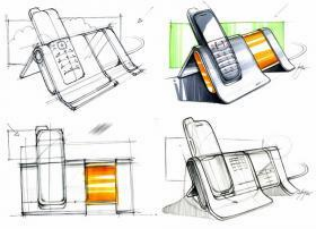
Product Design

GCSE Revision Guide



Use QR code for links to helpful sites

Material properties and characteristics

Key Word	Meaning
Strength	Withstanding force without breaking or bending permanently
Tensile Strength	Withstanding force when stretched
Compressive Strength	Withstanding force when being crushed
Durability	Withstanding wear and tear and weathering
Flexibility	How easily a material will bend or distort
Elasticity	The ability to regain its original shape after it has been deformed
Plasticity	Changing in shape permanently without cracking or breaking
Malleability	The ability to be easily pressed, spread and hammered into shapes
Ductility	The ability to be stretched and permanently deformed without breaking
Brittleness	How easily a material will break without bending (the opposite of ductile)
Hardness	Resistance to scratching, cutting, denting and wear
Word Hardness	When the structure of the material changes as a result of repeated hammering or strain (most common in metal working)
Toughness	Resistance to sudden shock without breaking or deforming
Impact Resistance	Resisting denting
Shear	Strong sliding forces acting opposite to each other
Stress	Any forces acting on a material
Electrical Conductivity	How easily a material allows electricity to flow through it
Thermal Conductivity	How easily a material allows heat to flow through it
Chemical Resistance	Resists chemical attack
Strength-to-weight Ratio	Is the measure of the strength of the material compared to its weight

Material properties and characteristics

Key Word	Meaning
Aesthetics	How something looks. Think about the SHAPES, COLOURS, TEXTURE and OVERAL APPEARANCE. Don't just say 'good' or 'nice' – use an adjective for once in your life!
Function	How something works. A chairs function is to be sat on, support the weight of an adult. So what does the product your looking at need to do?
Manufacture	The way something has been made. Tools, machinery, finishes and equipment. Finger joints would need; try square, ruler, pencil, marking knife, tenon saw, coping saw, vice, chisel, glass paper and varnish. So it isn't a simple case of "it was cut out..." really think about how YOU would make it.
Processes	Similar to manufacture, but more to do with large machinery. Cutting a line in wood, would normally be a bandsaw or circular saw. See what I mean?
Specification	This is the list of points that a produce needs to meet in order to be successful. It's like a shopping list! If you go shopping and don't buy anything on that list, then you've done it wrong! So imagine if you didn't make the product the way you said you would?! It wouldn't be very useful would it?
Dimensions	THE MEASUREMENTS! HOW BIG IT IS! THE SIZE! Come on.... This is easy! Don't forget, it's in centimetre (CM), millimetre (MM) or metre (M). Never use inches or miles! Duh!
Quality Assurance	These are the checks that are done BEFORE the making to make sure that the product is made to the highest standard.
Quality Control	These are the checks that are done DURING the making so enable the highest quality possible. Think back to Page 9 and 12 for this one!
Ergonomics	How a product has been designed, shaped and weighted so that it fits the human body the best way it can. Think about the chairs you sit on, they are all made to try and be the correct height and width for people to sit on.
Sustainability	Does the material/product affect the environment? Think about where the materials come from. How are the materials disposed of? Or are they recycled/reused? What fossil fuels are used in the production process?

The impact of new and emerging technologies

Computer Aided Design (CAD): This is where you can produce a 2D or 3D drawing/example of your ideas before you can actually make it.

Advantage	Disadvantage
•Saves money on materials •Can make changes to designs •Can run tests on ideas •See a visual representation •before having to make anything	•Requires high level of skill •Needs modern/up to date machinery to run most •programs •Training can take a long time •Cost of staff/labour is •moderate to high

CAD programs can include:

- 2D Design
- TinkerCAD
- Google Sketch Up
- Solidworks
- Photoshop/Illustrator

Computer Aided Manufacture (CAM): This is where a machine, which is controlled by a computer, can carry out the actual making for you – according to the information you have put into the CAD design.

Advantage	Disadvantage
•More accurate than a human •Can often be faster than a •human •Less cost in staff/labour •Less waste materials •Machines can work •continuously without rest	•Machinery can take up a lot of room •Set up costs are high •Staff costs tend to be high •Expensive should machinery •break down

CAM machinery can include:

- Laser Cutter
- CNC machine
- 3D Printer
- Vinyl Cutter

Rapid Prototyping is becoming more and more common now; especially with the use of 3D Printers.

Advantage	Disadvantage
•Allows the designer to see and handle a product in real life before production begins. •Decreases the product development time. •Costly production mistakes can be avoided as problems can be identified early in the design process. •Minimise changes to the produce once manufacturing has started.	•Costly specialist machinery. •Need for highly skilled staff. •High quality models can take •a long time •Large products sometimes •need to be made in parts, which takes up time and resources.

Automation

The **automation** of workplaces has led to an increase in skilled workers but a decrease in job opportunities, as machines have taken over the jobs previously done by humans. Automation has streamlined the manufacturing system by increasing production and reducing errors.

Flexible manufacturing systems (FMS)

Flexible manufacturing systems (FMS) are a series of different machines producing different parts for a product. The system is flexible because, at any time, machines in the process can be **reprogrammed** to change their task and production can be changed to produce more or fewer parts without stopping the other areas of the process.

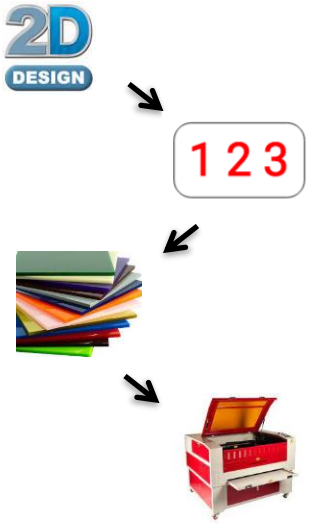
Just in time (JIT)

Just in time (JIT) manufacturing is triggered by a customer order. The correct amounts of materials are ordered in to cover the order, and these arrive just as they are needed by production. This saves money on storage, reduces waste and ensures there is no money wasted producing stock that will remain unsold. There are disadvantages to the system in that, if any part of the product cannot be sourced, **clients** have to wait for their order to be produced.

Lean manufacturing

Lean manufacturing is a Japanese concept, based on minimising costs and maximising efficiency by cutting down on waste and the amount of materials and energy used in production. This is done by adapting designs and making changes to the production process. For example, to reduce waste, a packaging net could be redesigned to include a tessellating pattern or, to improve efficiency, changeover times between production runs could be reduced.

The impact of new and emerging technologies



Laser Cutter

The Exam board have set out the following as the basic instruction you need to know for using the laser cutter:

1. Material placed on bed of Laser.
2. Laser focused to thickness of material.
3. Settings applied – high speed/low power for engraving (red) low speed/high power for cutting (black).
4. Settings sent from PC to laser.
5. Reference to extraction (extraction turned on or can be automatic).
6. Engraving operation carried out first followed by cutting operation.
7. Work removed from laser.

3D Printer

3D Printer: This uses layers of plastic (around 0.5mm thick) to build up a 3D product of whatever has been drawn out on 3D Drawing CAD software (we use TinkerCAD).
The best way to describe this, is if to imagine that you are building layers up on top of each other, like a hot glue gun.

Material for 3D printing– **ABS or PLA**

CNC Router

The exam board have set out the following as the basic instructions you need to know for using a CNC machine.

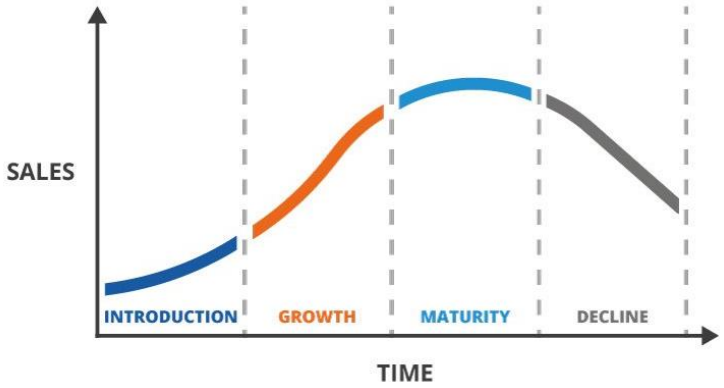
1. Setting the data needed (i.e. the 2D design drawing)
2. Attaching material to bed so it doesn't move whilst cutting.
3. Tool paths – set the way the router bit cuts away the materials
4. Cutting depths – how deep does the router bit need to go? Brittle materials need to down in smaller steps (like acrylic, it needs to go down 0.5mm each step) but softer materials (like MDF, it can go down 3mm each step).
5. Cutting speeds are set to allow for a high quality finish.

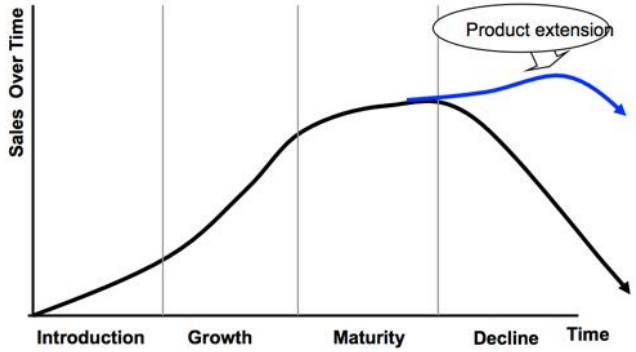
Vinyl Cutter

Vinyl Cutting Machine: This is like a CNC machine, but it uses a knife instead of a router bit. The knife is controlled by the 2D Design outlines only – and it only see's one colour, black. These machine are used to create stickers/vinyls. The same the go onto cars and vans when advertising their company.

Product Life Cycle

• **Introduction Stage** – This stage of the cycle could be the most expensive for a company launching a new product. The size of the market for the product is small, which means sales are low, although they will be increasing. On the other hand, the cost of things like research and development, consumer testing, and the marketing needed to launch the product can be very high, especially if it's a competitive sector.
• **Growth Stage** – The growth stage is typically characterized by a strong growth in sales and profits, and because the company can start to benefit from economies of scale in production, the profit margins, as well as the overall amount of profit, will increase. This makes it possible for businesses to invest more money in the promotional activity to maximize the potential of this growth stage.
• **Maturity Stage** – During the maturity stage, the product is established and the aim for the manufacturer is now to maintain the market share they have built up. This is probably the most competitive time for most products and businesses need to invest wisely in any marketing they undertake. They also need to consider any product modifications or improvements to the production process which might give them a competitive advantage.
• **Decline Stage** – Eventually, the market for a product will start to shrink, and this is what's known as the decline stage. This shrinkage could be due to the market becoming saturated (i.e. all the customers who will buy the product have already purchased it), or because the consumers are switching to a different type of product. While this decline may be inevitable, it may still be possible for companies to make some profit by switching to less-expensive production methods and cheaper markets
• **Product Extension**– Just as the current product is declining in sales, a new, upgraded version is released to drive new sales for the company





The 6Rs

	Meaning
Recycle	Processing materials to make new ones! Plastic is a HUGE material for this point.
Re-use	Using old products/parts for other uses.
Reduce	Use less energy and resources throughout the whole product life cycle.
Repair	Instead of throwing the whole product away, repair the part that's broken. Think about it like a car!
Rethink	Changes to the way we think about how materials are used and where the come from.
Refuse	Saying "no" to bad/wasteful design. Thinking of alternatives instead. Don't make a new product/part if you don't need it.

Mobius loop

Aluminium recycling

Glass recycling

Steel recycling

'Kite' Mark
British Standards Institution

This means that product has undergone lots of testing by the BSI and is approved to be made to a very high standard.

FSC
Forest Stewardship Council

his shows that the wood that has been used is from a managed source. Most likely, for every tree cut down another (or more) is planted in its place.

Renewable energy means that it can be used over and over again. It will not run out.

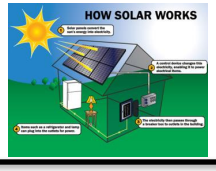
The impact of new and emerging technologies – Renewable Energy

Solar Energy

Photovoltaic panels on a roof produce electricity when exposed to sunlight. They produce direct current (DC) that can be used to charge batteries or converted to high voltage and fed into the mains.
Solar water heating panels can be used directly to heat water

Advantages
•Renewable (wont run out)
•No greenhouse gases omitted

Disadvantages
•Inconsistent power – no sun= no power
•The storage of power for when they are needed is expensive
•Visual – some people think that it ruin the look of houses



Wind Turbine

Wind rotates the turbine which generates electrical current. This is collected through a substation. The more wind, the faster the turbines rotate generating more electricity.

Advantages
•Renewable (wont run out)
•No greenhouse gases omitted

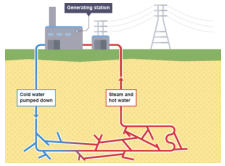
Disadvantages
•Inconsistent power – no wind = no power
•Noise pollution
•Visual – some people think that it ruins the landscape
•Risk to bats and birds

Geothermal Energy System

Geothermal energy is when cold water is pumped underground, where it is heated by the Earth's natural heat. The hot water (or steam) that returns can heat homes, or it can be used in power stations to generate electricity.

Advantages
•Renewable (wont run out)
•No greenhouse gases omitted
•Consistent power output

Disadvantages
•Most parts of the world do not have suitable areas where geothermal energy can be exploited.

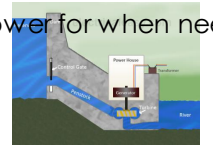


Hydroelectric Energy

A dam is built to trap a natural river, forming a lake. The water is released, under control, and the pressure of the escaping water turns turbines that generate electricity. Small hydroelectric generators don't need a dam and rely on the energy of fast- flowing river.

Advantages
•Renewable (wont run out)
•No greenhouse gases omitted
•Consistent power output
•Variable output on demand

Disadvantages
•Dependant on location – mountainous areas with heavy rainfall
•Visual – people think it spoils the landscape
•Storage of power for when needed is expensive

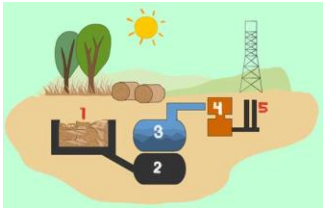


Biomass

Biomass can generate electricity in a number of ways, but the most common is combustion – burning agricultural waste or woody materials to heat water and produce steam, which spins turbines.

Advantages
•Renewable (wont run out)
•Uses waste materials
•Can be stored easily for use when required

Disadvantages
•Materials can need transportation
•Creates greenhouse gases

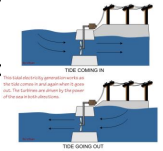


Tidal Energy System

Tidal – Tidal electricity generation works as the tide comes in and again when it goes out. The turbines are driven by the moving water (as the sea goes in and out in both directions). This is then converted into electrical energy.

Advantages
•Renewable (wont run out)
•No greenhouse gases omitted
•Consistent power output

Disadvantages
•Dependant on location
•Visual – people think it spoils the landscape
•Hard to produce large amounts of energy
•Tidal barges destroy the habit for living species
•Can flood farm land and make people move homes – Also coastal erosion



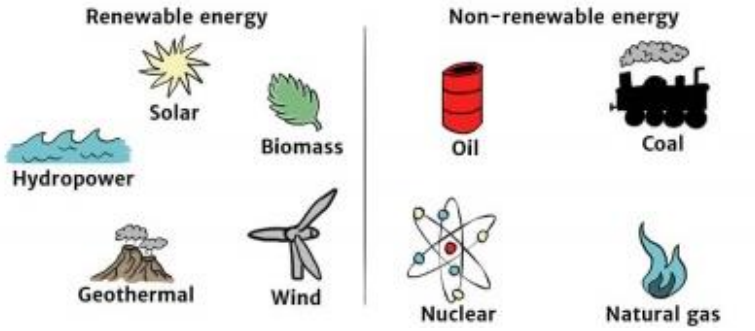
The impact of new and emerging technologies – Renewable Energy

Renewable energy

Advantages	Disadvantages
They'll **never run out**. That's right - these natural energy sources can **replace themselves**, making them **sustainable** and abundant natural resources.	**Unreliable weather can affect energy supply.** As renewable energy often relies on certain weather conditions, this can impact the reliability of a constant energy supply. For example:
They **don't damage our planet**. These clean energy sources are **non-pollutant**, produce **minimal or no waste products**, and don't contribute to global warming - great news for the environment!	**It's hard to produce the same amounts as non-renewable sources.** It can be difficult to generate quantities of electricity that are as large as those produced by traditional fossil fuel generators.
Cheaper than non-renewable resources	The cost factor – Renewable energy sources **high high initial set up costs.**
They're **low-maintenance** energy sources. Renewable energy facilities tend to require **less maintenance** than traditional generators. And as they come from natural, abundant resources, the operating costs are generally **lower** too.	
They're good news for regional areas. As most renewable energy projects are located in regional areas - away from the big cities - they can bring **economic** benefits to these places. For example, this could come from more people using local services.	

Non-Renewable energy

Advantages	Disadvantages
They generate **large** amounts of energy **quite cheaply**	They release **carbon dioxide** when they are burnt, creating **pollution**. Carbon dioxide **contributes** to the **greenhouse** effect and **global warming**
Locating where fossil fuels are is quite **easy**.	**Oil spills** can cause **environmental damage**.
Oil and gas can be **transported** through **pipelines**.	Mining can create ugly scars on the **landscape**. Mining can be **dangerous**, especially as the most easily accessible deposits are used up.
The means for extracting fossil fuels is already in **existence**.	Supplies are **running out** and new sources are **harder** to get to. Oil and gas are both predicted to run out within **100 years**.
As technology improves, more **reserves** can be **accessed**	Oil is mainly produced outside the UK, so **prices** are set by other countries.



The impact of new and emerging technologies

Wood

Wood is a renewable resource that can be replaced by tree. Usually two saplings (trees) are planted ('two for one) to replace each tree cut down, and the weaker one pulled up later. Natural rainforest is a precious resource and shouldn't be destroyed.

Trees store carbon in their trunks (carbon capture(, and if the wood rots or burns this carbon is released into the atmosphere. So, rather than being burned, wood products should be reused or recycled.

Wood dust, chips or off cuts can be recycled into chipboard or Medium Density Fibreboard (MDF)

Types of wood:
- Hardwood
- Softwood
- Manufactured boards (Man made woods)

Metals

Metals come from non-renewable ores that are mined from the ground. There are heath and safety issues with the working conditions of the miners diggers in dangerous places and breathing in dust.

Ores need to be smelted to provide the pure metal. The heat energy required to smelt and shape metals usually comes from burning non-renewable fossil fuels, which give off toxic fumes and release carbon dioxide into the atmosphere. The smelting process also gives off toxic fumes.

So, recycling metals is important in order to:
- Preserve the limited resources
- Reduce the amount of energy needed to work the metals

For example, Bauxite (aluminium ore) is plentiful metal, but producing new aluminium from bauxite uses nine times as much energy as melting recycling cans.

Plastics

Most plastics are made from oil (a non-renewable resource). Stocks of oil are now running out so alternative sources have been found in plant materials, known as bio fuel. But, growing plants to provide bio fuel or starch polymers, uses land that could have been plants for food. This increases food prices and can lead to food shortages.

Energy is used to work and produce plastics. The toxic by products also have to be disposed of.

Decisions have to be made about whether plastics are the best material to choose for making products. Most plastics can be recycled, but because there are so many different types it's difficult to separate them for the different processes required.

Smart and composite materials

Composite Materials are materials which are mixture of more than one material and/or element. It is similar to an alloy but these are not just metals. ALLOYS ARE NOT COMPOSITE MATERIALS!

GRP consists of strands of glass fibres that are coated in polyester resin.
Common Uses: sailing boat. Kit car

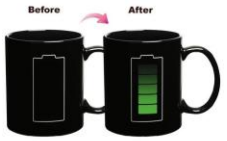
Kevlar is similar to carbon fibre matting. Very strong plastic material woven to form a mat.
Common Uses: Kevlar is used make items as badminton and tennis rackets, helmets and bullet-proof vests. Body armour

Carbon Fibre is reinforced plastic – similar to GRP. Strands of carbon that are coated in polyester resin – used in high performance products.
Common Uses: F1 car, track bike, tennis rackets

Smart Materials have properties that react to changes in their environment. This means that one of their properties can be changed by an external condition, such as temperature, light, pressure or electricity. This change is reversible and can be repeated many times.

Polymorph is a thermoplastic material that can be shaped and reshaped any number of times. It can be heated in hot water (62 degrees) and when removed it can be shaped into almost any form and on cooling it becomes as solid as a material such as nylon.
Although expensive, polymorph is suitable for 3D modelling as it can be shaped by hand or pressed into a shape through the use of a mould.

Thermochromic inks are those that change colour in response to changes in temperature. These inks have serious applications such as in the food industry. They can be used to indicate when a packaged food has reached the correct temperature in an oven. They are also used in forehead thermometers made from card, with Thermochromic ink as a temperature sensor.



Shape-memory alloy (SMA). A shape-memory alloy is an alloy that "remembers" its original shape and that when deformed returns to its pre-deformed shape when heated.

In-depth material knowledge

Sources and origins

Ores are naturally occurring rocks that contain metal or metal compounds in sufficient amounts to make it worthwhile extracting them.

Iron ore is used to make iron and **steel**. **Copper** is easily extracted, but ores rich in copper are becoming more difficult to find. Aluminium and titanium are metals with useful properties, but they are expensive to extract. Most everyday metals are mixtures called **alloys**.

Extracting metals

The Earth's **crust** contains metals and metal **compounds** such as **gold**, **iron oxide** and **coaluminium oxide**, but these are often mixed with other substances when found in the Earth. To be useful, the metals have to be extracted from whatever they are mixed with. Metal ore is a rock containing a metal, or a metal compound, in a high enough concentration to make it economic to extract the metal.

Social and ecological issues

When considering the ecological and social implications of using metal, its **non-renewable** nature is the main concern. Metal cannot be grown and is a **finite resource** - there is only a certain amount within the Earth's **crust**. To create **aluminium**, the ore **bauxite** is mined as it contains aluminium hydroxide minerals. The bauxite is **purified** so that **aluminium oxide** is produced, and the aluminium is **extracted** from this through **electrolysis**. Huge amounts of energy are used to extract aluminium and convert it into a usable material. Recycling it requires some energy to make it usable again, but nowhere near as much. Steel is made in huge and exceedingly hot cauldrons. Its production uses a lot of energy and contributes approximately 5 per cent of the world's **greenhouse gas emissions**.

The 6Rs

The term 'the 6 Rs' can be applied to the design of new products or when a product is finished with, used up or no longer wanted. Here are some questions to prompt 6Rs thinking:

- **Reduce** - Can the amount of metal used be reduced? Can the metal be bought locally to reduce product miles?
- **Reuse** - Can the metal be reused for another purpose once a product is finished with?
- **Recycle** - Can the metal be disposed of correctly so that it can be recycled?
- **Rethink** - Can the way a product is made be redesigned so that less metal is used?
- **Refuse** - Refusing to use metal could be a consideration; could a material that is sustainable be used instead?
- **Repair** - When a product is broken, can it be repaired rather than discarded?

Raw Material	
Manufacturing	
Distribution	
Usage	
Recycling	
Landfil	

In-depth material knowledge

Metals

Ferrous metals are metals which contain **iron**. They will **corrode if unprotected**. Ferrous metals will be attracted by a **magnet**.

Non-ferrous are metals which **do not contain iron**. Pure metals such as aluminium, copper, tin and lead are non-ferrous, **do not rust** and are **not attracted by a magnet.**

Alloys are metals which are a **mixture of two or more metals**, benefiting from the properties of both. For example, brass is an alloy of copper and zinc.

- **Elasticity** – that ability to regain its normal shape after it has been reformed
- **Ductility** – the ability to be stretched without it breaking
- **Malleability** – the ability to be easily pressed, spread and hammered into shapes
- **Hardness** – resistance to scratching, cutting and wear
- **Work hardness** – a change in the hardness of a metal due to repeated hammering or strain
- **Brittleness** – break easily without bending
- **Toughness** – resistance to breaking, bending or deforming
- **Tensile strength** – strength when stretched
- **Compressive strength** – strength when under pressure

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

Metals

In-depth material knowledge

How to make a metal more robust?

This process is called **hardening**
Heating a metal can enhance the strength and hardness of a metal. The metal is heated above 720 degrees then cooled rapidly in water. This makes the metal (steel) hard but does make it very brittle.

How to change the shape of a metal

It is the process of softening a metal so it can be bent or hammered. The metal is heated so it become malleable / softer, the shape is changed by force and then left to naturally cool. This process is call **annealing**

Reinforcing and stiffening

Forces act on materials all the time - even if a material appears stationary it still has a force acting on it. There are five terms used to describe what type of force can act on a material:

- **tension** - a pulling force
- **compression** - a pushing force
- **bending** - forces at an angle to the material
- **torsion** - a twisting force
- **shear** - forces acting across the material

Finishing a metal

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

Finish	Description
Plastic dip coating	Used mainly on **steel**. Metal is heated and dipped into plastic powder. Good for anti corrosion and a range of colours for aesthetics
Anodising	**Aluminium** is placed in an acid bath and an electric current is passed through and coloured dye added
Painting	Creates a barrier for corrosion resistance. Is prepared first with a **primer**. Needs regular maintenance
Blueing	**Steel** is heated then dipped in oil. This creates a anti-corrosion layer which is usually blue / black in colour
Powder coating	Similar to dip coating but the powder is sprayed on. This is used more in industry and mainly for white goods eg washing machine, fridges…
Galvanising	A ferrous metal is coated in a thin layer of zinc to protect it from corrosion. Use on street lights and fences. Has a durable and speckled finish
Enamelling	High temperatures are used to melt glass onto a metallic surface for corrosion resistance and aesthetic appeal. Used for tin mugs and jewellery

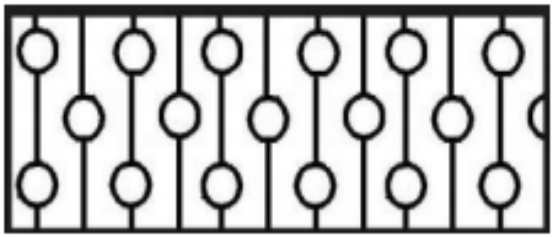
In-depth material knowledge

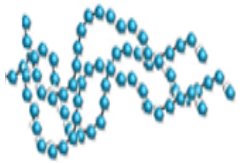
THERMOPLASTICS

Thermoplastics are made from long chain polymers, joined by **weak chemical bonds**. When the plastic is **softened by heat** the bonds break making the plastic 'semi fluid' and able to be **shaped**. As the plastic **cools**, new weak bonds form and the shape will be fixed. Because no chemical reaction has taken place this process can **be repeated many times**, making them **recyclable**.

Names of thermoplastics:

- High / Low Density Polythene (HDPE)
- Acrylic
- Acrylonitrile Butadiene Styrene (ABS)



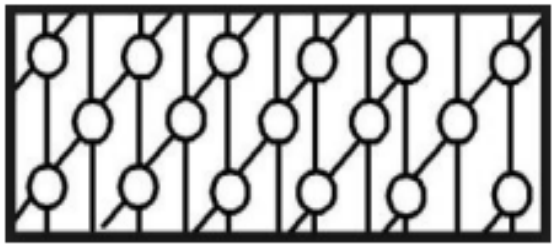


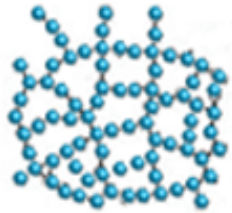
THERMOSETS

Thermosets or thermosetting plastics are plastics which are converted into their **final form by heat**. Once set, they **cannot be softened by further heating** as they undergo a **chemical change**. They **have strong chemical bonds** that hold the long chains together (Cross linked). These make thermosetting plastics **heat resistant** but **not recyclable**.

Names of thermosetting plastics:

- Melamine Formaldehyde
- Urea Formaldehyde (Bakelite)
- Phenol Formaldehyde





In-depth material knowledge

Production Method	Description	Example	Equipment and Tooling cost	Labour Costs	Skill Level	Costs	Efficiency
One-off	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 lev el of design and manufacturing skills are needed. An example of one- off production would be a made-to-measure wedding dress.		↓	↑	↑	↑	↓
Batch	Batch production occurs when a series of identical products are made together in either small or large amounts. Once made, another series of products can be produced using the same equipment as last time. For example; a stool or loaves of bread.						
Mass	Mass production involves the product going through different stages on a production line where the workers at a particular stage are responsible for a certain part of the product. The product is made over a number of days or weeks. The best example is a car or plastic containers.						
Continuous	This is where the product is made continually over a period of hours, days or even years (24/7). Making the product cheaper because of the large number being made. For example; screws or processed foods.						
Just-in-time (JIT)	Also known as 'JIT'. This involves the arrival of different parts at exactly the time they're needed at the factory. Using less on storage space which saves warehouse expenses. If there is a delay, production can become very expensive quickly. Example: Customised products, Toyota uses this method in their cars or even some fast food!		With just in time, a business holds no stock and instead relies upon deliv eries of raw materials and components to arriv e exactly when they are needed. Instead of occasional large deliv eries to a warehouse, components arriv e just when they are needed and are taken straight to the factory floor. The benefits of reduced warehouse costs must be balanced against the cost of more frequent deliv eries and lost purchasing economies of scale from bulk buying discounts.				

Joining materials - Metals

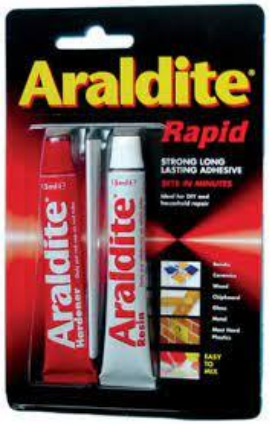
Soldering Soft soldering joins metal parts together using a lead-based alloy. Its used for light applications eg Electrical components and plumbing joints

Gas welding is when a acetylene touch is used to heat up two parts of metal melts the two metals together with heat.

MIG welding is when an electrical spark (which is very bright) creates heat to join the two metals.

Spot welding is used a attach thin sheets of steel together (cars). Electrodes (normal copper) sandwich the metals together and a current is passed through them. The resistance creates the heat to bond the two metals in a tiny spot.

Epoxy Resin is an adhesive which forms as a result of a chemical reaction between two resins, one of which is a hardener. It comes in two parts that you have to mix the to together.
A common brand of epoxy resin is **Araldite**



Joining materials – Adhesives

What are they?
A substance used to stick things together

Preparation: All adhesives need the material to be clean, dry and free from oil and dust if they are to achieve their maximum grip. Some areas may need to be covered in masking tape to prevent the glue from spreading.

Some adhesives require the joint to be keyed. This means that the joint should be made roughly

(usually done with an abrasive paper

	Fabric	Plastics	Metals	Wood
Wood	PVA	Contact Adhesive	Contact Adhesive	PVA or Polyester Resin
Metals	Contact Adhesive	Contact Adhesive	Epoxy Resin	Contact Adhesive
Plastics	Contact Adhesive	Solvent Cement	Epoxy Resin	Contact Adhesive
Fabric	Latex Adhesive	Contact Adhesive	Contact Adhesive	PVA

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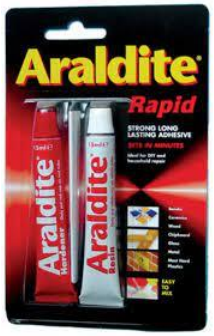
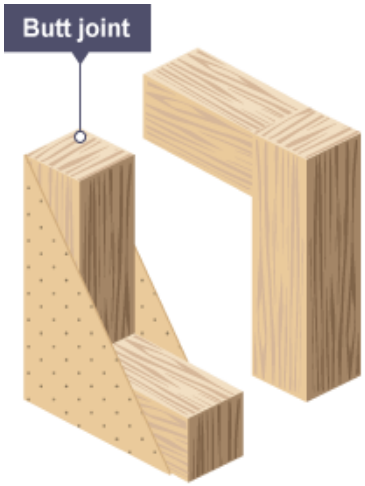
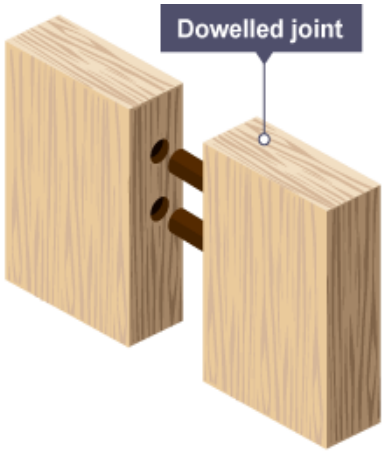


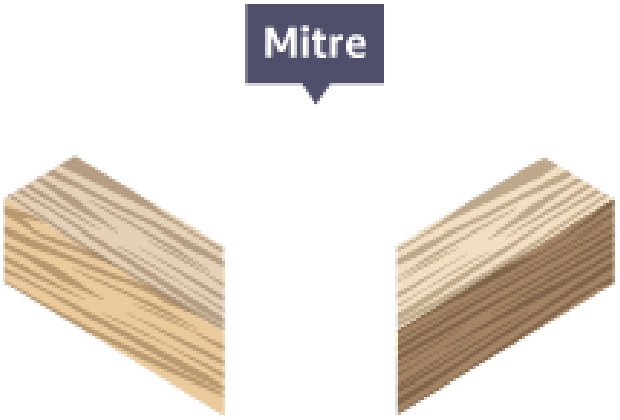
Name	*Material*	*Drying Time*	*Use*
PVA	Wood	4-24hours	Gives a strong joint. It comes in a liquid form.
Liquid Solvent Cement 'Tensol'	Thermo-plastic	Up to 5 Mins	It is waterproof and gives a medium strength joint. It comes in a liquid form. The joint needs to be held together while the glue dries.
Contact Adhesive	Wood, metal, plastic.	20mins dry time but instant upon contact.	It is waterproof and gives a medium strength joint. Ideal for plastic laminates to chipboard for kitchen worktops. It comes in a liquid form.
Epoxy Resin	Wood, metal, plastic	About 20 mins	Is waterproof and gives a strong joint. Equal amounts of resin and hardener are mixed together and applied with a spreader. Must be held together whilst glue dries.
Latex Glue	Fabrics	1/2-1 hours	It is flexible and takes up the very small spaces between the different threads that make up the fabric.

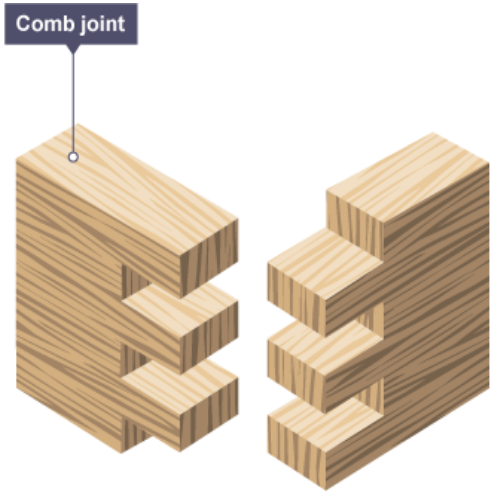
Joining materials – Wood Joints

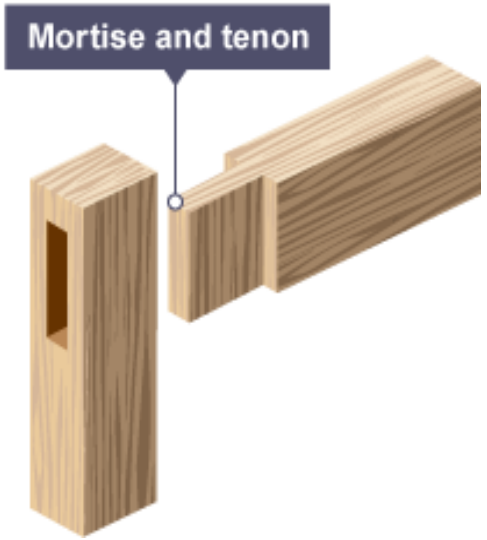
Joinery is a part of woodworking that involves joining pieces of wood or timber, to produce more complex items. Some wood joints employ fasteners, bindings, or adhesives, while others use only wood elements. The **characteristics of wooden joints - strength, flexibility, toughness, appearance**, etc. - derive from the properties of the materials involved and the purpose of the joint. **Wood often uses PVA glue to secure to together and used saw to cut to length along with other woodworking tools.**











Joining materials – Modelling

What is modelling?
Modelling is an **inexpensive** tool designers use to **refine** and **communicate** their ideas to clients and manufacturing companies.

It allows designs to be moved forward and improved.
Modelling can also help you test:
- Ergonomics
- Materials
- Construction

Types of modelling
Quick Modelling - These are the first initial models you will make of an idea. You will use materials that are easy to hand, such as paper and card.

Prototyping - This is a type of modelling that happens later on in the project. When the idea is more refined. The model will be an accurate reflection of what the final idea will look like and how it will work. It will help manufacturers to determine dimensions and a final product spec.

CAD Modelling – Ideas can be modified rapidly, shared electronically, and even involve virtual testing!

Modelling material	Description
Paper and Card	• Easy to cut and fold • Paper not as rigid as card
Corrugated Card	• Easily available • Good for large scale models • Not easy to fold
Polystyrene Foam	• Good for shaping in solid block shapes • Lightweight and glues well
Foamboard	• Clean and crisp models • Can be cut with a knife
Balsa and Jelutong	• Can be cut in a school workshop • Sanding gives smooth finish
Wire and Straws	• Good for representing piping and tubing • Wire easily bent into complex shapes
Polymorph	• Can be reused • Easy to shape by hand or by using moulds • Can be painted

Using ICT as a modelling tool
- Computer Aided Design (CAD) allows designers use many different software programmes to help develop ideas.
- CAD can help you "render" an idea, giving it a realistic colour or material effect.
- CAD can allow you to run simulations of constructing the ideas, or testing materials and how they stand up to various forces.
- It can also help you to see all the different components separately, in what we call an "exploded view".
- Manufacturers find CAD modelling vital, as they can find out accurate dimensions and other details of the product from a single "engineering drawing" – which can be produced at the click of a button from a CAD programme.

Joining materials –Modelling / Manufacturing

Stages of how to model (prototyping)

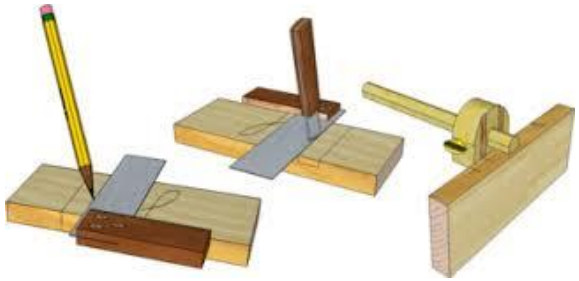
1. Sketch out set of initial ideas for know what you are going to model and then select appropriate material.
2. Measure and mark out using a range of tools including steel rules, templates and tri-squares.
3. The materials are then cut to size using fret saws, coping saws and scissors. All measurements are checked before cutting.
4. The model is then assembled and parts fixed together using a hot glue gun and other modelling adhesives (masking take, super glue).
5. Add colour and texture to make the the model more realistic.
6. The model is then visually checked and quality control for any improvements.
7. The final model is then shown to the end user and a focus group to get suggested improvements and alterations before the final product goes into manufacture. Suggestion may be taken into account and another model made.

Stages of how to finish wood (Painting or Varnishing)

1. Sand down the woods surface in the direction of the grain using a variety of different grades of sand/glass paper – Starting with a low grit (80) working to a high grit (400).
2. Stir/shake the paint / varnish and apply evenly using a brush along the grain of the wood in the same direction. You can also use a roller for paint.
3. Wait to dry and sand any rough texture down with a high grit of sandpaper.
4. Repeat and reapply additional coats if required – Usually 3 or 4 will be needed.

Stages of how to cut wood

1. Gather material (wood)
2. Using a tape measure / steel rule mark out wood – Use a tri-square for straight lines. You can use a pencil or a marking gauge.
3. Select appropriate saw and cut on the **outside** of the line.
4. Using a disc sander / sand paper remove unwanted material.
5. Check measurements for quality control.



Manufacture processes – Injection Moulding

Injection Moulding

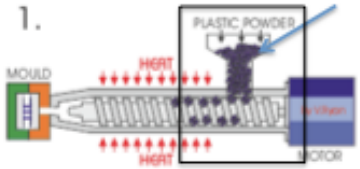
What is injection moulding?
Injection Moulding is a manufacturing process for producing parts in large volume. It is most typically used in mass-production processes where the same part is being created thousands or even millions of times in succession.

An injection moulding machine uses **thermoplastics** (can repeatable be used over and over / recyclable)

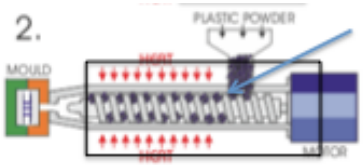
Advantages:
- **Repeatable** - the same design can be achieved every time with very good accuracy.
- Once cooled the product is ready, **no finish** is required to the plastic.
- **Quick** - designs can be produced very quickly
- **Accurate** - designs are produced to a high level of accuracy each time.
- **Little waste** - there is very little flash and hence very little waste plastic.
- **Economic** - hundreds of copies of the design can be produced before the machinery needs to be maintained.
- **Intricate** - intricate designs can be achieved very easily.

Disadvantages:
- **Costly**: the capital costs of machinery, development and maintenance are high.
- **Restricted**: designs are restricted by what can be achieved with the die.
- **Materials**: restricted to thermoplastic materials.
- Takes away **jobs** from skilled worked
- Once the mould is made, it is **costly for a new one**. Also unable to **modify** a mould once created

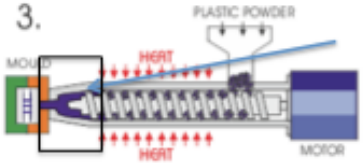
The injection moulding process



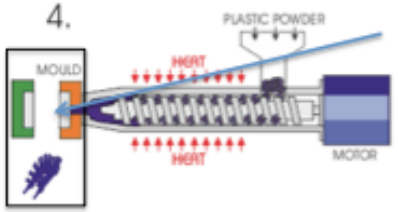
1. Granules of plastic powder are poured or fed into a hopper which stores it until it is needed



2. A heater heats up the tube and when it reaches a high temperature a screw thread starts turning.



3. A motor turns a thread which pushes the granules along the heated section which melts then into a liquid. The liquid is then forced into a mould where it cools into shape.

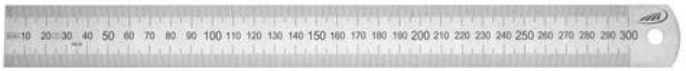


4. The mould then opens and the plastic product is removed

Manufacture processes – Marking out tools

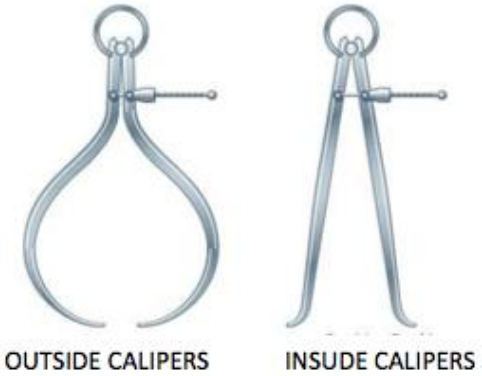
Scribe– used to mark out along the surface c material, usually metal.

Steel rule– used to measure. Simple as that.



Tri-square / Engineers square– used to draw lines that are perpendicular to the edge of material, typically metal.

Callipers– used to find out the measurements of materials. Generally pipework, but can be used generally.



Dividers– Essentially used like a compass. Use to mark out circles.

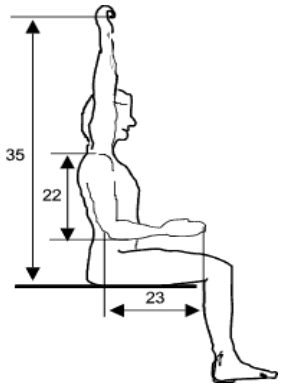
The **centre punch** is made form mild steel with the point hardened and tempered so that it withstands impact with the material it is marking. It is normally used to mark the centre of a hole to be drilled either by hand or on the drilling machine.
The **dot punch** is a lighter and thinner version of the centre punch and is used basically for the same job. However, it is more accurately as the dot produced is smaller.

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

Manufacture processes – Ergonomics and Anthropometrics

Anthropometrics (IN SIMPLE TERMS) – What kind of measurements have been taken from the target market to make sure the product is the right size and shape?

Thinks to think about – Who is the target market / What size is the end user? / What size hands do they have for holding the product?

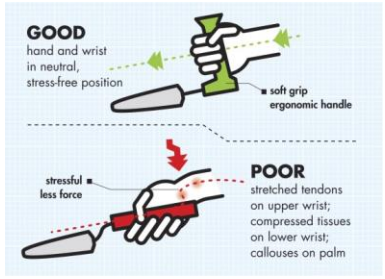


Anthropometrics is the study of the sizes of people in relation to products. For example, chairs used in schools need to be suitable for the average size of pupils in the schools. ***Used to determine the size**

Ergonomics (IN SIMPLE TERMS) – How easy and comfortable is the product to use?

Thinks to think about – Shape / Texture / How does it feel to hold and use?

Ergonomics is the practice of making a work space and working habits healthier for the body. This should prevent degradation in posture and reduce wear and tear from repetitive use of hands and wrists. **Using Anthropometric measurements to improve the products use**



Quality Control and Quality Assurance

What is it?

Quality Control: a check made to ensure that a component meets the specification a manufacturer has set. For example: correct shape, size or colour.

Quality Assurance: A complete system of ensuring quality control checks are carried out correctly throughout the manufacture of a product.

Benefits of applying QC and QA checks to the manufacturer are:

1.Standard and consistent quality parts reduce manufacturing costs
2. Makes production run more efficiently
3.Reduces the risk of incorrect or bad quality parts being made
4.Allows products to get approval for sale to the public
5. Improves safety standards in production
6. Workers standards and "manufacturing pride" increases

And the benefits to the consumer?

"I would be reassured of the quality and know that the product will be safe to use."
"I would be encouraged to buy from the same company again and again."
"I can hold somebody to account if something does go wrong."

Examples of Quality Control (QC)

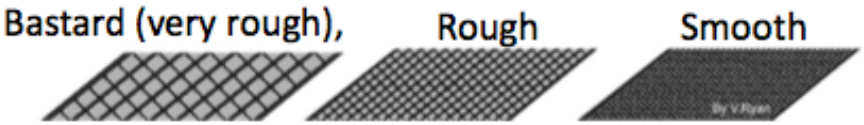
- Measurement checks
- Process checklists
- Sign in/sign out of tools (to ensure they don't get left in a car engine for example!)
- Product testing
- Visual checks
- Use of CAD/CAM
- Use of templates, jigs or gauges

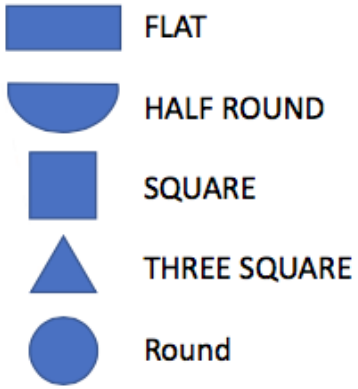
Examples of Quality Assurance (QA)

- Paperwork – sign off sheets/checklist
- Systems where certain staff are responsible for certain parts/jobs. Traceability.
- On-going staff training programmes
- Supervisors overseeing staff checking procedures
- Standard symbols awarded to approved products (CE symbol or BSI kitemark)

Manufacture processes – Cutting / shaping tools

File– diagonal teeth which are used for shaping and smoothing plastic and metals. NOT ON WOOD (this is a rasp – looks just like a file). Comes in various shapes to perform different jobs. 3 stages of files:





Hack saw – Large framed saw, with a straight saw blade and fairly large teeth. Mainly used in metal work, but can cut most materials. Very rough finish though.

Coping saw– Used for cutting curves and around tricky edges. Has a large D shape frame to allow it to fit over work. Ideal for wood and plastic.

Piercing saw – Almost the same as a coping saw, but only used for metal. Has a very thin, fine toothed blade which can cut very tight curves/turns.

Junior Hack saw – Similar to a regular hack saw, this works in the same way but with a smaller blade which has smaller teeth.

Tenon saw – Tenon saw has a relatively short blade with a reinforced back providing stability. It has hard point teeth and creates a fine finish so is ideal for carpentry as it makes a straight, precise cut.

Manufacture processes – Cutting / shaping machinery

Scroll / Fret saw– used to cut intricate curves. Use blades similar to coping saws. Different blades are available for a selection of different materials and tasks. Sometimes called a Hegner (brand name)or Reciprocating saw.

Band saw – used to cut most woods and plastics, even metals. Useful to cut straight lines and comes curved pieces.

Belt sander– used to rapidly smooth the straight edges of woods. Some which have aluminium oxide paper can be used for metals.

Disc sander – the shape allow for accurate, smaller objects to be smoothed.

Bobbing sander– used to rapidly smooth CONCAVE curves in woods. Various sized parts can be used for tight or gently curves.

Buffing machine– used to polish the prepared surfaces and edges of Plastics and metals. Normally there are 2 mops, one hard and one soft. Use the hard one first and move onto the soft for the best results.

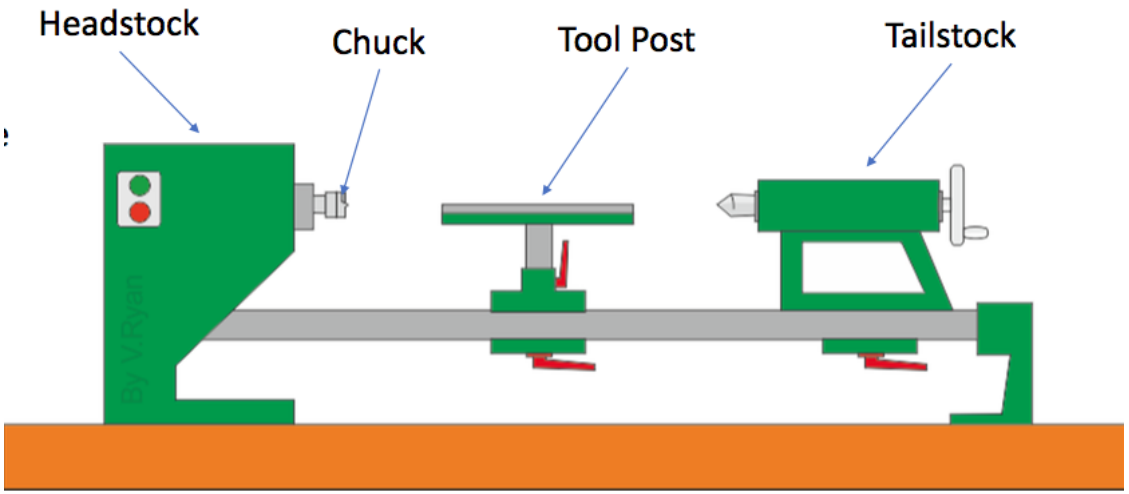
Manufacture processes – Wood and metal lathe

Obviously, there are two types of lathe – one for wood and one for metal. You aren't expected to know too much, the basic ways to use a lathe the named parts and the Risks/Precautions involved. A lathe is used to turn wood / metal into a round shape.

Wood turning lathe

Metal / centre lathe

Risk	Precaution
Work being thrown from chuck.	Make sure that work is tightened in chuck/between centres.
Chuck key being thrown from chuck.	Ensure the work is securely held in place.
Work becoming too hot.	Adjust speed/Lubricate the work during turning.
Clothing/hair becoming caught in moving parts.	Hair tied back/wear apron.
Guard not fitted or not lowered.	Fit guard/Ensure guard is in place.
Work being thrown from faceplate.	Ensure work is clamped and balanced on faceplate.
Waste material thrown from the lathe can injure the user's eyes.	To wear eye protection such as safety goggles or a visor.



Manufacture processes – Drilling

DRILL BIT

HOLE SAW

FLAT BIT

FORSTNER BIT

AUGER BIT

STEP DRILL BIT

COUNTER SINK

DRILL COUNTER SINK

Pillar drill – fixed style of drill that may be mounted on a stand or bolted to the floor or workbench.

Ratchet brace and hand drill - These are used for drilling a range of sizes of hole and they are very useful especially if machine drills are not available. The hand drill generally holds drill sizes from 1mm to 9mm whilst the brace will hold larger drill bits called 'forstner bits' and 'auger bits'. These larger bits can be used to drill 'blind holes' (holes that do not go the entire way through material).

RATCHET BRACE

HAND DRILL

Electric hand drill – Just like the pillar drill but is portable. Easy to use. Safety glass to be worn.

Manufacture processes – Holding devices

G clamp – generally used for clamping work securely to a surface/workbench top. They can also be used to hold parts together whilst glue is drying. The clamp is tightened by turning the small tommy bar which turns the threaded rod. Some G Cramps have a wing nut in place of the bar making it easier to turn by hand. However, if a tommy bar is used more pressure can be applied to the thread in order to tighten the clamp.

Hand vice – It has two jaws that are closed by turning a wing nut. For example the acrylic is held in the jaws.

Mitre clamp – used to hold work at a 90 degree angle. Useful when trying to glue/panel pin a mitre joint!

Machine vice – Its twisting handle makes this tool very affective for holding work securely whilst drilling.

Toggle clamp – Used on to provide a tight grip in a small piece of material. Can be used for drilling or whilst using contact adhesive and epoxy resin.

Sash clamp – Sash clamps are used to clamp work together when it is glued. They vary in size and are normally used in pairs. Mainly used for larger work, furniture etc.

Vice– Used to hold metal and wood whilst cutting/hammering.

Questions

1. What does '**hardness**' mean?
2. What does '**strength**' mean?
3. What does '**flexibility**' mean?
4. Write a short paragraph to explain **sustainability**?
5. Can you state **three** advantages of **CAD**?
6. Can you state **three** advantages of **CAM**?
7. Name a **CAD** program.
8. Name a **CAM** machine.
9. In your own words write out the process of how to use the **laser cutter.**
10. What are the four stages of the **product life cycle**?
11. Label the **6Rs** – Write a short definition of each one.
12. Choose **two renewable** energy sources. Write <u>how it words</u> and state <u>two advantages</u> / <u>disadvantages</u>
13. Write **three** benefits of using renewable energy sources
14. Give a definition of what a **smart material** is
15. How does a **thermochromic** material work?
16. What is meant by the **circular economy**? What are the different stages?
17. State the names of **two** types of **plastic**?
18. Which type of plastic has a **weak chemical bond** and is **easily recycled**?
19. Name a product that uses **one-off production**?
20. Why do products that are **mass produced** tend to be cheaper in price than products that are manufactured by **one-off production**?
21. State **two** benefits of **modelling** a product to the manufacturer?
22. Why would you use **cardboard** to model rather than **oak wood**?

Questions

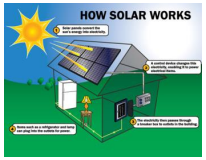
1. Write a short paragraph to explain **Quality Control and Quality Assurance**? What is the difference?
2. Write out the 4 stages of an **injection moulding machine**?
3. Why is an injection moulding machine great for **mass** producing products?
4. How would **anthropometrics** help you when designing a product?
5. Name **two ergonomic** features of the chair pictured.
6. Describe what you would use a **coping saw** for?
7. Give **two** examples of **Quality Control** checks.
8. Why does using **CAM** result in companies employing **less staff**?
9. What does '**elasticity**' mean?
10. What does '**tensile strength**' mean?
11. What does '**brittleness**' mean?
12. State **three disadvantages** of **CAM**?
13. Choose **two renewable** energy sources. Write <u>how it words</u> and state <u>two advantages</u> / <u>disadvantages</u>
14. Why is **MDF** easily **finished**?
15. Why is **MDF** a **good material** to manufacture products from?
16. What is the use of a **specification** when designing a making a product?
17. How does a **photochromic** material work?
18. State **two** stages of the **circular economy** and state how it affects the environment (positive or negative).
19. Why would a **handle for a saucepan** need to be manufactured from a **thermosetting** plastic?
20. State the function of a **venner**?
21. What material can you **3D print**? Name the plastic.
22. What is the use of the **BSI Kite** mark?
23. State **three advantages** of using renewable energy over non-renewable energy sources?

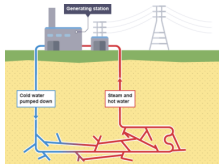
Questions

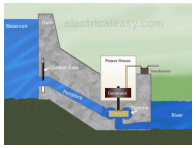
1. Why would **ABS** be a suitable material to make a child's chair from (state 3 reasons)?
2. Why is **steel** a suitable material to use for a prison cell door (state 3 reasons)?
3. Why would **beech** be a suitable material for a table (state 3 reasons)?
4. Why would **MDF** be a suitable material for a wardrobe (state 3 reasons)?
5. What is the use of a **knock down** fitting? Can you think of a product that would use this type of wood joint.
6. What is a **push fitting joint**? Can you think of a product that would use this type of joint.
7. Why would a company use **renewable energy** rather than non-renewable energy?
8. Choose a product and describe how it is **ergonomically** designed.
9. State the affect on the **environment** that each stage of the product life cycle has on the environment (this can be **positive** or **negative**).

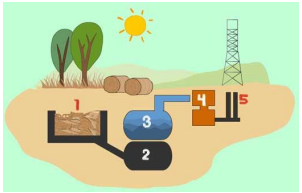
Raw Material	
Manufacturing	
Distribution	
Usage	
Recycling	
Landfil	

10. What is a **benefit** and **negative** of purchasing a product from **China**?
11. What are the stages when **marking out** wood (write at least 5 stages).
12. What is the use of **vernier gauge**?
13. State **three** advantages of **modelling** a product?
14. Choose **two renewable** energy sources. Write <u>how it words</u> and state <u>two advantages</u> / <u>disadvantages</u>
15. State **two** actions that you could do with your old watch if you purchased a new one.


HOW SOLAR WORKS


Generating station
Cold water pumped down
Steam and hot water


electricaleasy.com
Reservoir
Dam
Sluice Gate
Power House
Transformer
Generator
Turbine
River


1
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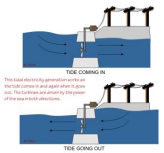
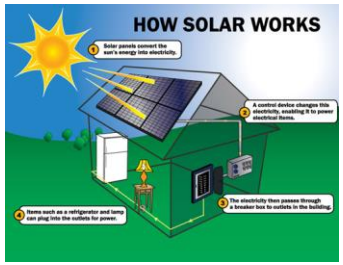
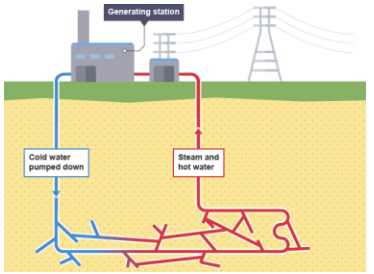
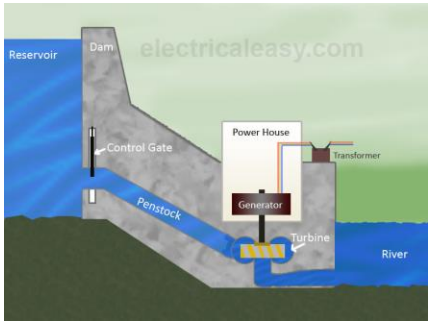

TIDE COMING IN
TIDE GOING OUT

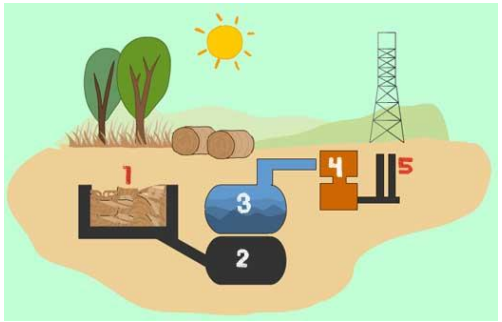
Task

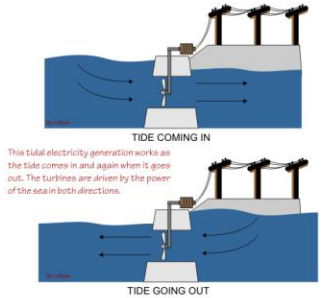
- Name the renewable energy source
- Write a sentence or 2 of how the renewable energy source works
- Write two advantages and two disadvantages





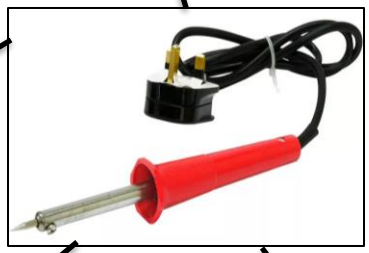






Shown below are 3 typical plastic products on the market today.

Evaluate how selection of a plastic material for the body of each product has been influenced by **functional** and **aesthetic** factors. Give reasons for each point made – write 4 points around each picture.



Like many products today, the plastic products are manufactured using injection moulding. Evaluate the benefits and limitations of injection moulding components for products such as the glue gun. (5 marks)

Functional

- **Heat resistant** – wont get burnt
- **Electrical resistance/insulator** – wont get electrocuted
- **Hardwearing** – if dropped wont break, with stand force if pressed hard/everyday use
- **Waterproof** – kettle – will hold the water

Aesthetics

- Plastic is available in a range of **colours** – Looks nice / get a product to suit yourself
- **Contrasting colours** – shows how to use the product / where to press
- **Complex forms/shapes** and styling can be achieved
- **Decorative** features or **functional textures** can be easily achieved.

The body of the glue gun is made from plastic because it is hardwearing and will be able to withstand everyday use and will not break if accidently dropped. Plastic has both good heat and electrical insulation functions because the glue needs to be heated to be able to flow and the user needs to be protected from any possible electrical shocks. It is aesthetically pleasing to look at because it has two contrasting colours. The contrasting colours also indicate key parts such as the trigger mechanism for use.

Benefits of injection moulding:

- Ideal for **mass** produced items - complex shapes are easily achieved **Speed** – very quick manufacturing process
- **Finish** – high quality finishes are achieved
- Plastic granules are **readily available**, **range of colours** and at competitive **prices**.

Limitations of injection moulding:

- Initial set up/tooling **costs are high**. The mould is very **expensive** to manufacture to the tolerances required.
- Changes to the design are **not easy to implement**, often the mould will need to be **re-made** and this is expensive.

The body of the glue gun would be injection moulded because it is a quick and effective process to produce vast numbers in a short period of time. The quality of the basic body will need very little cleaning or working after manufacture and this will reduce the cost of the final product. Injection moulding is a very expensive process mainly due to high tooling costs at the beginning of the manufacturing process. The initial cost of the making mould is high due to the high tolerances and finishes required.