicked out of the cut to reduce blockages. - Do not cut off too much material in one pass. - Use the cutting guides to ensure correct speed and feed rates are used. - Use of a coolant when operating the machine.	2			2
	(b) (i)	Name the method of reinforcing a structure to make it stronger. Method – Triangulation/trussing	1			1
	(b) (ii)	The design and manufacturing of the roller coaster has developed over the years. Discuss how. Indicative content: - Materials used in manufacturing the track. - Materials used in manufacturing the carts. - Calculation of forces involved in the ride. - CAD simulations for forces. - Size/length of the rides (modern ones tend to be shorter rides but more fun/complicated/exhilarating) - Maintenance of the roller coaster. - Safety features of the ride. - Higher speeds/more excitement generated. - More complicated shapes/tracks. - Material joining techniques.		8		8

AO2: Apply skills (including practical skills), knowledge and understanding in a variety of contexts and in planning and carrying out investigations and tasks.

7-8 marks

An excellent response which demonstrates:

- a highly effective and detailed explanation of how the design and manufacturing of the roller coaster has developed.
- consideration of a wide range of possibilities effectively applied to the context of the roller coaster.

5-6 marks

A very good response which demonstrates:

- a highly effective and detailed explanation of how the design and manufacturing of the roller coaster has developed.
- consideration of a wide range of possibilities effectively applied to the context of the roller coaster.

3-4 marks

A good response which demonstrates:

- an effective explanation of how the design and manufacturing of the roller coaster has developed.
- consideration of a range of possibilities that are applied to the context of the roller coaster.

1-2 marks

A basic response which demonstrates:

- some explanation of how the design and manufacturing of the roller coaster has developed.
- consideration of some possibilities that are partially applied to the context of roller coaster.

0 marks

Response not creditworthy or not attempted.

Question		Answer	AO1	AO2	AO3	Total Mark
	(b) (iii)	Describe the issues that the theme park would have in disposing of both roller coasters at the end of their use. Indicative content: - Recycling procedures/initiatives. - Dismantling of the roller coasters. - 6R's (Rethink, Refuse, Reduce, Reuse, Repair, Recycle) - Life Cycle Analysis		6		6

AO2: Apply skills (including practical skills), knowledge and understanding in a variety of contexts and in planning and carrying out investigations and tasks.

5-6 marks

An excellent response which demonstrates:

- a highly effective and detailed explanation of issues that the companies would have in disposing of both roller coasters at the end of their use.

3-4 marks

A good response which demonstrates:

- an effective explanation of issues that the companies would have in disposing of both roller coasters at the end of their use.

1-2 marks

A basic response which demonstrates:

- some explanation of issues that the companies would have in disposing of both roller coasters at the end of their use.

0 marks

Response not creditworthy or not attempted.

Question	Answer	AO1	AO2	AO3	Total Mark
4.	Developments in technology over recent years have had an impact on society. Below are pictures of virtual reality devices.				
(a)	Discuss the advantages and disadvantages of using virtual reality devices in the design and manufacturing industry.			10	10
	Indicative content: Advantages could include: - Designs can be seen before any money is spent on materials. - Designs can be manipulated before manufacture. - A virtual design could identify faults or issues with a design. - Dangerous situations can be simulated and evaluated. - Can calculate the length of a project, beforehand. - Training can be done remotely/different countries. - Designs can be refined and modified before committing resources. Disadvantages could include: - Accuracy when working with forces. - Cost of buying the system. - Design could be stolen through hacking. - Implementation is expensive. - Health risks associated with VR headsets. Award up to a maximum of 8 marks for each individual point discussed, then a maximum of 2 marks for the quality of writing. (2 marks for extended answers, 1 mark for bullet points)				

Band	AO3 - Analyse and evaluate information making reasoned judgements and present conclusions
4	9-10 marks An excellent response which demonstrates: • consistent and appropriate analysis/evaluation skills used in an effective way • well-developed and balanced arguments • perceptive and rational judgements with clear and relevant links between conclusions and evidence.
3	6-8 marks A good response which demonstrates: • mostly consistent analysis/evaluation skills used in a generally effective way • developed arguments that may not be presented in equal measure • rational judgements, with relevant links between conclusions and evidence.
2	3-5 marks A basic response which demonstrates: • some analysis/evaluation skills used but may lack precision • only one side of the argument is presented but is not developed • generalised judgements and conclusions, with limited use of evidence.
1	1-2 marks A limited response which demonstrates: • limited analysis/evaluation skills used with little or no competence • judgments and/or conclusions that are not supported.
	0 marks Not attempted or not creditworthy

Surname	Centre Number	Candidate Number
First name(s)		4



LEVEL 1/2 VOCATIONAL AWARD

5799U30-1



S24-5799U30-1

TUESDAY, 21 MAY 2024 – AFTERNOON

ENGINEERING

UNIT 3

Solving Engineering Problems

1 hour 30 minutes

ADDITIONAL MATERIALS

In addition to this paper you may require a calculator and a ruler.

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	20	
2.	27	
3.	23	
4.	10	
Total	80	

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The total number of marks available is 80.

You are reminded of the need for clear and accurate written communication.

Question 4 provides an opportunity to draw together knowledge and understanding from across the full course of study. You will be rewarded for drawing together knowledge and understanding of different areas of the specification.



JUN245799U30101

Answer **all** questions.

1. The pictures below show two different tall bicycles. A tall bicycle is a type of bicycle that is made by people as a hobby. Typically, they are two conventional bicycle frames that are connected together.



- (a) The main body of the tall bicycle is made from two different frames.

- (i) State a possible method for joining both frames together.

[1]

.....

- (ii) State **two** safety features that should be built into the design of these bicycles.

Safety feature 1:

[1]

.....

Safety feature 2:

[1]

.....



- (iii) A variety of materials have been selected for the different parts of the tall bicycle based on their properties.

Complete the table below by suggesting a suitable material or identifying a suitable property for each of the parts.

[3]

Part	Material	Property
Handlebar grips	Rubber	..... ..... ..... .....
Seat post	.....	Light and hardwearing material
Spokes	Stainless steel	..... ..... ..... .....



- (iv) State **two** possible reasons for using a surface finish on the main body of the tall bicycle. [2]

Reason 1:

.....

.....

Reason 2:

.....

.....

- (b) Different materials are used for different parts of the bicycle. This is due to the different properties of each material. The bicycle brake lever would need to perform well under tension (tensile strength).

Using notes and sketches, describe a simple test that can be performed to test the tensile strength of the brake lever. [6]



- (c) The tall bicycle will be made using a variety of permanent and semi-permanent joining methods.

Identify **two** semi-permanent joining methods and describe where they would be used on the tall bicycle. [2 × 3]

Semi-permanent joining method 1:

Description:

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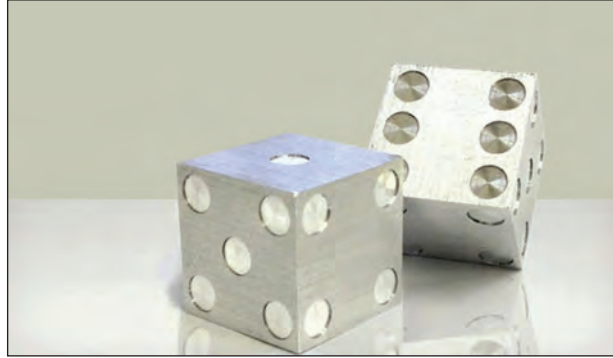
Semi-permanent joining method 2:

Description:

.....



2. Below is a picture of a pair of paperweights in the shape of a dice. These were made as part of an engineering project in a school workshop. They are made from 18 mm square section metal. Each face has a number of pips (dots), ranging from 1 to 6. The pip locations are marked and then drilled on a bench or pillar drill.



- (a) (i) Name a suitable metal to make the dice from and state **two** properties that make it a suitable metal.

Metal: [1]

Property 1: [1]

Property 2: [1]

- (ii) Describe a method to ensure that every pip is drilled to the same depth every time, using a bench or pillar drill. [2]

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.....



- (iii) Shown below are three pieces of tooling and equipment used in the production of the dice paperweights. [6]

Complete the table below by correctly naming each tool and piece of equipment and stating its use.

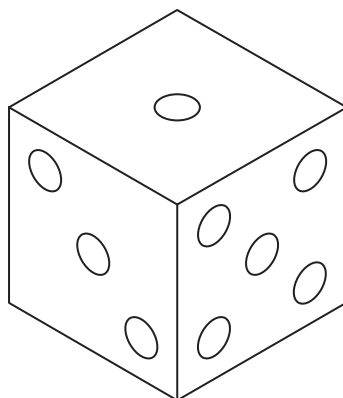
Equipment	Name	Use
		
		
		



- (b) Using notes and sketches, show how you would create a chamfer on each edge of the dice. [6]



- (c) Below is an isometric view of one dice.

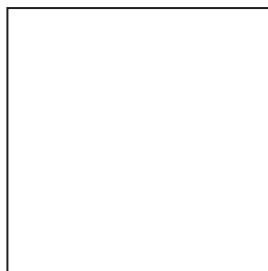


- (i) In the squares below, accurately mark where the drill marks should be located, following the instructions given.

1 pip – The pip should be at the centre of the face.

[1]

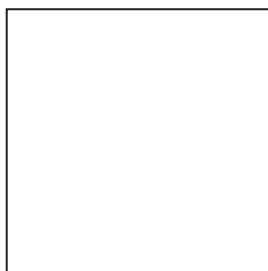
1 pip



5 pips – 4 of the 5 pips should be equal distance from the centre.

[3]

5 pips



- (ii) The 18 mm square section metal is purchased in lengths of 400 mm.

Calculate how many lengths of square section metal will have to be ordered for all 32 learners in the class to produce a dice. [3]

Show all your calculations.

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- (iii) State **three** typical safety precautions that must be carried out before starting the drilling operation. [3]

Safety precaution 1:

.....

Safety precaution 2:

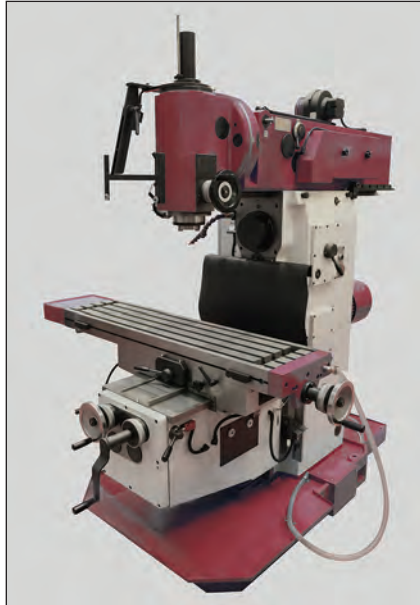
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Safety precaution 3:

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3. The picture below shows a typical machine, usually seen in an engineering workshop.



- (a) (i) Name the machine shown and name **one** engineering process that can be carried out on it. [2]

Name of machine:

.....

Engineering process:

.....

.....

.....

- (ii) List **four** sequential steps you would carry out to cut 2 mm off the surface of a piece of square section aluminium block on this machine. [4]

Step 1:

Step 2:

Step 3:

Step 4:



- (iii) State **two** methods of maintaining/prolonging the life of the cutting tool on the machine. [2]

Method 1:

.....

Method 2:

.....

- (b) Below is a picture of an old-style roller coaster and a modern roller coaster.



- (i) Name the method of reinforcing a structure to make it stronger. [1]

Method:



- (ii) Discuss how the design and manufacturing of the roller coaster has developed over the years. [8]

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- (iii) Describe the issues that the theme park would have in disposing of both roller coasters at the end of their use. [6]

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- A woman with long dark hair, wearing a VR headset and a dark long-sleeved shirt, is shown in profile. She is reaching out with both hands towards a vibrant, abstract digital environment. The environment is filled with glowing particles in shades of red, orange, yellow, and green, set against a dark background. The overall scene suggests an immersive virtual reality experience.



[10]



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